Concept Maps: Theory, Methodology, Technology
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SIX YEARS OF DESIGN EXPERIMENTS USING CONCEPT MAPPING - AT THE BEGINNING AND AT THE END OF EACH OF 23 LEARNING PROJECTS

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Abstract. The results of a 6-year period of field testing of concept mapping are described. Very few long-term series of concept mapping experiments have been published. Most publications report very short experiments. Our research was conducted over two 3-year experimental periods, and included partial replications. During each period, two intact school classes with 20 pupils each were tested. The pupils were from grade levels 4 – 6 (10-12 years old). Concept mapping clearly revealed that pupils did learn during each learning project. Number of relevant concepts and number of relevant propositions were used as indicators of meaningful learning. Statistically significant differences between those indicators at the beginning and at the end of learning projects were found for both experimental periods. Pupils were happy to see for themselves that they really learned during the learning projects. Moreover, it seemed to increase their self-esteem and happiness with the teaching-studying-learning process. For the teacher, this was constructivism at its best. She could easily and clearly monitor and promote her pupils' metalearning and metathinking. Qualitative research results of this project include the teacher's observations as well as her tentative theory of the benefits and drawbacks of concept mapping after 6 years of experimenting. Reliability was estimated in the preliminary quantitative analysis. Statistical tests were performed to determine the relationship between the two indicators of meaningful learning and variables including: 1) shared teaching-studying-learning time, 2) sex of pupil, and 3) earlier school achievement levels.

1 Introduction

Very few long-term field experiments with concept mapping have been reported to date. Most published articles describe relatively short-term experiments. The studies presented here, however, were conducted from 1997 to 2003 and longer, with concept mapping incorporated into the experimental design at the beginning, the end, and sometimes even the middle of the learning project. For most teachers, concept mapping is an innovation. The second author of this paper heard about concept mapping only a couple of days before she decided to join this research project and learn to use concept maps. She had no previous conceptions or theory of concept mapping. As mentioned above, concept mapping is often used only for a short experimenting period, which means that we cannot know how things might develop in long-term use. We have not come across any theories of the effect on classroom teachers of using concept mapping. Neither have we seen any research on how much previous school achievement, teaching-studying-learning time, or pupil's sex account for variation in indicators of meaningful learning. As part of this project, however, a tentative theory was constructed by a classroom teacher who participated in our experiments over a 6-year period.

There are different conceptions of what constitutes concept mapping and its indicators of meaningful learning. This paper describes a research project that utilizes a version of concept mapping developed over the years by Ahlberg (1993, 1998, 2001, 2002; Ahlberg, Aanismaa, & Dillon, 2005; Ahlberg & Ahoranta, 2002; Ahlberg, Turja, & Robinson, 2003; see also Ahoranta, 2004). Ahlberg calls it an improved method of concept mapping, and clearly admits that he builds on the work done by Novak and his research group in the United States. However, there are many differences between these two versions of concept mapping. One of the most important differences is that in the improved method of concept mapping, concept maps can also be built from the center outwards. These concept maps are interpreted as pyramids seen from above. It can be easily observed whether or not there is conceptual hierarchy,. which is the only aspect of hierarchies that interests us. We have taken as a starting point the modern cognitive science view that concepts are elements of learning and thinking. Propositions are made out of concepts. That is why we calculate the number of relevant concepts and relevant propositions, and regard them as indicators of meaningful learning. Certainly, conceptual hierarchies are also important, but if, according to modern science the world is thought of as a system, then our best evolving tentative theories of the world have to be conceptual systems. They may not always be hierarchies, but we think that truthfulness of our conceptions is more important than hierarchical presentation.

The research problems this project addresses include:

1) After 6 years of experiments with concept mapping, what kind of theory has the teacher constructed about the benefits and drawbacks of concept mapping?

2) How reliable is long-term concept mapping?

3) How much does:
    a) the shared teaching-studying-learning time
    b) prior school achievement level, and
    c) sex of pupils account for variation in selected indicators of meaningful learning?

