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CONCEPT MAPPING AND TEXT WRITING AS LEARNING TOOLS IN PROBLEM-ORIENTED LEARNING

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Abstract. In two studies we investigated whether concept mapping or summary writing better support students while learning from authentic problems in the field of business. We interpret concept mapping and summary writing as elaboration tools aiming at helping students to understand new information, and to integrate it with prior knowledge. We hypothesize concept mapping to be superior to summary writing. Both studies had a pre-test and post-test design with two experimental groups (concept mapping and summary writing). In the first study, 26 students of a commercial high school (pre-university level) in their next to last year took part. In the second study 30 students aged 16-18 years from the pre-final year of pre-university education participated. Contrary to our expectations, in both studies the groups did not differ significantly in pre-test and post-test scores. However, the concept mapping condition seems to better support meaningful argumentation and elaboration of information.

1 Introduction

Students should be supported in acquiring complex knowledge in order to adequately understand and cope with complex problems, both in school and in daily life. While solving problems, students learn domain concepts, the discourse of the domain, and problem solving itself (Kneppers, 2007; Kneppers, Elshout-Mohr, Van Hout-Wolters, & Van Boxtel, 2007). However, in schools, learning almost exclusively takes place on an abstract level. In addition, students are often not encouraged or motivated to learn actively. Consequently, often rote learning instead of meaningful learning takes place (Novak & Cañas, 2008) and the application of concepts in daily life or in the workplace, and contextual reasoning will be difficult.

Against this background, authentic problems should be integral part of instruction. However, learning from authentic problems often leads to deficient results. Students have difficulty understanding main ideas and complex interrelationships of relevant topics. They are not able to develop a structured knowledge base. To avoid the obstacles mentioned, problem-oriented learning can be supported by using learning strategies, such as organization and elaboration strategies (Weinstein & Mayer, 1986). Organization helps structuring the contents to be learned. Elaborations go beyond the original problems because they are constructed by the learner independently. In the course of organization and elaboration, the learner activates his/her prior knowledge and combines it with given information. Thus, a rich knowledge base is generated which may result in better memory and better understanding of the learning material (Reder, 1980). Concept mapping and summary writing can be regarded as organization and elaboration tools.

Concept maps are two-dimensional structural representations of a topic consisting of nodes and labeled lines between the nodes. The nodes represent important concepts; the lines are relations between the concepts. The combination of two nodes and a labeled line in between is called a proposition. A proposition is a basic semantic unit which can be assessed true or false (Ruiz-Primo & Shavelson, 1996). In the process of concept mapping students translate information or knowledge into a visual format which displays the main ideas and their interrelations. As a prerequisite, students have to recognize the important concepts and decide about their interrelationships. Thus, concept maps help structure knowledge and information und by that aid meaningful learning (Novak & Cañas, 2008). This is an active and reflective process which leads to elaboration (Beyerbach & Smith, 1990).

Similar to concept maps, summaries have the function of consolidating information in a macrostructure (van Dijk, 1980). In the process of summary writing, students have to both select important and to omit irrelevant concepts, and they have to construct sentences which do not or not identically exist in the text (Christmann & Groeben, 1996). Thus, summary writing and concept mapping are active and reflective processes. The most important difference between the two strategies is the format. While concept maps represent information in a structured graphic, summaries represent information in a linear order. Concept maps are assumed to be advantageous for displaying all relations between concepts in an unequivocal manner. In contrast, summaries contain the relations between the main concepts in several sentences, and the universe of interrelationships as well as potential hierarchies might not be as clear as in the graphic (Nesbit & Adesope, 2006). The decisions about the information structure do not necessarily have to be as precise as in the concept map. Furthermore, the advantage of concept maps may be explained by the fact that the diagram format corresponds with the notion of knowledge as a semantic network (Dansereau et al., 1979). Thus, the similarity

of knowledge and concept maps (as learning media/learning strategy) may support students in externalizing their cognitive structure and in using concept maps as learning aids.

