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EFFECT OF THE NATURE OF THE FOCUS QUESTION ON PRESENCE OF DYNAMIC PROPOSITIONS IN A CONCEPT MAP

Norma L. Miller, Universidad Tecnológica de Panamá & Proyecto Conéctate al Conocimiento, Panamá
Alberto J. Cañas, Institute for Human & Machine Cognition, USA
E-mail: norma.miller@utp.ac.pa, norma.miller@conectate.edu.pa

Abstract. The effective use of concept maps in education has been limited by a generalized tendency amongst learners to construct descriptive concept maps, characterized primarily by static propositions. Adequate representation of knowledge, however, calls for both description and explanation, that is, a combination of both static and dynamic propositions. This is especially true of scientific and mathematical reasoning, where dynamic relationships are necessary to establish interdependencies and covariation among two or more concepts. Experiments have shown that dynamic focus questions significantly increase the presence of dynamic propositions in concept maps. The results presented in this paper confirm this finding, and suggest further that the two vary in direct proportion to one another, that is the more open and dynamic the focus question, the more dynamic the resulting propositions.

1 Introduction

At the closing of the Second International Conference on Concept Mapping, in Costa Rica, Cañas & Novak (2006) called for a re-examination of the foundations of concept mapping in order to make better use of the tool. In their address they noted that in spite of the increased usage of concept maps worldwide, much of the tool's representational power continues to be lost to most users.

One of the reasons identified by Cañas & Novak (2006) is the tendency, pervasive among mappers, to construct descriptive concept maps, as opposed to explicative maps. This in turn appears to be the result of focusing on objects rather than events. According to these authors, concept maps that deal with objects generally end up being descriptive maps, characterized almost entirely by static propositions; in contrast, concept maps that involve events are usually more explanatory and contain more dynamic propositions.

Derbentseva, Safayeni, & Cañas (2004), for their part, have pointed out that in general adequate knowledge representation requires both static and dynamic propositions, as it is the latter that capture covariation and changing relationships among two or more concepts. This assertion is especially true for scientific and mathematical knowledge, where causal relationships and interdependencies among two or more variables often show up. Thus, propitiating dynamic propositions in concept maps is a most desirable goal.

Recently, Derbentseva, Safayeni, & Cañas (2006) experimented with two different strategies to increase the number of dynamic propositions in a concept map. One approach involved quantification of the root concept, while the other involved experimenting with the nature of the focus question. For the purpose of the present article, we center our attention on the second strategy, namely, on the relationship between the nature of the focus questions and the kinds of propositions that show up in a concept map.

As Novak & Cañas (2008) indicate, focus questions make explicit the questions or problems which concept maps are supposed to address. In this manner focus questions help direct the learner's attention to the issue under consideration. Additionally, since hierarchies among concepts and relationships are highly context dependent, focus questions help establish a specific context within which to rank and relate concepts, thereby guiding concept map construction.

According to Novak & Cañas (2008), the nature of the focus question influences the type and quality of the resulting concept map. The study by Derbentseva *et al*. (2006) provides evidence that this is indeed the case. In their research they compared a focus question asking "what is concept X?" with a focus question asking "how does concept X work?" Their results showed that the "how" condition produced significantly more dynamic propositions than did the "what" condition.

In this paper we present evidence that substantiates the findings of Derbentseva *et al*. (2006). Our results suggest, furthermore, that the more open and dynamic the focus question, the more dynamic the nature of the resulting propositions, i.e., that there may be directly proportional relationship between the two variables.

2 A classification of focus questions

In considering types of focus questions two criteria were considered: first, the degree to which a question admits a variety of answers across different individuals, that is, how open to personal input a question is; and second, the degree to which the answer requires explanation through dynamic propositions. With these criteria, focus questions were classified as: 1) closed or classificatory, 2) open-static, and 3) open-dynamic. Closed or classificatory questions tend to have a universally accepted answer and therefore do not allow much variation among respondents. Maps responding to this type of question tend to be quite similar to one another, as room for personal input is minimal. Examples of this type of question are *"What are the layers of the Earth?"* or *"How is Panama divided politically?"* Open-static focus questions generally request descriptions of concepts. They admit a variety of responses, since personal experience can be incorporated into these descriptions; however, they tend to lead to maps that depict unchanging relationships, i.e., maps that are basically static in nature. Examples of these kinds of questions are *"What is magnetic resonance?"* or *"Who was Picasso?"* Finally, open-dynamic focus questions generally deal with events, rather than objects, and go beyond requiring mere descriptions to demanding reasons and explanations for these events, be they situations or happenings. Maps responding to this type of question account for changing relationships and interdependencies among concepts, hence their overall dynamic nature. Furthermore, responses vary greatly among learners, since personal experience and understanding plays a major role in map construction. Examples of open-dynamic questions are *"Why do birds migrate?"*, *"Why is it important for pregnant women to ingest folic acid?"*, or *"How does an airplane fly*?" As can be appreciated, the classification proceeds simultaneously from less openness to more openness, and from requiring fewer dynamic propositions to requiring more. Also, one can see that the typical "What is...?" focus question tested in Derbentseva *et al*.'s study falls in the open-static category, whereas the "How does...?" question pertains to the open-dynamic class.