2 Methods

Research design and subjects

Two 3-year periods of experimenting produced the data for this 6-year project. In all, 23 learning projects were completed and 46 pupils made concept maps. A total of 920 individual concept maps were collected and analyzed. The data for 9 pupils from each 3-year period were selected for further analysis, and included 414 concept maps. These pupils were partial replicates to each other in many senses.

The school from which these data were collected is an ordinary municipal comprehensive school in Eastern Finland. The classroom teacher who collected these data also used them for her doctoral (PhD) thesis in the Applied Sciences of Education. There were 20 pupils in the first school class. They started at the beginning of fourth grade, at 10 years old. The last concept mapping experiments were done at the end of their sixth-grade year, when they were 12-13 years old. During the 1997 – 1998 school year, individual concept maps were collected from five learning projects. Pupils also completed five learning projects that involved using concept mapping in a similar way, during the 1998 – 1999 school year.. Over the course of the third school year, pupils completed four learning projects in which concept mapping was used both at the beginning and the end of each project. In the second intact school class there were also 20 pupils. During three school years (2000 – 2003), they completed three learning projects per year, for a total of nine projects. Pupils constructed individual concept maps at the beginning and the end of each learning project. Individual Vee heuristics were also constructed in 20 of the 23 learning projects, but the data are not analyzed here. Examples of the data that were collected are presented in Figures 1, 2, and 3.

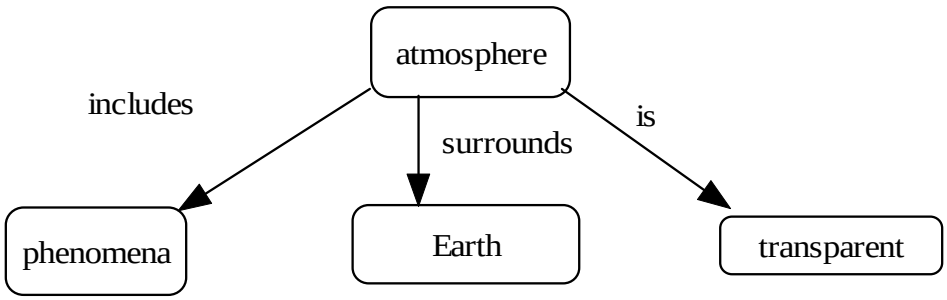

Figure 1. The first concept map completed at the beginning of the experimental unit on Atmosphere, by a male pupil (code:208). The sum of relevant concepts is four, and the sum of relevant propositions is three. ‘Atmosphere’ is the most central concept because it has more links (3 links) with other concepts than any other concept.