In a couple of studies concept mapping proves to be an effective learning-from-text strategy. Amer (1994), for example, shows that both, translating a scientific text into a knowledge map and underlining important information in a scientific text is superior to just reading a text. However, no significant differences could be found between concept mapping and underlining. Further more, Nesbit and Adesope (2006) report in their meta-analysis that concept mapping only has a small advantage compared to other construction tasks like note taking or summary writing. Against this background the aim of our research is to investigate whether concept mapping or summary writing is more effective for promoting students' learning from authentic problems in the field of business. For that purpose, we conducted two studies using the same material, one focusing on individual concept mapping and one focusing on concept mapping of pairs.

2 Study 1: Concept Mapping vs. Summary Writing as Learning Tools in Problem-Oriented Learning of Individuals

2.1 Research Question and Hypothesis

Research Question: Does concept mapping lead to better learning results than summary writing while learning from authentic problem-oriented texts?

Hypothesis*:* Concept mapping is superior to summary writing.

2.2 Learning Material

We developed an authentic case (see Fig. 1) which should support students in learning different forms of financing. In addition, we provided the students with learning material consisting of data about the case and information necessary for solving the problem.

Taxi firm *Speedy Rite* is a one-mans' business. The owner, Mister Simons, is also the manager. The firm possesses 6 cabs. All cabs are from trademark Cicerro. Two of the cabs are 6 years old, two 4 years and two 2 years old. The economic working life of the cabs is 6 years, so two of the cabs have to be replaced. Until now Simons has bought all new cars by a bank loan. He is wondering, however, if it is wise to continue that habit now during the financial crisis. Besides, he is asking himself if the bank is willing to give him a loan again. Simons considers if he is better off leasing the cabs. But, unfortunately, he is not capable of deciding about which form of financing will best meet his needs. And, he does not understand the meaning of the two different forms of leasing – financial and operational – and the consequences they will have for his business.
Therefore, he is asking you for help. Figure out what is best for Simons: buying the cabs with a bank loan or leasing the cabs: financial or operational. The advice you will give Simons has to be reported in a clear manner.

Figure 1: Authentic Case

2.3 Method

2.3.1 Participants and intervention

A total of 26 students of a commercial high school (pre-university level) in their next to last year took part in the study during the school year 2010/2011. They were 18.4 years old on average. All students had prior knowledge about management but not about forms of financing. The students were randomly assigned to a control group or to one of two experimental groups, i.e. either concept mapping or summary writing. The students of the control group just studied the learning material and had to find a solution for the problem (see Fig. 1). They did not accomplish an additional learning strategy. The students of the two experimental groups had to work through the learning material and in addition construct a concept map (using paper & pencil) or write a summary on the relevant information. All groups spent the same time on task. As an aid every student of the experimental groups received a list of concepts. In addition, the students of the concept mapping groups received a list of relations. The concepts and relations were gained in a pre-study with a comparable group of students. The summary writing group was introduced to a summary writing technique PQ4R (Preview, Questions, Read, Reflect, Recite, and Review) (Thomas & Robinson, 1972). Four days before starting the study, we put the respective strategy across to the students by means of familiar topics.

2.3.2 Data Gathering

Before and after the treatment the students took a knowledge test consisting of tasks in short answer or essay format. Questions in multiple-choice format were not included. The pre-test consisted of 8 questions aimed at assessing the basic economic knowledge necessary to understand the task and to integrate information with prior knowledge. The students could reach 44 points at most. Cronbach's α was 0.62. The post-test consisted of 9 questions aiming at assessing retention and transfer of the specific information to be learned from the material, that is to say the forms of financing (see Fig. 1). The highest point score is 31. Cronbach's α was 0.61. In addition, we collected both the summaries and the concept maps in order to gather data about the quality of the learning process.

2.3.3 Data Analysis

The students' answers were analyzed using a qualitative content analysis procedure. This is a systematic, replicable technique for assigning words or phrases of a text to content categories based on explicit rules of coding. On the basis of the qualitative content analysis a test score was calculated for each student. To determine whether the differences in knowledge could be explained by prior knowledge or by the respective learning strategy (concept mapping or summary writing), Analyses of Covariance (ANCOVA) (controlled by pre-test score or controlled by the quality of concept maps/summaries) were carried out with post-test scores as dependent variable. In addition, we calculated Analyses of Variance (ANOVA) in order to control differences in pre-test and post-test knowledge between the groups and in order to control differences in quality of summaries and concept maps between the groups. In addition, we calculated correlations (Pearson) of pre-test scores, post-test scores, and quality.