3 Dynamic propositions

Safayeni *et al*. (2004) define dynamic relationships as those that establish implication, functional interdependence and covariation among the concepts. Static relationships, on the other hand, "describe, define and organize knowledge for a given domain" (ibid, p. 10). In our work, dynamic propositions are defined slightly differently: we consider a proposition to be *dynamic* if it involves 1) physical movement, 2) action, 3) change of state, or 4) it establishes some form of dependency or causal relationship. Propositions that are not dynamic are *static*.

We further classify dynamic propositions as causative or non-causative. In order for a dynamic proposition to be causative, one part of the proposition must embody the "cause" or "probable cause," while the other part must correspond to the "effect." Alternatively, one part of the proposition must be identifiable as the "source" from which that which the effect stated in the other part of the proposition originates. In non-causative dynamic propositions no such identification is possible. The propositions given below exemplify these three types of propositions:

- Examples of static propositions:
  - *The sun is a star*
  - *Means of transportation include land transport*
  - *Panama is located in Central America*
  - *Animals may be vertebrates.*

- Examples of non-causative dynamic propositions:
  - *Roots absorb water*
  - *Herbivores eat plants*
  - *Living beings need oxygen*

- Examples of causative dynamic propositions:
  - *Cigarettes produce cancer*
  - *Rule of law attracts foreign investment*
  - *Heat melts ice*
  - *Paper comes from trees*

Causative propositions, in turn, may be divided into quantified or non-quantified. Quantified causative propositions explicitly indicate the manner in which a certain change in one concept induces a corresponding change in the other concept, unlike non-quantified propositions that make no reference to directionality or any other measure of the causal relationship. The following examples help clarify these distinctions:

- Examples of quantified causative dynamic propositions:
  - ***Increased*** *transparency in public affairs* ***discourages*** *corruption*
  - ***Under-activity*** *of the thyroid gland* ***decreases*** *body metabolism*
  - ***Increased*** *quality of education* ***contributes to greater*** *national development.*

In evaluating the dynamic nature of the propositions, the specific categories considered were the following: 1) only static propositions are present in the concept map (there are no dynamic propositions of any kind), 2) only non-causative dynamic propositions, 3) one to two causative dynamic propositions, 4) more than 2 causative dynamic propositions, and 5) one or more quantified causative dynamic propositions. This sequence of categories attempts to reflect an increasing degree of explanation in propositions. Static propositions, for instance, do not explain, they describe structural aspects of concepts. Non-causative dynamic propositions also are not explicative; rather they tend to describe functional aspects of concepts. Causative dynamic propositions, in contrast, explain how one concept produces or results from another; quantified causative dynamic propositions, additionally, provide a direction or measure of the covariation between cause and effect, that is, they explain how change in one concept cause changes in the other. Thus, according to this description, the more dynamic a proposition the greater its explanatory nature.

4 Methods and procedures

The results presented here were obtained as part of a larger research program that investigated the acquisition of skill in concept mapping by in-service Panamanian public elementary schoolteachers participating[1] in Panama's *Conéctate al Conocimiento* Project (see Tarté, 2006). To this end, initial and final concept maps created using CmapTools[2] (Cañas *et al*., 2004) were gathered via the CmapTools Recorder feature (Miller, Cañas & Novak 2008). The sample was obtained from 18 different training groups, taught by different pairs of Project facilitators over the course of a 3-month period extending from July through September 2006, and ended up consisting of 258 teachers. For both these maps teachers worked individually. Topics for the final map were freely chosen by the teachers; for the initial map, topics were chosen in 14 of the 18 groups, while in the remaining 4 groups maps were based on an assigned reading. In all cases teachers posed their own focus questions. Time allotted for map construction varied among training groups, but generally was between 1.5 – 2 hours. However, some teachers stopped before the time was up, while others continued working afterwards.[3] Thus, mean construction time for the first map was 1 hour 32 minutes, and 1 hour 58 for the final map.