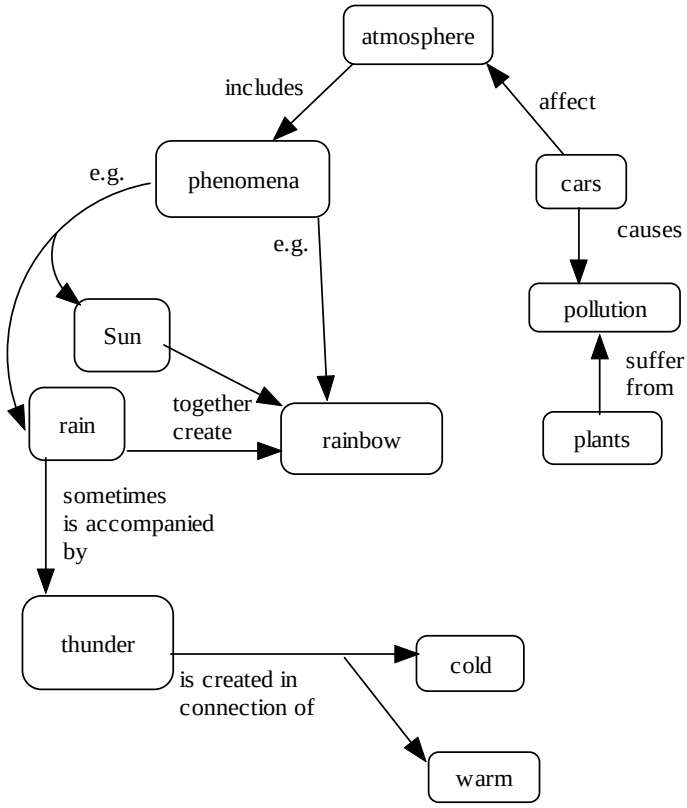

Figure 2. The last concept map completed at the end of the experimental unit on Atmosphere, by the same male pupil (code: 208). The sum of relevant concepts is 11, and the sum of relevant propositions is 12. The most central concept is 'phenomena,' because it has more links (4 links) with other concepts than any other concept.

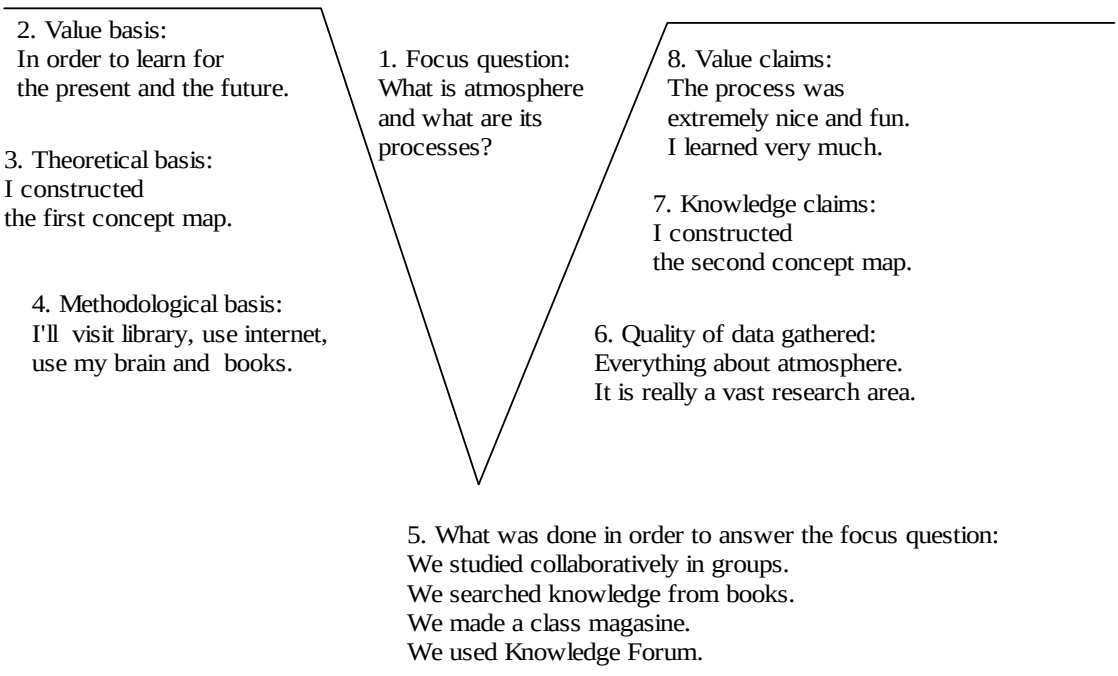

Figure 3. An example of a pupil (code: 208) constructed Vee heuristic from the experimental unit on Atmosphere.

3 Results

Answer to the first research problem: After 6 years of experiments with concept mapping, what kind of theory has the teacher constructed about the benefits and drawbacks of concept mapping?