To assess the quality of the summaries, we constructed an expert's summary based on the respective curriculum and textbook. The expert's summary represents the learning objective. We, then, divided the summary into 50 units of meaning, such as "leasing instalment depends on contract period" or "debtor has to have securities". The same procedure was applied to the students' summaries. We divided every summary into units of meaning. In case the student's unit of meaning matches the expert's unit of meaning we coded a "1", otherwise a "0". Consequently, the score of a student's summary could range between 0 and 50 points. In the same manner as for the summaries, we constructed an expert's concept map which consisted of 35 propositions. In order to determine the quality of the individual maps, we calculated the percentage of accordance between individual concept map and expert's concept map based on the propositions as unit of analysis. In case the student's proposition matches the expert's proposition we coded a "1", otherwise a "0". Consequently, the score of a student's concept map could range between 0 and 35 points. The higher the score, the closer the summary or the concept map comes to the learning objective.

2.4 Results

In terms of test scores, the concept mapping group had lowest prior knowledge (18 points), the control group scored second best in the pre-test (19.6 points), the summary group had the highest prior knowledge (20.9 points) (see table 1). In the post-test, the summary group scored best (17.6 points), followed by the concept mapping group (16.9 points) and finally by the control group (13.4 points). At large, the summary group outperformed the two other groups, but the difference between the summary group and the concept mapping group was smaller in the post-test than in the pre-test whereas the difference between summary group and control group increased from pre- to post-test. Based on the percentages, the concept mapping group had the highest increase in knowledge (see Tab. 1).

The ANCOVA (controlled by pre-test scores) showed that the groups did not differ significantly in their post-test scores ($F_{(2,22)} = 2.392$; $p = .115$, $\eta^2 = .179$), but that the pre-test scores significantly influence the post-test scores ($F_{(1,23)} = 11.579$; $p = .003$, $\eta^2 = .345$). Thus, the results in the post-test can be partly explained by the prior knowledge of the students, and not by the assignment to one of the experimental or the control group. Additional ANOVAs support the fact that the 3 groups did not differ significantly in pre-test scores ($F_{(2,23)} = .460$; $p = .637$, $\eta^2 = .038$) or in post-test scores ($F_{(2,23)} = 1.581$; $p = .227$, $\eta^2 = .121$).

The quality of the summaries is much better than the quality of the concept maps (see table 1). An ANOVA proved that the groups significantly differ in quality of maps and summaries ($F_{(1,19)} = 19.256$; $p = .000$, $\eta^2 = .503$). The ANCOVA (controlled by quality of summaries/concept maps) showed a significant main factor group ($F_{(1,17)} = 4.579$; $p = .047$, $\eta^2 = .212$), a not significant main factor quality ($F_{(1,17)} = 1.624$; $p = .22$, $\eta^2 = .087$), and a significant interaction factor group*quality ($F_{(1,17)} = 7.945$; $p = .012$, $\eta^2 = .319$). Because of the significant interaction effect it was not possible to calculate a saturated model. The complementary correlation

analysis reveals that the quality of the maps correlates significantly and positively both with pretest-scores (r = .619, p = .032) and with post-test scores (r = .646, p = .023) whereas the quality of the summaries correlates negatively and not significantly with both pre-test (r = -.659, p = .054) and post-test scores (r = -.562, p = .115). This means that high pre-test scores go along with high quality of concept maps and high quality of concept maps with high post test scores and vice versa. In contrast, high pre-test scores go along with low quality of summaries, and low qualities of summaries go along with high quality of post-test scores.

