Concept Mapping to Learn and Innovate
Proc. of Sixth Int. Conference on Concept Mapping
Santos, Brazil, 2014

HOW TO TEACH THE CONCEPT OF PROPOSITIONS? A WORKED-EXAMPLE APPROACH TO HIGHLIGHT THE NEED OF PROPOSITIONAL SEMANTIC MEANING IN CONCEPT MAPS

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Abstract. Concept map (Cmap) elaboration is a cognitively demanding task. It involves dealing with the topic to be mapped and the challenge of expressing knowledge through high-clarity semantic propositions. The combination of these tasks can be overwhelming and impair the Cmap construction, producing poor propositions and limited associations among concepts (both cases lead to imprecise understanding about the conceptual relationship). Worked examples (WE) are useful for optimizing the limited cognitive resources available in working memory (WM). They can avoid cognitive overload, making explicit the expert rationale about the topic under study. This reduces the extraneous cognitive load and makes available cognitive resources to be allocated to schema acquisition and automation (germane load). The aim of this paper is to develop and test a WE about propositions during the training session on concept mapping with graduate students. Twenty-six participants were randomly assigned to the control group (CG, no access to WE, n = 12) or experimental group (EG, access to WE, n = 14). A pairwise comparison was conducted for the performance in near (questionnaires) and far transfer tests (Cmap elaboration). The main results indicated that near transfer showed no effect of studying with WE while far transfer study with WE somewhat enhanced the conceptual understanding about proposition. The EG used verbs more frequently in linking phrases to express conceptual relationships than the CG. The Cmaps made by the EG presented propositions with more semantic clarity, suggesting a positive effect of using WE.
Keywords. Concept mapping, cognitive load theory, proficiency, proposition, worked example.

1 The challenge of making propositions with semantic meaning

Concept maps (Cmaps) are powerful graphic organizers that represent knowledge and promote meaningful learning (Ausubel, 2000; Correia, 2012; Novak, 2010). Despite the potential of Cmaps (see, e.g., Nesbit & Adesope, 2006; Novak, 1990), there are main difficulties in their classroom implementation (Kinchin, 2001). Solving proficiency issues depends on achieving benchmarks that characterize good Cmaps, such as propositions as Cmap building blocks (Aguiar et al., 2014; Aguiar & Correia, 2013; Cañas et al., 2014; Cañas & Novak, 2006). During the Cmap elaboration, the learner must deal with the content's complexity (topic to be mapped) and the process to make propositions with semantic meaning. The combination of these processes can be overwhelming and lead to the elaboration of concept association (mind-mapping approach) rather than the formulation of propositional statements that reveal the conceptual relationships. The result is a Cmap with propositions without semantic clarity or linking phrases (Correia et al., 2014).

According to Cognitive Load Theory (CLT), we need to optimize information processing in working memory (WM) to avoid cognitive overload and foster learning processes (Sweller et al., 2011). Worked examples (WE) are one of the instructional guidelines offered by CLT to improve instructional design and avoid cognitive overload.

1.1 Cognitive Load Theory and Worked Examples

CLT proposes that all information is processed by the limited resources available in the WM and stored in the unlimited long-term memory (LTM). The learning process involves the acquisition of schemas through the combination of new knowledge and the information already organized in LTM. CLT assumes that WM suffers from the interference of three types of cognitive loads (Sweller et al., 2011):

- Intrinsic load, which depends on the complexity of the content to be learned.
- Extraneous load, which depends on the instructional methods and materials that will be used during the learning tasks.
- Germane load, which is related to the WM resources allotted to acquire and automate schemas.

Intrinsic and extraneous loads are additives, and the cognitive overload happens when their sum extrapolates the resources available in WM. Learning is impaired under this overload condition because there is no cognitive resource at WM available to acquire and automate schemas.

Well-designed instruction considers the limited resources of WM and keeps the extraneous cognitive load as low as possible. The ultimate goal of instructional design minimizes the extraneous cognitive load to make WM resources available for dealing with intrinsic and germane cognitive loads to acquire and automate schemas (Sweller et al., 2011). WE are useful for clarifying the expert rationale to address problem solutions. The schemas are organized and accessible to students, thereby reducing the extraneous cognitive load (Atkinson et al., 2000). WE can be product- (focus on the final result) or process-oriented (focus on the intermediate steps to reach the final result), depending on the features they present. In both cases, WE scaffold the learning process because students have access to the expert rationale during the task solution (van Gog et al., 2006).

