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THE TYPES OF CONCEPTS STUDENTS PREFER TO ADD TO INCOMPLETE CONCEPT MAPS

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Abstract. The main goal of this study was to explore different potential components of science and technological literacy. The study explores student's skill of grouping concepts and creating a concept map. The sample for the study consisted of 131 grade 11 secondary school students from all over Estonia. A test comprising 2 problems was compiled to investigate the grouping of alcohol related concept and creating a concept map. Findings from the study, showed that students mostly make subject related groups and they don't see relationships between different types of terms. To create a concept map students added mostly social and value related terms, students avoids subject related terms If students have a possibility to avoid social factors, then they don't use them. Only students who have good problem solving skill (good STL skill), can associate subject content to social factors and also show how different subject content were related.

1 Introduction

It is widely assumed that science education needs to promote students' scientific and technological literacy (STL). It is not clear from the literature what STL actually is, but many authors have considered its impact on the goals of teaching. (OECD/PISA, 2003; Holbrook & Rannikmäe, 1997; Bybee, 1997; AAAS, 1989; NRC, 1996). NSTA in its statement on the attributes of a scientifically and technologically literate person (NSTA, 1981) recognised that content was not a key factor and that intellectual development, personal development, social considerations and interdisciplinary learning were important attributes.

One component important for the teaching of science based on an STL philosophy is the development of problem solving and critical thinking abilities in students. It is recognized that this requires a conceptual base related to the problem to be solved, or the critical situation being investigated. Developing problem solving abilities in a non-meaningful context means that students are also required to transfer their problem solving skills to context in which they which to carry out 'real' problem solving. This has been shown to be difficult for students and saw the abandonment of a project –Science – A Process Approach (where the processes were thigh in isolating from a real science context) being abandoned. To achieve good STL we need larger goals in science education then just good subject knowledge. Bybee (1993) clarified the structure of science education in terms of five major components:

a) Empirical knowledge of physical and biological system;
b) Scientific methods of investigation;
c) Personal development of the students;
d) Social development, or achieving the aspirations of society;
e) Career awareness.

Solomon & Aikenhead (1994) went further and showed that besides a structure for science education it was necessary to elaborate the personal developments and suggested these as consisting of attitudes, problem solving skills, critical thinking ability, as well as exhibiting creativity. And behind these abilities are others skills such as grouping and finding relationships between concepts. How we can find relationships between different types of terms shows that how good is thinking order skill. One way to improve students thinking is to use concept maps. Like Hsu (2004) said 'Concept mapping can promote students problem-solving and critical thinking to help students organize complex patient data, process complex relationships and offer holistic care to patient'. Also concept mapping requires a students to sort out and present data in a way that is logical, orderly and unambiguous (Wilkes et al. 1999). Its shows that students need to know concepts and relationships between them to achieve high level thinking. Even more, just memorizing concepts isn't enough, because to use concepts it is necessary to acquire a meaning for such concepts and how they are related to other concepts. 'Just rote learning isn't effective; you need to use meaningful learning' (Novak, 2002).

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Concept mapping has been put forward as an easy way to encourage very high levels of cognitive performance (Novak, 2002), and when the process is done well, it illustrates one reason why concept mapping can be used as an evaluation tool (Edmondson, 2000) and can use d to measure the structure and organization of an individual's knowledge (Novak and Gowin, 1984; Ruiz-Primo & Shavelson, 1996). A concepts map presents a person's knowledge about a certain concept or subject (Zele, 2004). Every concept in a concept map can be linked with many different concepts (cross-linking) although it is not suggested that all concepts are linked with each other; only the prominent and most useful cross-linkages need be identified. This process involves what Bloom (1956) identified as high levels of cognitive performance, namely evaluation and synthesis of knowledge.

This study investigates how students group concepts and find relationships influenced by teaching related to the development of intellectual skills in a social environment based on an STL model of science education, where subject conceptual learning is grouped with an appreciation of the applicability of science in understanding everyday life and science playing an important role in the decision making related to socio-scientific issues (Kolstø, 2006). In particular the study considers how far students relate concepts, linked to alcohol, to the conceptual understanding associated with academic chemistry, as well as to concepts related to the uses or misuse of alcohol in everyday life (referred to in this study as technological concepts) and to problems or issues in which the chemistry conceptual knowledge plays a role in the decision making process in everyday life (social concepts). The study explicitly examines how students group different alcohol-related chemistry concepts through trying to complete a partially developed concepts map and examining the relationships they make. To illustrate the difference between the groupings and to find relations, the study also explores:

- what type of groups students make;
- how much students see relationships between different type of concepts (how much the include linked groups):
- what concepts students add to existing concept maps;
- the number of different (chemistry, technological, social) concepts and the relationships they add;