	Cmap (N=12)		Summary (N=9)		Control (N=5)	
	Mean (in % of max. score)	(SD)	Mean (in % of max. score)	(SD)	Mean (in % of max. score)	(SD)
Pre-test	18 (40.9)	(8.5)	20.9 (47.5)	(4.5)	19.6 (44.5)	(4.9)
Post-test	16.9 (54.5)	(5.5)	17.6 (56.8)	(2.2)	13.4 (43.2)	(4.2)
Quality of Maps/Summaries (accordance with expert's version)	25.04%	14.2%	52%	13.45%		

Table 1: Results of Pre- and Post-Test: Means and (Standard Deviations); Quality of Maps and Summaries

3 Study 2: Concept Mapping vs. Summary Writing as Learning Tools in Problem-Oriented Learning of Teams

3.1 Introduction

This study differs in some way from the first study. The first study was comparing text writing and concept mapping for individual learning. However, many studies stated that collaboration is effective for learning. Chi (2004) and Roychoudhury (1993, 1994) conclude that concept mapping in collaboration can lead to effective discussions about concepts. That supports learning. Roth and Roychoudhury (1992) are seeing collaborative concept mapping as an activity that contributes to the development of the discursive practice. Concept mapping serves to force students to communicate in a scientific manner. Students become, as they call it, *members of a community of knowledge and practice.* They learn strategies to negotiate in the domain language and other usual communication forms in the domain. This type of interaction is described in literature as *explorative talk* (Mercer & Wegerif, 1999) and *construction and reconstruction* (Dekker & Elshout-Mohr, 1998). In a qualitative research study we wanted to find out if concept mapping results in more meaningful learning and better problem solving than summary writing.

Research Question:

Does concept mapping lead to better learning results than summary writing while learning from authentic problem-oriented texts? Can we explain the difference between the two conditions by a different learning process?

Hypothesis:

We expect that concept mapping as a tool for problem solving produces a more meaningful learning process than summary writing.

3.2 Method

3.2.1 Evaluation

In the second study we performed a qualitative experiment with two experimental conditions: the concept mapping condition and the writing condition. Students were working in pairs. They were randomly assigned to the two conditions. Pairs were formed by use of the 'middle group-method' (Pijls, Dekker, & Van Hout-Wolters, 2003). First the students were divided into four groups: high, high/middle, low/middle and low grade point averages, consecutively. Then, students from the group with the high grade points averages were teamed up with students from the high/middle group and students from the group with the lowest grade point averages were teamed up with students from the low/middle group. This method resulted in pairs that were heterogeneous but not extremely so.

Two pre-tests were administered to check whether or not the groups differ in prior knowledge. One measured the verbal ability of the students and one measured prior knowledge as precondition for the tasks. The post-test – that was different from the pre-task - measured what the students learned from the task.

3.2.2 Participants and instruction

Thirty students 16-18 years old from the pre-final year of pre-university education participated in the study. They were following a three years course - called *Management and Organization* beside other economic and general education. The students were in their second year. The subject chosen for the experiment – a loan from the bank for investment and leasing - had not been taught before. All students were experienced with word processing. The CmapTools program used in the experiment was trained in two lessons before.

The instructions and the tests were part of the regular schedule at school. The research period covered five lessons: in the first lesson we assigned a verbal ability test and the pre-test to the students. The instruction followed in the second, third and fourth lesson. In the fifth lesson the students took a post-test.

3.2.3 The Learning Material

We developed the context case (see Fig. 1) for both conditions. Problem solving requires not only domain knowledge but also problem solving strategies. Because we cannot expect the students to be capable of problem solving in this phase of their study, we structured the problem according to the sub processes of Jonassen (1997).

In the first lesson students in the concept mapping condition were asked to construct a concept map guided by the following questions: 1. What do you know already about the different financial resources? 2. Show in the concept map what you have to know about the taxi firm to be able to give an advice. 3. Report in the concept map what you want to learn about this subject.

The students should use all related concepts they know and they had to define the relations between them. First they had to do that individually with paper and Post-its™. After that they had to compare their work in pairs. Then, they got information about the topic and specifications about the taxi firm's business and had to construct one concept map together on the computer. They must reach consensus about the map. Consequently, they had to discuss. The writing condition had the same task, but they were asked to write a summary instead of making a concept map. Their learning material consisted of information about bank loan, financial lease, operational lease, a balance sheet and a profit-and-loss account balance of the firm. In the second lesson students were asked to write down the priorities of the firm for financing new cabs and based on that to make comparisons between the financial resources. Their writings served as a help for that. In the third lesson students had to write the advice for the taxi firm.

3.2.4 Tests

A verbal ability test was performed by the students, which measures the students' ability to identify synonyms and interrelationships between words. The pre-test consisted of 14 questions. Possible minimum and maximum scores were 0 and 24, consecutively. Cronbach's α was 0.72.