The aim of this paper is to develop and test a process-oriented WE about propositions with semantic meaning and clarity to be used in a training session on concept mapping. It was hypothesized that students who have access to the WE (experimental group) will have a better understand of the role of linking phrases to express meaning through propositional structures. The level of understanding about propositions for both groups will be evaluated though near and far transfer tests.

2 Methods

2.1 Participants and Materials

Twenty-six graduate students from the University of São Paulo's EDM5103 Collaborative Learning and Concept Mapping: Fundamentals, challenges and perspectives course participated in this study (first semester 2014). Participants were randomly assigned to the control group (CG, did not study WE, n = 12) or experimental group (EG, studied WE, n = 14).

2.1.1 Worked Example

Figure 1 shows the WE about propositions studied by the participants assigned to the EG. The WE was divided into four topics. The first topic offered a proposition generic structure (and an example), explaining that propositions must have a verb in the link and are made by two concepts (e.g., nouns, adjectives, expressions). The second topic dealt with the importance of the verb in the linking phrase and the semantic clarity. Five examples were presented and explained. The third expressed the idea that small changes in the linking phrase can cause huge differences in the propositional meaning. Four examples showed changes included not only an inversion between concepts, but also negative words. The last topic dealt with how to evaluate propositions. Two questions must be asked to ensure the propositional quality: one about the semantic clarity and the other about conceptual correctness.

2.1.2 Near and far transfer tests

Transfer is the application of a schema to a problem that more or less deviates from problems encountered during the learning phase (Paas, 1992). In this study, the near transfer test (relatively simple and closely resembling the problems associated with learning phase with WE) consisted of a 13-statement questionnaire using a 4-point Likert scale, ranging from completely disagree to completely agree. The far transfer test (more complex and considerably different from the training problems) consisted of a Cmap elaboration of the text discussed in class.

2.2 Procedure

The data collection process in the classroom was organized in six steps (Figure 2): 1. Students discussed a text previously provided by the teacher (Kinchin et al., 2008). 2. Students were randomly assigned to the CG or EG. 3. The EG received WE to study for 10 minutes (the CG waited outside the classroom). 4. Both groups completed the near transfer test. 5. Both groups completed the far transfer test. 6. The teacher presented some final comments about the WE to both groups. All the students consented to participate in the research and declared their perceived mental effort during the tasks using a 7-point Likert scale (Paas, 1992).

2.3 Data analysis

A student *t*-test was used to compare the questionnaire answers and declared mental efforts of EG and CG. The far transfer test generated Cmaps (n = 26). All propositions were independently categorized by the authors of this research according to their semantic clarity (Table 1), without considering the conceptual validity. All statistical analyses were made using SPSS (v. 22.0, IBM, USA).

PROPOSITION

- **Structure of the propositions**

Propositions must contain messages with semantic and syntactic clarity. It is possible to understand and judge the declared conceptual relationship.

Ex: CHOCOLATE – is made from → COCOA

- **Semantic clarity depends on the linking phrase.**

Choosing an appropriate verb is critical to both describe the correct conceptual relationship and communicate it clearly through the proposition.

Ex:

CHOCOLATE – a → FOOD	No semantic clarity (**absence** of verb).
CHOCOLATE – **has** → FOOD	No semantic clarity (**with** verb).
CHOCOLATE – is a type of → FOOD	With semantic **clarity** and **correct**.
CHOCOLATE – **was** a type of → FOOD	With semantic **clarity** and **wrong**.
CHOCOLATE – **will be a** type of → FOOD	With semantic **clarity** and **wrong**.

- **Small changes can have huge impacts on meaning**

Reversing reading direction can completely change the proposition's meaning.

Ex:

CHOCOLATE – is made from → COCOA	With semantic **clarity** and **right**.
COCOA – is made from → CHOCOLATE	With semantic **clarity** and **wrong**.

Including small words (especially negative ones) in the linking phrase completely changes the message to be communicated.

Ex:

CHOCOLATE – is made from → COCOA	With semantic **clarity** and **right**.
CHOCOLATE – is not made from → COCOA	With semantic **clarity** and **wrong**.

- **Propositional evaluation**

Good propositions must present semantic clarity to allow for checking their conceptual suitability. We can use two questions to evaluate the quality of our propositions:

1) Does the proposition have semantic clarity? Is it possible to understand the meaning?
   No. In this case, the absence of semantic clarity reveals a problem in the proposition structure. It is not possible to check its conceptual suitability.
   Yes. The proposition's general structure is okay. It is possible to understand the meaning. In this case, we can move on to question 2.
2) Is the proposition conceptually correct?
   No. The message is clear, and it is possible to detect a conceptual error. Specific remediation actions can be implemented to overcome the identified error.
   Yes. The message is clear and conceptually correct. Further advances on the topic under study can be suggested because the mapped knowledge seems to be well assimilated by the mapper.