2 Methods and Sample

The sample for the study consisted of 131 grade 4 secondary school students from all over Estonia. The sample was formed from students whose teachers participated in an interdisciplinary in-service course (Interdisciplinary teaching for science courses: Interesting problems from everyday life and they scientific explanation) and who expressed an interest in STL. Respondents were from different schools – small country schools, big city schools, schools where students undertake advanced science studies. All students had completed their study of inorganic chemistry and had begun studying organic chemistry in grade 11. By the time they took part in the study they had already studied hydrocarbons, alcohols, aldehydes and carboxylic acids. It was thus assumed these students had all the necessary knowledge to solve the problems. The profiles of the teachers who taught these students were different. Some had more than 35 years of school experience, whereas others had only two-three years of school experience.

The data for the present study were collected using a test compiled by the authors to investigate student's skill of grouping and making concepts map skill. The test consisted of two problems. The first problem tested student's empirical knowledge. In this problem, students were asked to group subject content (related to alcohol) and to give reasons why they formed such groups. Of interest was to know how (and why) students grouped different concepts and what type of groups students created. Did students use only similar groupings (for example: ethanol, methanol, ethanal are organic compound or oxidation, alcohol dehydrogenase, vaporization are processes/reactions in chemistry) when placing concepts into the same group, or did students create groups where different concepts related to linked groups (for example: ethanol, oxidation, ethanal, ethanoic acid, enzymes; all words relate to alcohol oxidation in the human body).

Problem two examined interdisciplinary skills related to how students find relationships between subject content and social factors and asked students to add different concepts/words to an existing concept map, plus show relationships between the concepts added. Also studied were the numbers of relationships students form per concept. The initial concept map gave different types of concepts. Some concepts related to the subject, some to technological processes used in everyday life and others to societal problems or issues. The concepts were at different levels, some were considered key, while others were minor and not necessarily found in all textbooks. As Krajcik (1991) said 'understanding other subject content depends on students developing an integrated understanding of basic concepts'. In this part of the test, the truth of Kracjik's assertion was investigated, but in addition social factors were added to further determine students' interdisciplinary skills. This problem showed us what type of concepts students add to concept map and how many different relationships they can do.

The completed test was validated before the collection of data by the teachers who participated in the interdisciplinary course (35 science teachers) and also by 65 11th grade students. This was carried out by a small pilot study, in which one class of students were given the two questions, to ensure the questions were understood and the students were able to work individually in giving meaningful answers to the questions in a reasonable time period. It was concluded that the test had appropriate construct validity and the tasks required were well understood by the students.

3 Results and Discussion

Outcomes from the questions were considered by determining the number of subject groups formed, the number of technological groups in which students relate to concepts from everyday life and the number of linked groups which illustrate student ability to link concepts across the academic and technological concept domains. If students see relationships between such different domains, i.e. they illustrate more linked groups, the students are perceived to have high levels of thinking based on Bloom's taxonomy (1956).

Results from question 1

Student's answers from problem 1 can be categorised into four different groups. The first group is made up of similar groups, where the same type, subject related, concepts (like methanol, ethanol, aldehyde or oxidation, alcohol dehydrogenize, burning) are put together. The second group consists of technology related groups, where mostly concepts related to the breathalyzer and analyses based on this are included. The third group consists of linked concepts, where processes and related concepts are linked (such as alcohol, alcohol dehydrogenize, aldeyde). The fourth group was a no meaning group where students did not give any relationships between concepts.

The results from problem 1 (Table 1) showed that students mostly used similar grouping (same type of words in one group); only 30% groups, created by students, were through the use of linked groups. The result showed that students could group the same type of terms, but they were far less likely to use relationships between dissimilar terms. Where students did include linked groups, most (70%) related this to analyzing alcohol in the blood. Only a few students using linked groups which were purely chemistry (for example: ethanol, oxidation, aldehyde, temperature – alcohol can oxidized to aldehyde and the speed of that process is related to temperature.) The outcome showed that students were familiar with the breathalyzer showing alcohol breath content and from this calculating the alcohol content in blood.

In problem 1, students also needed to group all terms. Approximately 70% students didn't use all terms; also most of them didn't write why all terms were not used. Some students formulating another group indicated "I don't know these terms". In general, 34% students didn't make linked groups at all and 35% students did so using only subject related groups.

