# How Can We Use Concept Maps for Prior Knowledge Activation – Different Mapping-Tasks Lead to Different Cognitive Processes

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**Abstract:** A think-aloud-study was conducted to examine how characteristic affordances of concept maps could be used for prior knowledge activation. Characteristic affordances of concept maps are connection lines representing the relationships between concepts and the labeling of these lines specifying the type of the semantic relationships. To investigate the effects of generating semantic relationships versus labeling existing semantic relationships during prior knowledge activation, 20 psychology students were given two concept-mapping tasks: 1) They had to draw and label the connections between the concepts of a map, and 2) they were given a map of concepts with connection lines and had to label the connections. Thinking-aloud protocols indicated more elaboration processes in the labeling-the-lines task than in the finding-and-labeling-the-lines task. On the other hand, the protocols indicated more overview and organization-processes in the finding-and-labeling-the-lines task. Thus, particular concept-mapping tasks elicit qualitative differences in prior knowledge activation processes, which has important practical implications.

## Introduction

The importance of prior knowledge influencing learning has long been acknowledged (e.g. Ausubel, 1986). Prior knowledge influences learning through cognitive processes of selection, organization, integration and recall (Renkl, 1996; Mayer, 1997; Weinert & Helmke, 1998). For selection, prior knowledge focuses the learner's attention on problem-relevant information and away from meaningless or distracting information, thus conserving information-processing resources. For organization, prior knowledge facilitates the combining of information into meaningful "chunks" that can be processed as a whole, thus also conserving information-processing resources. For integration, prior knowledge provides a framework or scheme through which new information is actively assimilated (integration in existing schemes) or accommodated (modification of existing schemes that conflict with the new information). For recall, the above described influences of prior knowledge on the selection, organization, and integration of new information reduce the amount of information to be recalled and provide association cues for recalling the new information from short-term and long-term memory.

Ausubel (1968) emphasized the importance of prior knowledge and developed the idea of the advance organizer in a general way, but did not provide educators with simple functional tools to assess and activate prior knowledge (Novak & Gowin, 1984, p. 40). Based on Ausubel's work, Novak and Gowin (1984) described hierarchical concept maps as tools for getting students to examine their prior knowledge before studying new materials. Concept maps provide an external network-like representation of knowledge structures. Concept maps consist of spatially grouped nodes with key-words representing concepts, connection lines representing the semantic connection of concepts, labels on the connection lines to specify the kind of the semantic connection, and arrows on the connection lines to specify the directions of the relationships or to guide the reader through the map (Ruiz-Primo, Shavelson, Li, und Schulz, 2001; Duit, Häußler & Prenzel, 2001). Concept maps have been shown to facilitate learning in a variety of contexts (for review, see O'Donnell, Dansereau, & Hall, 2002). Many studies have examined the benefits of studying concept maps compared to traditional text (or some other representation like an outline) or the benefits of using concept maps to study text compared to using a traditional study technique (e.g., outlining).

In this study, we examined the use of concept maps as tools for activating prior knowledge. Following Larkin and Simon's (1987) distinction between sentential representations, where data was indexed by a position in a list versus diagrammatic representation in which information is indexed by location, concept maps would be classified as diagrammatic representations. This simple distinction has implications why a diagram can be superior to a verbal description for solving problems. Spatial grouping might reduce search processes and facilitates perceptual inferences, which are extremely easy for humans (Larkin & Simon, 1987, p. 98). As many other external representations (e.g. outlines, tables, graphs) share these affordances, two characteristic affordances of concept maps are connection lines visualizing the semantic relationship and the labeling of the lines to specify the semantic relationship between the concepts. We share the hypothesis that different mapping tasks evoke different cognitive and metacognitive processes (Ruiz-Primo et al., 2001). When using concept maps for activating and examining prior knowledge, generating and labeling connection lines in a concept map versus just labeling connection lines in a concept map should lead learners to focus on different aspects of their prior knowledge. In particular, the process of finding and labeling connection lines should require learners to evaluate the organizational aspects of their prior knowledge, whereas the process of just labeling connection lines should not, or at least not as strongly, elicit the evaluation of organizational aspects of prior knowledge. Labeling connection lines, however, might lead learners to focus on justifying or elaborating on the reasons for the drawn connections.

## Research Questions

In particular we were interested how cognitive processes and acceptance for prior knowledge activation differ for two characteristic affordances of concept maps.

1. Are elicited cognitive processes different for labeling-the-lines and finding-and-labeling-the-lines?
2. Is the acceptance of these techniques for prior knowledge activation different for labeling-the-lines and finding-and-labeling-the-lines?

## Method

### Participants and Design

Twenty German psychology students (age $M$ = 26.5 years, 17 female, 3 male) participated in the study. Concept maps were new to 18 subjects, two subjects knew about concept maps and had frequently used them. Prior experience with the use of concept maps was not a threat to the validity of the study, because we were comparing two mapping-tasks, finding-and-labeling-the-lines and labeling-the-lines, not concept mapping to some other method.