Figure 1. Process-oriented WE about propositions. Each topic (in bold) was followed by an explanation and example (in italics).

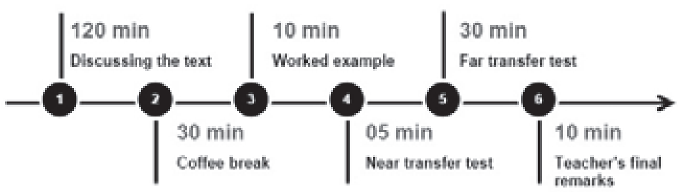

Figure 2. Steps for data collection in the classroom.

Table 1: Categories of propositional semantic analysis for the Cmaps produced during the far transfer test.

Categories	Description	Example
L1	Limited by missing the linking phrase	*University –→ knowledge*
L2	Limited by the absence of a verb	*University – and → knowledge*
L3	Limited by problems in verb conjugation	*University – increasing → knowledge*
L4	Limited by the absence of an arrow	*University – increases – knowledge*
NL	Non-limited (i.e., it is semantically clear)	*University – increases → knowledge*

3 Results

The results for the near transfer test showed no difference between the EG (M = 8.25, SD = 1.12) and CG (M = 7.46, SD = 1.20). Both groups perceived the same mental effort during this task (EG: M = 4.75, SD = 1.29; CG: M = 5.00, SD = .61).

The results for the far transfer test are presented in Figure 3. Although the EG made 70% non-limited (NL) propositions, the CG made 63%. The L1 (missing linking phrase) and L4 (absence of arrow) categories had the lower percentages, and their sum did not exceed 6% and 8% for EG and CG, respectively. The main difference between the CG and EG was the lack of a verb in the linking phrase to make clear propositions (L2 category): 17% of CG propositions did not have a verb whereas only 1% of EG propositions fit this situation. The EG presented higher problems with verb conjugation (L3 category) than the CG. The EG used verbs more frequently to make linking phrases (NL+L3 = 93%) than the CG (NL+L3 = 76%).

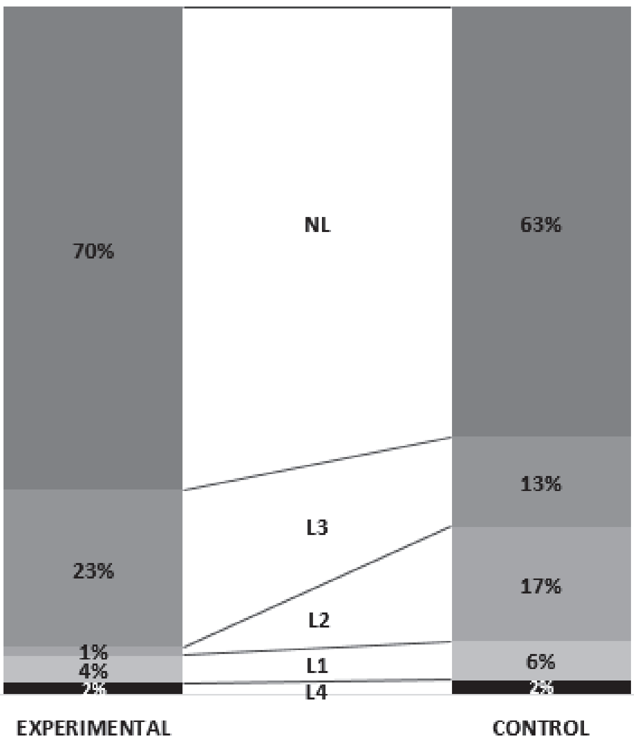

Figure 3. Comparison between the frequencies of categories of propositional analysis for each experimental condition.

4 Discussion

A pairwise comparison shows that the near test results were statistically equal - that is, neither performance nor mental effort for this task was affected by studying the WE about propositions. The 120-minute teacher's discussion about the selected reading (Kinchin et al., 2008) might scaffold the schema acquisition about the propositions to all students (in the CG and EG). Considering this specific condition (discussion about Cmaps before using the WE), the similar results for the CG and EG can be explained because the WE effect did not make a pronounced difference. A future study should be conducted in which the WE is presented before the text discussion about Cmaps to eliminate its potential interfering effect.