School nr	Similar subject groups (% from all groups)	Technological group (% from all groups)	Linked groups (% from all groups)	No meaning groups (% from all groups)	TOTAL % (subject + technological + linked)	Unused terms (% from all terms)
1	56	14	28	2	100	21
2	59	14	22	5	100	18
3	40	8	36	16	100	39
4	45	9	29	17	100	30
Average	50	11	30	9	100	28

Table 1. Types of concepts groups formed by students (as a % of all groups formed)

Table 2 shows that approximately 70% students, on average, did not use all terms. Mostly the unplaced terms were: temperature, indicator, analyze diffusion and alcohol dehydrogenize. Reasons for this may be that students did not understand sufficiently the meaning of the term, or how that term related to other terms.

Nr	Subj. (S)	Techn. (T)	Linked (L)	S+T	S+L	T+L	S+T+L	Unused Terms
1	83	47	57	43	43	7	7	73
2	93	43	67	43	60	17	17	63
3	48	23	60	20	23	3	3	73
4	45	7	34	19	39	6	6	68
Average	70	32	61	34	40	8	8	69

Table 2. Percentage of students creating the different types of groups per school (shown as % of total students per school)

From Table 3, we can see that subject groups were mainly composed of 3 to 4 terms (26% and 23%). But 16% students created groups using only two terms, even though it is not usual to consider two nouns as a group. If we add these groups to the percentage to unused terms, the percentage of unused terms increases substantially. In forming the technological groups, students mostly found using three nouns per group, the easiest. On the other hand, linked groups were mostly formed from five terms, with the range mainly from 4 to 7 terms. To link many different types of terms into the same linked group needed high order thinking skills and not all students were able to exhibit this.

Nouns	Subject (S)	Technology (T)	Linked (L)
2	16	11	1
3	26	35	12
4	23	14	20
5	13	14	24
6	11	8	15
7	4	14	20
8+	6	5	7

Table 3. Percentage of groups (as % of total groups for that category) created with the indicated number of nouns

From problem 1, results show that student's responses can be combined into four types of groups with students mostly giving similar groups. Generally, students don't give relationships between different types of terms and only a small percentage of groups were linked groups. This would suggest a possible lack of higher order thinking among the students. Also, the number of terms in each group was generally low, further suggesting a lack of higher order thinking. If students have high order thinking then they able to transfer their thinking to new situations and see relationships between many different terms (Hsu, 2004).

Results from question 2

Students answers to problem two were also categorised into four groups. The first group was science concepts, mainly chemistry concepts but also integrated concepts, where chemistry was related to biology or physics. The second group was technological concepts, where students added concepts related to technology, mainly the breathalyzer. The third group was social related concepts, affecting people in their everyday life and the fourth group is value related concepts, affecting the individual in society. The existing, partially completed concepts map included examples of all four different possibilities and allowed ample opportunities to add concepts in each group. This contrasted with problem 1, where only subject related terms were given.

Results from the second problem showed that more than half (60%) of the additional concepts were related to social factors. Students were able to change a concept map by adding social factors if asked to do so; only a small percentage of students (10%) used chemistry content to complete the map. Some students (16%) also used integrated content (chemistry, physics, biology) to complete the map, but almost all students (92%) didn't add technological concepts and presumably did not see technological relationships.

School	Group 1 Science	Group 2 Technological	Group 3 Social	Group 4 Values
1	17	8	50	25
2	16	8	52	24
3	14	7	53	25
4	18	9	51	24
Total	16	8	52	24

Table 4. Percentage breakdown of concepts added by students in groups 1-4 (as a % of all concepts added)

Table 4 shows that more then 50% concepts (52%) which students added were socially related concepts and 24% concepts were value related. The number of science and technological related concepts was low (science 16% and technological 8%). A possible reason for this is that students find it easier to add social and value concepts. They know more about social life and adding concept to that part is clearer to them.

Figure 1 combines all students' answers into the same concept map. It shows that 75% concepts are social, or value related. In the science, part there are only three different concept types, one related to burning, another to other alcohols and the last to poisoning. The technological group illustrates only one concept type – that related to measuring alcohol blood content by using a breathalyzer. By contrast, in the social part, students added five types - the first related to hospitals and car accidents, a second to criminal conviction, a third to addiction by alcohol, a fourth to being drunk and getting a hang-over and a final type to alcoholic drinks or alcohol like drugs, solvents, etc. For the value types, students added different types of diseases which may be caused by alcohol and the consequences deriving from the use of alcohol such as unsocial people.