At the beginning of this research project the teacher who participated had no idea, no conception, and no tentative theory of concept mapping. The ideas below represent the teacher's insights since the start of the project in 1997. The teacher's tentative theory consists of the following propositions:

1. Concept mapping is an excellent way of finding out what pupils have in their metacognition about the theme of a learning project.
2. For pupils it is important to know at the beginning of the learning project what they already know about the theme of the project.
3. The teacher can plan and implement her teaching according to what pupils already know at the beginning of the learning project.
4. The teacher can put pupils into cooperative learning groups based on the results of the first concept maps so that knowledge building in the classroom is facilitated.
5. The teacher understands deeply, broadly, and more clearly what kind of learner each of her pupils is. Concept mapping is the fastest and most practical way I know to get an overview of what pupils know both individually and as a group.
6. Concept mapping is a good method for both teachers and pupils to avoid rote learning, and to learn and think meaningfully. It promotes collaborative knowledge building, according to my observations.
7. Concept maps are constructed individually in my classroom. Each pupil takes full responsibility for her own learning and thinking. There are times when knowledge is built collaboratively, and there are many kinds of collaborative learning, but in the end concept maps are individual products.
8. When pupils compare their concepts maps from the beginning of the learning project to the end of the learning project, they see clearly how much they have learned. This supports their positive self image as a learner. They feel happy and empowered. At the same time, the teacher becomes more empowered.
9. Concept mapping is a concrete way to demonstrate to pupils just how much they know and learn about themes that are studied at school.
10. Concept mapping is a good tool for assessment of learning.
11. Misconceptions are easily revealed by concept mapping.
12. Constructing concept maps is often an enlightening experience for pupils. They have deep, positive feelings toward their learning and their concept maps. They see constructivism in practice as they witness an increase in concepts and propositions in their thinking, understanding, and learning.
13. Concept mapping promotes meaningful learning. School learning is no longer rote learning, but understanding the sum as well as its parts, and the contexts in which they are connected.
14. Concept mapping facilitates other kinds of written composition tasks.
15. The teacher can monitor and promote better learning by individual pupils.
16. Constructing concept maps is hard and energy-demanding work. There is an optimal frequency for using concept mapping, however. As with all other methods of monitoring and promoting learning, if it is used too often pupils become bored.
17. Concept mapping is a method of learning to learn, which can be used any time it's needed.
18. Constructing concept maps is hard work. Pupils are like most people, who try to avoid hard, intellectual work. Although they do understand the importance of concept mapping from time to time, pupils generally do not ask themselves to construct more concept maps than required by the teacher.
19. Most pupils quickly learn how to construct good concept maps, though some pupils need more help and instructions.
20. Some of the brightest pupils try to include all they know into their concept maps. Then the teacher has to teach them to select only the most relevant items. It is probably a very educative experience for those otherwise advanced pupils.
21. If a pupil has very little or no prior knowledge of the theme, she may feel herself helpless. On the other hand, as the learning project proceeds and she clearly sees how much she has learned, then it does not matter that she did not know it all at the beginning.
22. Individual concept maps can be complemented by constructing also, from time to time, collaboratively constructed concept maps. It seems to promote shared understanding and learning.

Answer to the second research problem: How reliable is long term concept mapping?

From the data collected during the first 3-year research period (1997 – 2000), a total reliability estimate was calculated from the sums of relevant concepts and relevant propositions. The resulting Cronbach's alpha was 0.88 when calculated from raw scores, but 0.96 when standardized scores were used. A large variability was observed in the raw scores, which ranged from a sum of 62 to a sum of 210 relevant concepts. Therefore, the standardized scores were considered to be the best estimate.

A total reliability estimate was also calculated from the sums of relevant concepts and relevant propositions for data collected during the second 3-year research period (2000 – 2003). The resulting Cronbach's alpha was 0.93 when calculated from raw scores, but 0.99 when the standardized scores were used. Again, a very large variability was observed in the raw scores, which ranged from a sum of 49 to a sum of 395 relevant concepts, making the standardized scores the best estimate.

Overall, the reliability estimates were very high. When calculated separately for relevant concepts and for relevant propositions, however, the reliability estimates were a little bit lower as shown in Tables 1 and 2.