Four types of maps were created. Learners completed either a label-the-lines economics mapping task (see Figure 1) and then a finding-and-labeling-the-lines meteorology mapping task or vice versa. The task order was counterbalanced across participants. We used this design to control for sequence-effects of topic and mapping-task. Participants were randomly assigned to the conditions.

### Procedure

In the beginning participants received the written instructions that explained concept mapping. The instructions included an example from biology, and explained how to label the lines (plus for a positive relationship or a minus for negative relationships). Using the same example, participants also completed a label-the-lines task and a fill-in-and-label-the-lines task on the computer to familiarize themselves with the software used in the research portion of the study. The mapping-software (Easy Mapping Tool, for more information see www.cognitivetools.com) was specifically adapted to the research so that concepts could not be changed, rearranged or added. The only possible actions for subjects were drawing and labeling lines.

After this introduction subjects read written instructions for their first mapping-task. To introduce a meaningful setting, we asked subjects to imagine being in a meteorology or economics-class (depending on the mapping topic) and to imagine that before the lesson started they think about what they know and do not know about the topic. We stressed that we were interested in the process of prior knowledge evaluation and that it was not the learning-product that mattered and stressed the importance of using the concept maps as a tool for this self-assessment. If subjects did not talk aloud for more than five seconds, the experimenter prompted them to continue talking.

After each mapping-task, participants completed a questionnaire addressing the usefulness of the technique for activating prior knowledge. After both mapping-tasks were completed subjects rated which of the two mapping-

tasks they found more useful for examining their prior knowledge. As a reward for participation subjects could choose between 7 EUR or the concept map program Easy-Mapping-Tool. The whole experiment lasted about 50 minutes while each of the two mapping-tasks took 10 minutes.

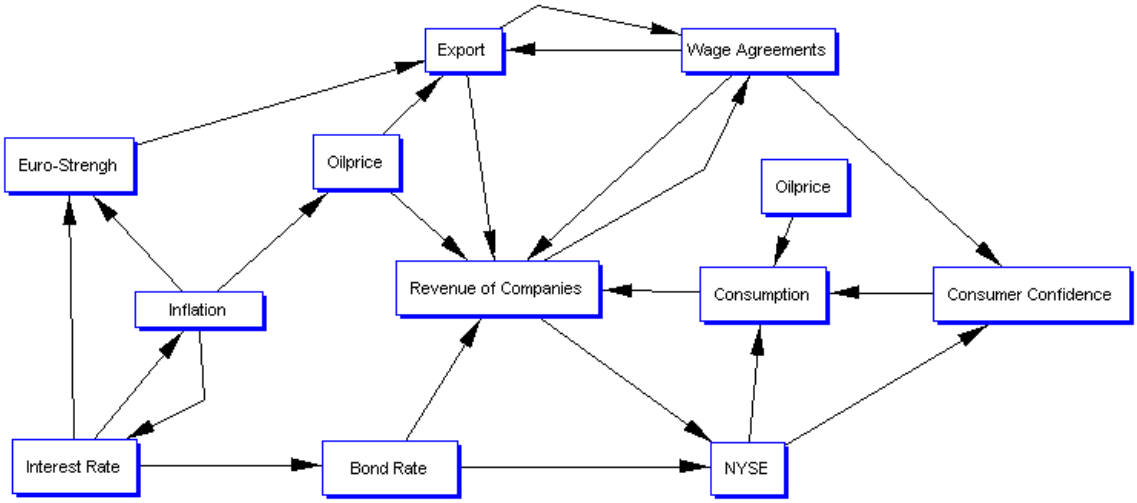


Figure 1. Example of the map on economic-relationships used for the labeling-the-lines task.

## Results

Talk aloud protocols were transcribed and separated into verbal units (Ruiz-Primo et al., 2001). One verbal unit was defined as one coherent semantic block, that is, thinking about a single concept or a concept-pair (Ruiz-Primo et al., 2001). Verbal units then were rated for elaboration, organization, definitions, overview, and negative monitoring (see Table 1).

Table 1: Categories that were used to rate think aloud protocols

| Category | Description | Examples from our think-aloud protocols |
|---|---|---|
| Elaboration | Elaborations are processes, to connect new knowledge with existing knowledge structures. Indications of elaborations are the generation of examples, the imagination of a picture, or other cognitive processes that enhance the given information (Weinstein & Mayer, 1986). | "Rising oilprice, has a negative influence on export of most companies. Or, yes, let me think, if you need more money for the production of some plastic then the product will be more expensive and it will be more difficult to sell it on the international markets, yes this has a negative influence." |
| Organization | These strategies are used to organize and reduce the new knowledge on the key features and to relate new knowledge pieces to each other (Weinstein & Mayer, 1986). As the task did not include the rearrangement or reduction of the learning content, we concentrated on the second aspect, thinking processes dealing with relations between two concepts. | "The higher the temperature the higher the evaporation." |
| Definitions | The learner clarifies the meaning of a word. | "NYSE, what is NYSE, New York Stock Exchange." |

| | | |
|---|---|---|
| Overview | Do learners draw a conclusion, do they relate more than two concepts and get an understanding of the "larger picture"? | "It seems that many paths lead to the cash flow. The cash-flow seems to be related with almost all other concepts. So this is the view of the business-owner…" |
| Negative Monitoring | Negative monitoring concerns processes, where the learner "looks himself over her/his shoulder" and finds out, what she/he did not know, or where she/he is not sure. | "For example, I'm not sure about the concepts interest rate and bond rate, but I'm sure I did hear them before. Still, to relate them is very difficult for me." |