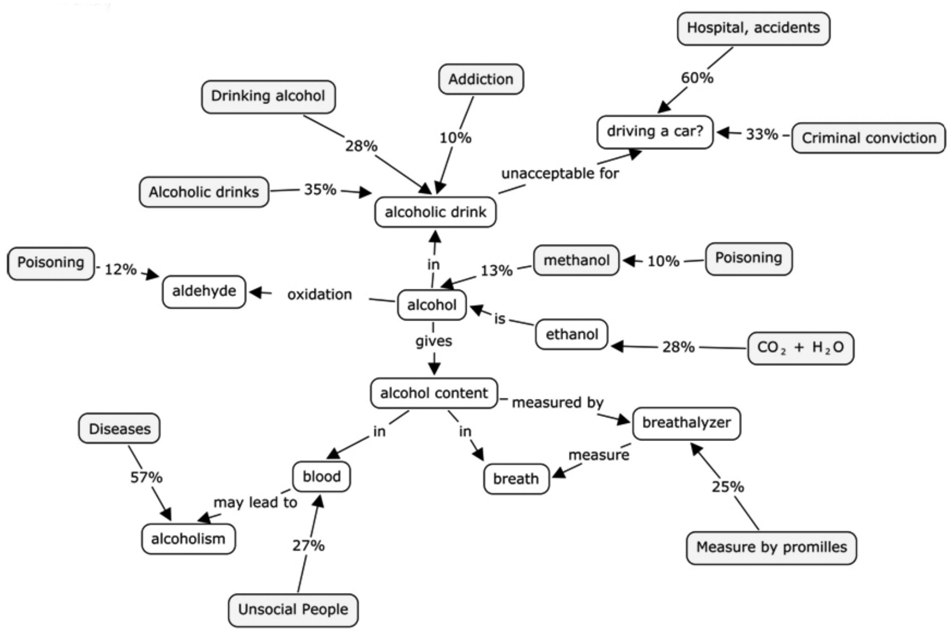

Figure 1. Typical concept types (percent of students who created this type of concepts)

Figure 2 shows an example of one concept map created by students. It shows typical concepts, although not all students added so many different types of concepts. The scheme shows nicely that students added more concepts to the social part. In general; students did not include scientific concepts if they had the opportunity to use social, or value related concepts.

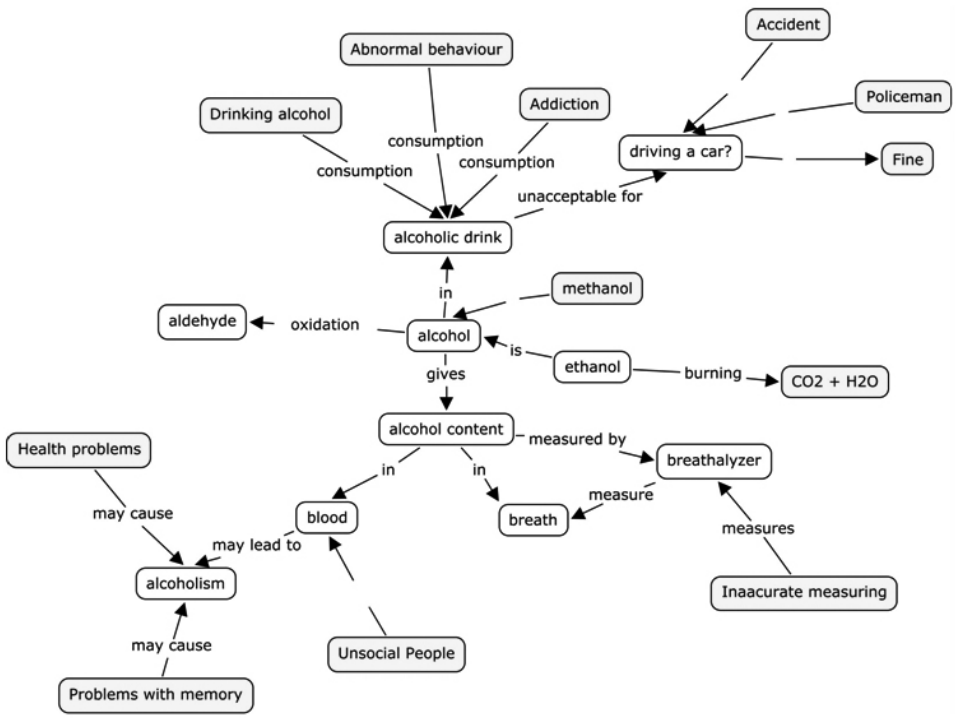

Figure 2. Typical student concept map

4 Conclusion

In the first problem students answers can be categorised in four different types. Students created more similar groups than linked groups and did not see relationships between processes and related terms. Only a small percentage of students formed linked groups.

In general, when students were faced with an incomplete concept map as was the case to answer the second problem, students didn't use scientific content to enlarge the concept map. They using mostly social and value related terms, illustrating student's tendency to avoid the use of scientific context and use other contexts such as social. Students probably found it easier to add concepts to social related terms, because it is related to everyday life and like some papers show students are interested in aspects relevant to them such as alcohol and alcohol related phenomena (Teppo & Rannikmäe 2003; Osborne & Collins 2001).

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