Learning projects during 1997 – 2000	Reliability estimates at the beginning of the learning projects	Reliability estimates at the end of the learning projects
Reliability of sums of relevant concepts calculated from pupil's concept maps.	α = 0.75 (α = 0.72)	α = 0.87 (α = 0.89)
Reliability of sums of relevant propositions calculated from pupil's concept maps.	α = 0.76 (α = 0.73)	α = 0.85 (α = 0.87)

Table 1. Reliability estimates are shown separately for the sums of relevant concepts and relevant propositions at the beginning and at the end of the learning projects during the first 3 years of research (1997 – 2000). The estimates were calculated first from raw scores. Estimates calculated from standardized scores are provided in parentheses.

Learning projects during 2000 – 2003	Reliability estimates at the beginning of the learning projects	Reliability estimates at the end of the learning projects
Reliability of sums of relevant concepts calculated from pupil's concept maps.	α = 0.87 (α = 0.88)	α = 0.90 (α = 0.93)
Reliability of sums of relevant propositions calculated from pupil's concept maps.	α = 0.88 (α = 0.89)	α = 0.91 (α = 0.94)

Table 2. Reliability estimates are shown separately for the sums of relevant concepts and relevant propositions at the beginning and at the end of the learning projects during the second 3 years of research (2000 – 2003). The estimates were calculated first from raw scores. Estimates calculated from standardized scores are provided in parentheses.

Answer to the third research problem: How much does a) the shared teaching-studying-learning time, b) prior school achievement level, and c) sex of pupils account for variation in selected indicators of meaningful learning?

a) The amount of variation in meaningful learning accounted for by teaching-studying-learning time was calculated as follows. First, a paired samples t-test was performed comparing the sums of relevant concepts and sums of relevant propositions at the beginning and at the end of each learning project. The test showed a statistically significant increase in sums of relevant concepts from the beginning of learning projects (M = 85.44, SD = 17.10) to the end of learning projects (M = 145.44, SD = 44.93), t (8) = -5.732, p = 0.000 for the 1997 – 2000 research period. The eta squared statistic (.80) indicated a very large effect size, and means that 80

% of the variation of sums of relevant concepts are explained statistically by the shared teaching-studying-learning time variable, from the first concept map to the last concept map of each learning project.

For the 2000 – 2003 research period, a statistically significant increase was also found for sums of relevant propositions from the beginning of learning projects (M = 83.33, SD = 17.20) to the end of learning projects (M = 148.67, SD = 53.10), t (8) = -4.555, p = 0.002. The eta squared statistic (.72) again indicated a very large effect size, and means that 72 % of the variation of sums of relevant propositions are explained statistically by the shared teaching-studying-learning time variable, from the first concept map to the last concept map of each learning project.

b) The amount of variation in meaningful learning accounted for by prior school achievement was calculated as follows. According to prior school achievement, pupils were selected and categorized into three groups that included three pupils of low achievement (Group 1), three pupils of average achievement (Group 2), and three pupils of high achievement (Group 3), for a total of nine intensively studied pupils. A one-way analysis of variance was conducted to explore the impact of prior school achievement on variation of indicators of meaningful learning (sums of relevant concepts and sums of relevant propositions). No statistically significant differences were found for data collected from the first research period (1997 – 2000), indicating that prior school achievement did not statistically account for variation of meaningful learning measured by concept mapping.

For the second research period (2000 – 2003), however, prior school achievement was shown to account for variation of indicators of meaningful learning. Statistically significant differences were found in all four analyses: Sums of relevant concepts at the beginning of the learning projects (F (2, 8) = 9.701, p = 0.013) and at the end of learning projects (F (2, 8) = 6.123, p = 0,036); and sums of relevant propositions at the beginning of the learning projects (F (2, 8) = 9.412, p = 0.014) and at the end of learning projects (F (2, 8) = 8.283, p = 0.019). The effect size estimates (eta squared) were very large, varying from 0.67 – 0.76.

There is no good explanation as to why prior school achievement accounted for variability in meaningful learning in the second 3-year period but not in the first. This shows only that these kinds of analyses should be done separately for each group. The main point is that all pupils learned, as indicated by the concept maps, regardless of prior achievement.

c) A one-way analysis of variance was conducted to explore the impact of sex of pupils on the variation of indicators of meaningful learning (sums of relevant concepts and sums of relevant propositions). No statistically significant differences were found for either research period, indicating that sex of pupils did not account for variation of meaningful learning as measured by concept mapping. In other words, girls and boys learned equally meaningfully by concept mapping.