The results for far transfer test indicated that the EG was better than the CG when we consider the use of verbs to make clear propositions. The relationship involving semantic clarity and syntactic structure with verbs was clearer to the EG than to the CG due to the rationale offered in the WE. Figures 4a and 4b present Cmaps made by the CG and EG students, respectively. The comparison of these Cmaps draws our attention exactly because the L1 and L2 error types (only present in Figure 4a) do not open the possibility to evaluate problems with semantic clarity, which represents a poor propositional quality. Proposition *#2 Student – ???? → Higher education* (Figure 4a) is one example of statements that were classified as a L1-type proposition (as we found in a mental map) due to the lack of any linking phrase. When the learner stated a linking phrase, sometimes it was not possible to draw inferences about the conceptual relationship, like proposition *#10 New knowledge – acquisition → student*. Maybe the learners wanted to state that 'new knowledge was acquired by students,' but we will never be exactly sure about their real intention/meaning with this proposition and, consequently, about their knowledge.

On the other hand, if the student pointed out verbs in all his/her propositions (the case of the EG), error type L3 should be higher but has more quality in the semantic message. For example, in proposition *#13–14 Learn – to get feedback → Professor*, despite presenting a verb (NL), the message was not totally correct. The correctness evaluation was only possible because the student declared the relationship between 'learn' and 'professor.' In this case, the teacher could infer that this student understood 'learn' as a person who can do the action to get feedback from the 'professor;' actually, the person who does this action is the 'student' in the learning process. Demanding increasingly higher levels of proficiency in conceptual mapping should seek for propositions that convey meanings (i.e., more like the propositions of the EG than the CG). It is worth mentioning that the application of WE to teach about focus questions under similar conditions was also investigated by our research group (Pereira et al., 2014).

(a)

(b)

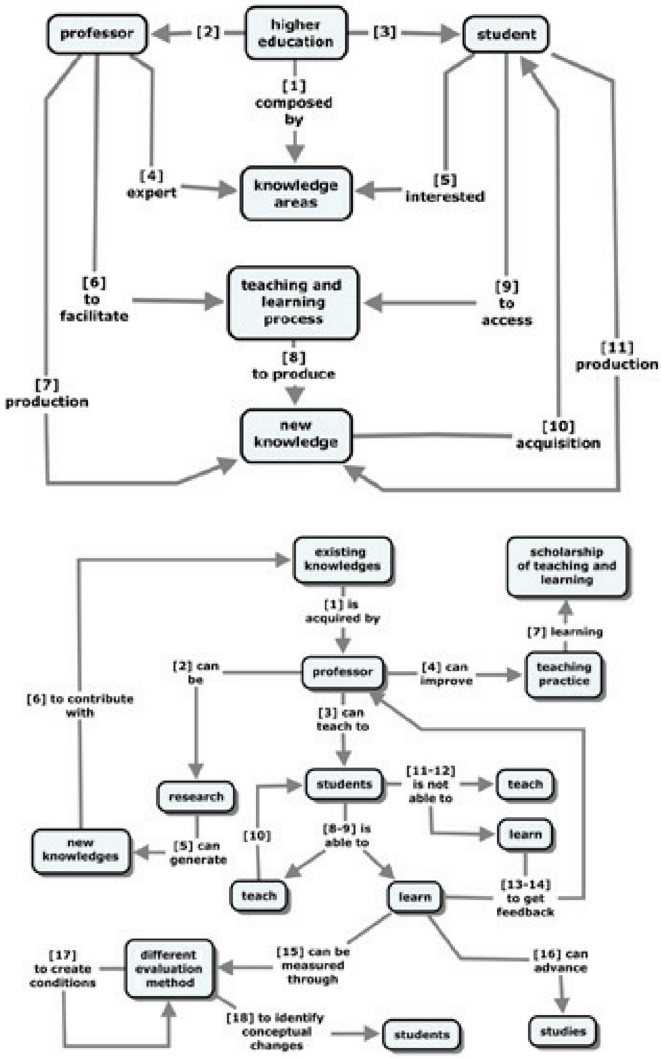

Figure 4. Cmaps made by students during the far transfer test: (a) CG (b) EG.

5 Acknowledgments

The authors thank CNPq (Grant # 486194-2011-6, National Counsel of Technological and Scientific Development) and FAPESP (Grant # 2012/22693-5, São Paulo Research Foundation) for funding our research group. R. L. R. thanks CNPq (# 149754/2013-2) for his scholarship. A. O. P. thanks NP-NAP (Research Center on New Pedagogical Architectures) for her scholarship. J. G. A. thanks CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) for her scholarship.

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