The post-test consisted of 14 questions. An example for the questions is as follows: "What does it mean for a firm when a financial resource has influence on the solvability?" Possible minimum and maximum were 0 and 31, consecutively. Cronbach's α was 0.71.

3.2.5 Coding

To analyze the *concept maps* of the students, we decided to use the CmapTools *(website: cmap.ihmc.us)* to pull out all propositions provided by the program for each concept map. Propositions have two key components, "concepts" and "linking words" (also referred to as "linking phrases"). The linking words are consecutively used to join two or more concepts there by forming propositions. We coded the concept maps on two categories, i. e. size and quality (Cañas, Bunch, & Reiska, 2010). Size describes how many propositions are in a concept map. More propositions given by students can mean more knowledge. We counted the complete propositions: consisting of two concepts and their relation. In some concept maps the students had not written the linking phrases between the two concepts, but they were included in the second concept. In these cases we adjusted the relationship. The quality of the concept maps is measured by rating the correctness of the propositions: 0 pts – The content displayed in the proposition is wrong, 1 pts – The proposition displays the main idea, but the wording used or the relation lacks correctness, 2 pts – The content, the relation and wording of the proposition are correctly used and displayed. In the end a total of valid propositions per concept map and a total of gained points were calculated in order to compare the concept maps.

We coded the *texts* of the writing condition in the following way: We aimed at creating a rating system comparable with the one of the concept maps. We looked for propositions in the text. We used a color coding scheme to identify the three different forms of financing (financial lease, operational lease and bank loan). Each rater applied this coding scheme separately to the texts. Afterwards, all texts were compared with each other in order to evaluate the content and validity. We counted the propositions and we rated them in the same way as we did with the concept maps.

We coded the *advices* students wrote for the taxi firm by counting the arguments they used. Double arguments we only counted one time. After that we assessed the used arguments, just (1 point) or not just (0 points)

3.2.6 Analyzing the observations

We have read and discussed the protocols of the work of the student pairs in the concept-map condition and the text condition. We decided to focus on the part of the protocols where the pairs had to compare their findings, got new information and had to make a concept map or text together. It was during this activity that the discussions in both conditions were very vivid in the sense that the key economical concepts were most intensely discussed. Yet we were curious if there was a difference in the quality of the discussions between the concept-map and the text condition. For that purpose we selected fragments in which a good insight or a wrong insight into the key concepts was shown. We analyzed these fragments with the codes based on the Process Model for Interaction and Insightful Learning, developed by Dekker and Elshout-Mohr (1998). In the Process Model key activities are discerned: to tell or *show* one's work, to *explain* one's work, to *justify* one's work and to *reconstruct* one's work. These key activities are crucial for insightful learning. Students can regulate the performance of these key activities by *asking* each other *to show* one's work, *asking to explain* one's work and *criticizing* one's work. We coded the presence of key and regulating activities in the fragments. To clarify this procedure we give an example of a short fragment of a discussion of a pair in the concept-map condition, Mat and Jim:

Mat: Well, for a company it is clear, because you have a fixed amount each month that will be paid for the price per mile.
Jim: But you don't know how many miles you will drive.
Mat: Yes, but here it says 'operational lease will take care that the constant price per mile will be guaranteed, because a fixed amount per month will be paid for the cars'.
Jim: OK, the other lease … a kind of rent buy. Economical risk is here with the taxi company.
Mat: Yes, that is a big difference. He is economic owner but actually not legal owner… He does not finance the car, but it is on his balance.

The insight is revealed in the last phrase of Mat where he *justifies* his solution. But it was triggered by the fact that he first *showed* his thinking and *explains* it and that Jim in reaction to that gives a specified *criticism***.**

3.3 *Results*

The results on the pre-test showed that the two experimental groups did not differ in the beginning of the experiment. The t-test showed that the difference was not significant: $t = 1.14$, $df = 25$, $p = 0.265$. There was also no significant difference between the conditions in the post-test: $t = 0.637$, $df = 25$, $p = 0.53$. That means that the concept mapping condition is as good as the writing condition (see Tab. 2).