4 Discussion

There are very few long-term research projects of any innovation, and concept mapping is not an exception. This paper has described some of the main results of a 6-year research and development project in which individual concept mapping was used both at the beginning and at the end of 23 learning projects. Individual Vee heuristics were were also used, but those data are not presented here. Over the course of the research, the teacher who participated developed a tentative theory about what concept mapping means for everyday classroom use in grade levels 4 – 6 (pupils ages 10-12 years). The data show that plenty of meaningful learning occurred between the beginning and the end of the learning projects, and that concept mapping is a sensitive tool that provides a useful method for statistically measuring learning gains. Shared teaching-studying-learning time was found to account for 72-80 per cent of the variation of the selected indicators of meaningful learning. Prior school achievement did not account for variation of meaningful learning in pupils from the first 3-year research period (1997 – 2000), though it accounted considerably for the variation found with the second group of pupils. However, there is no general regularity here. Finally, sex of pupils did not account for variation of indicators of meaningful learning. This is good news, because it shows that both females and males can use concept maps to promote meaningful learning, as indicated by concept maps made at the beginning and at the end of each of the 23 learning projects.

This paper was based on the version of concept mapping that has been developed by Ahlberg (1993, 1998, 2001, 2002; Ahlberg, Aanismaa, & Dillon, 2005; Ahlberg & Ahoranta, 2002; Ahlberg, Turja, & Robinson, 2003), and the empirical data presented in Ahoranta's (2004) doctoral dissertation.

References

Ahlberg, M. (1993, August). Concept maps, Vee diagrams and Rhetorical Argumentation (RA) Analysis: Three educational theory-based tools to facilitate meaningful learning. Paper presented at the Third International Seminar on Misconceptions in Science and Mathematics. Cornell University. Published electronically in the Proceedings of the Seminar: http://www.mlrg.org/proc3abstracts.html

Ahlberg, M. (1998). Education for sustainability, good environment and good life. In Åhlberg, M., & Leal Filho, W. (Eds.), Environmental Education for Sustainability: Good Environment, Good Life (pp. 25 – 43). Frankfurt am Main: Peter Lang.

Ahlberg, M. (2001). Concept mapping as a research method: www.metodix.com/showres.dll/en/metodit/methods/metodiartikkelit/kasitekartta_tutkimusmenetelmana/

Ahlberg, M. (2002). Translator's postscript: Twenty years research on theory of integrating education, improved concept maps and Vee heuristics in Finland [in Finnish]. In J. Novak Tiedon oppiminen luominen ja käyttö [Finnish translation of Learning, creating and using knowledge]. Jyväskylä: PS-kustannus, pp. 300 – 315.

Ahlberg, M., Aanismaa, P., & Dillon, P. (2005). Education for sustainable living: Integrating theory, practice, design and development. Accepted to be published in Scandinavian Journal of Educational Research 39(2).

Ahlberg, M., & Ahoranta, V. (2002). Two improved educational theory based tools to monitor and promote quality of geographical education and learning. International Research in Geographical and Environmental Education, 11(2), 119 – 137.

Ahlberg, M., Turja, L., & Robinson, J. (2003). Educational research and development to promote sustainable development in the city of Helsinki: Helping the accessible Helsinki Programme 2001 – 2011 to achieve its goals. International Journal of Environment and Sustainable Development 2(2), 197 – 209.

Ahoranta, V. (2004). Oppimisen laatu peruskoulun vuosiluokilla 4-6 yleisdidaktiikan näkökulmasta käsitekarttojen ja Vee-heuristiikkojen avulla tutkittuna [Quality of learning monitored and promoted by concept mapping and Vee mapping in school grades 4 – 6]. Doctoral dissertation. University of Joensuu. Publications in Education No. 99.