We used a one-factor, repeated measures ANOVA to analyze the data. For all statistical analysis alpha was set .05. Following Cohen (1988) a small effect is a $\eta^2$ up to .01, a medium size effect is a $\eta^2$ until 0.06 and $\eta^2$ bigger than 0.14 are big effect sizes. Table 2 presents an overview about the results. 10 of the 40 protocols were co-rated by a second rater. Interrater agreement was high (Kappa was between .97 for elaboration and .74 for overview processes). Thus, only one rater coded the rest of the protocols.

Table 2: Means and Standard Deviations (in Parentheses) of Dependent Variables

| | Labeling-the-lines | Finding-and-labeling-the-lines | F-Value[1] | $\eta^2$ | p |
|---|---|---|---|---|---|
| Elaboration | 7.1 (3.42) | 5.2 (3.70) | 6.57 | .25 | .021* |
| Organization | 21.9 (5.11) | 25.1 (7.15) | 6.04 | .24 | .024* |
| Definitions | 1.65 (1.56) | 1.65 (1.46) | .00 | .00 | 1.00 |
| Overview | 2.1 (2.63) | 3.6 (4.45) | 5.51 | .23 | .030* |
| Negative Monitoring | 11.1 (4.49) | 12.7 (5.86) | 1.20 | .06 | .287 |
| Acceptance (6-point rating-scale from 1 = not helpful to 6 = very helpful) | 4.7 (0.97) | 4.8 (0.72) | .01 | .00 | .915 |
| Favorite mapping-task for prior knowledge activation (number of subjects). | 10 | 10 | | | |

***Note.*** [1]df=1,19; all tests were two-sided, n = 20; * statistically significant.

ANOVA revealed that the label-the-lines task elicited significantly more elaborations in the think aloud protocols than the find-and-label-the-lines task, $F(1, 19) = 6.57$, $p < .021$, $\eta^2 = .25$ (strong effect). However, ANOVA also revealed that the find-and-label-the-lines task elicited significantly more organizational and overview processes than the label-the-lines task, $F(1, 19) = 6.04$, $p < .024$, $\eta^2 = .24$ (strong effect) and $F(1,19) = 5.51$, $p < .03$, $\eta^2 = .23$ (strong effect), respectively. The conditions did not significantly differ in the number of definition or the number of negative monitoring statements. Thus, for the find-and-label-the-lines tasks, participants focused on the organization of their prior knowledge, determining what they knew or did not know about the relationships between the concepts, whereas for the label-the-lines tasks, participants focused more on their ability to justify or elaborate on the depicted relationships.

There was no difference in the acceptance of the two tasks for knowledge activation, the mean value of acceptance was 4.7 for labeling-the-lines and 4.8 for finding-and-labeling-the-lines (6-point rating scale, 1 = not at all helpful, 6 = very helpful). This is consistent with the preference for one or the other mapping-task for knowledge

activation where 10 subjects preferred the labelling-the-lines task and 10 subjects preferred the finding-and-labelling-the-lines task. A general indicator for the acceptance of both mapping tasks was that 17 of the 20 subjects chose the Easy-Mapping-Tool as a reward for participation.

## Discussion

The main goal of our study was to examine how cognitive processes and acceptance for prior knowledge activation differs for two characteristic affordances of concept maps. The results showed that the finding-and-labeling-the-lines task elicited more overview and organizational processes compared to the labeling-the-lines, but the labeling-the-lines task elicited more elaboration processes than the finding-and-labeling-the-lines task. The different mapping-tasks did not elicit differences in negative monitoring processes and also did not differ in their high level of acceptance for prior knowledge activation.

These results indicate, that the "more restricted task" of only labeling the lines realized the potential to evoke more elaborative processes because learners had to complete no search processes for semantic connections between concepts. This may reduce cognitive load (Sweller, Merrienboer, & Paas, 1998) and uncertainty about which concepts might be connected. On the other hand constraining the task in this way also has a trade-off. It led to less organizational and overview processes. One central implication of these findings is that we should differentiate concept mapping based on the specific affordances and tasks that have to be completed. But generalization of these results should be interpreted carefully with respect to the realized topics, mapping-technique and subject-pool.

From a practical point of view, the data shows that instructors need to consider the relationship between the affordances of the concept mapping task and the focus of the lesson. If the results could be generalized to other topics and subject pools we could give teachers the following recommendation for activating and examining prior knowledge with the realized mapping-tasks: Generating and labeling connection lines leads learners to focus on organizational aspects of their prior knowledge, whereas the process of labeling connection lines on existing relationships leads to an elaboration of connected concepts.

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