	Pre-test			Post-test		
	N	Mean	Std.-Dev.	N	Mean	Std.-Dev.
Concept mapping condition	14	10.68	4.29	14	9.68	3.68
Writing condition	13	8.84	4.04	13	8.75	5.23

Table 2: Results of Pre-Test and Post-Test

The advice to the firm that the pairs had to write had a remarkable result. In the figure 2 we see that there is not much difference between the two conditions concerning the amount of arguments (75-72), but the value of the arguments is much higher (52) in the concept condition compared to the writing condition (38).

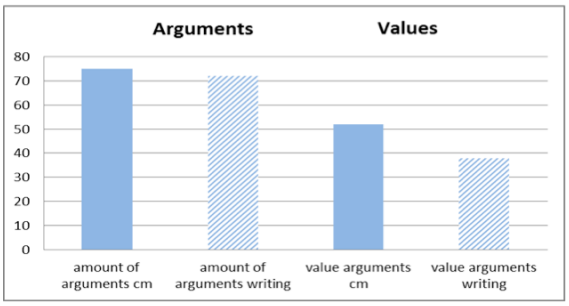

Figure 2: Amount and Value of Arguments

Concept mapping seems to be a good tool to stimulate the arguing between the students about the problem, so they are better prepared to give an advice. In the concept-map condition we found 52 fragments in which the students expressed a good insight of the key concepts and 13 fragments in which students expressed a wrong insight. In the text condition we found 39 fragments in which the students expressed a good insight and 29 in which the students expressed a wrong insight. So in the concept-map condition 80% of the fragments were positive, and in the text condition 57%. That is clearly a quality difference in favor of the concept-map condition.

Analyzing the fragments with the coding for the key activities revealed that in the concept-map condition 47% of all the key activities are explaining and justifying. In the text condition that is 28%. So the reasoning is much more evident in the concept-map condition than in the text condition.

4 Discussion

The learning strategies concept mapping and summary writing support the students' in problem-oriented learning. The groups using a strategy outperformed the control group using no additional strategy. Though the control group is very small in the first study and consequently not representative, the result is consistent with other studies according to which active involvement in knowledge construction, e.g. by the learning strategies such as concept mapping or summary writing, fosters learning. In addition, the results underline the meaning of learning strategies or learning tools.

However, the initial hypothesis in both studies has to be rejected. In both studies, the experimental groups did not differ significantly, neither in pre-test scores nor in post-test scores. Nevertheless, concept mapping seems to better stimulate both pair-arguing and individual reasoning about a topic. In the second study, the value of arguments in the concept mapping group is much better than the value of arguments in the experimental group. In the first study, though the quality of summaries is significantly better than the quality of maps, the concept mapping group gained ground in terms of test scores. In the post-test the concept mapping group is second best and there is no big difference between the summary group and the concept mapping group. In addition, the correlation analysis shows that the quality of the maps positively correlates with the test scores. The opposite is true for the summary group. Interestingly, high prior knowledge correlates with a low summary quality and high summary quality correlates with low post-test scores. We attribute these results to the fact that the specific summary writing technique (PQ4R) used in the first study may have misled the students to write off sentences from the original material without deep reasoning about the contents. Thus, the cognitive activity is reduced to the selection of sentences, not to knowledge construction. The more sentences they select, the higher the correspondence with the expert's solution and the higher the quality score. For a high quality score hints to not thinking about the contents it is no longer surprising that a high quality score corresponds with a low post-test score. In our case, a low quality of summaries presumably indicates a more critical selection process of information and thus more reasoning. In contrast to summary writing, the concept mapping condition forced reasoning at any rate, be it that the students had to transform text into maps and/or to negotiate with others. Thus, for learning and instruction we are in favour of concept mapping independent of the individual or pair condition. Admittedly, the post-test scores can be mainly explained by prior knowledge.

The fact that the experimental groups did not differ significantly and that the positive effects of concept mapping did not fully work through may be attributed to the comparatively new format for knowledge explication which is required by concept mapping. The students may not be familiar enough with the technique so that they cannot apply it confidently. Instead, the students may much more be used to summary writing. Thus concept mapping is more time consuming and causes more extraneous cognitive load (Sweller, 1988) compared

to summary writing. Continuous training in concept mapping previous to the study might have led to other results.

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