Completed Cmaps were analyzed using the taxonomy for concept maps developed at the Conéctate Project. This taxonomy consists of a topological taxonomy (Cañas, Miller, Novak *et al*., 2006), used to evaluate concept maps in terms of their structure, and a semantic scoring rubric (Miller & Cañas, 2008), to evaluate content. In addition to overall semantic evaluation of Cmaps, specific semantic elements such as focus questions, dynamic propositions and cross-links were scrutinized. This paper reports the results of the examination of focus questions and dynamic propositions, as well as the relationship between them.

At the Conéctate workshops focus questions are viewed as an important component guiding concept map construction. They provide not only a context for the map, but a specific query, problem or issue which the map must address and respond to. Facilitators in charge of teacher training introduce focus questions from the very first day of the workshop. Though specific remarks evidently depend on individual facilitators, most comments would have been aimed towards emphasizing their guiding/contextualizing role, and getting teachers' maps to answer the focus question.[4] Some facilitators may have gone a bit further, and encouraged teachers to pose questions outside the school curriculum, about topics pertaining to their everyday lives or subjects of general interest to them. One can be certain however that no mention would have been made about the classification described above, for the simple reason that it was unknown to the facilitators themselves.

Regarding dynamic propositions, most facilitators have been exposed to the term through the involvement of Cañas and Novak in the Conéctate Project, and their presentation at CMC 2006 (Cañas & Novak, 2006). However, the definition of dynamic proposition presented here, as well as the classification of concepts from

[1] It should be pointed out that the selection of teachers and schools to participate in the workshops, and the assignment of teachers to training groups, were beyond the control of the researchers.
[2] We denote concept maps created using CmapTools as Cmaps.
[3] Some would work during part of their coffee breaks or lunch period.
[4] Novak & Cañas (2008) have remarked on learners' tendency to veer away from the focus question and construct concept maps that respond to some other question, rather than the one originally put forth.

least to most explanatory, were and continue to be unfamiliar to all but a few of the facilitators. Moreover, the general idea of dynamic proposition at present is not a topic discussed in the Conéctate workshops. For all these reasons, one can rest assured that teachers were not familiar either with the notion of dynamic proposition, and much less with the categorization we made of them.

5 Results

Cmap Figure 1 displays the distribution of focus questions on the initial and final Cmaps, according to the classification given above. In both cases the distribution was centered on the open-static category; however, there was less dispersion in the final Cmap. It is interesting to note, that the overall the percentages in the closed/classificatory and open-dynamic categories remained virtually unchanged from one map to the other. However, as can be seen, the narrowing of the range in the final map resulted from a decrease of maps with no focus question and an increase of maps with open-static focus questions.

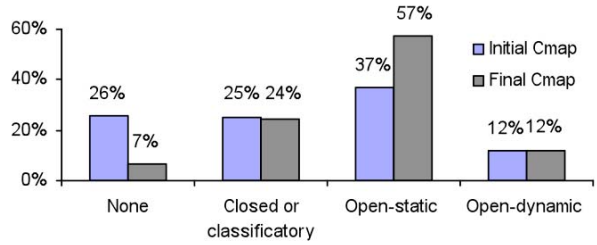

Figure 1. Distribution of focus questions in initial and final Cmaps.

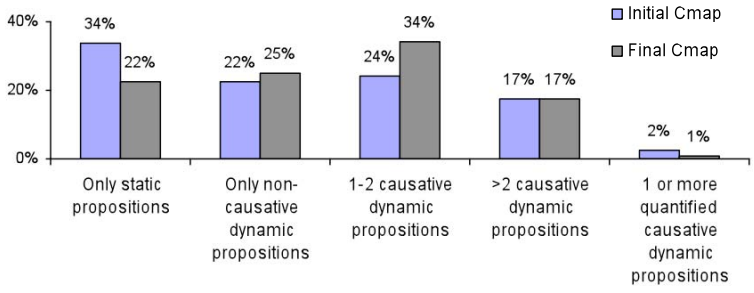

Figure 2. Distribution of dynamic propositions in initial and final Cmaps.

A corresponding analysis was carried out for dynamic propositions (figure 2). The graph shows a similar distribution pattern for dynamic propositions in the initial and final Cmaps. Both are characterized by a relatively uniform distribution across the first four categories, contrasting with the absence of propositions in the fifth category, the class of quantified causative dynamic propositions. The main difference between the two maps was a shift to the right, accounted for mainly by the decrease in the category of only static propositions and a corresponding increase in the 1-2 causative dynamic propositions category. Despite the decrease in the first category, there still remains in the final Cmap a considerable fraction (22%) with only static propositions in them. Likewise, close to half the maps (47%) contain no cause-effect propositions.

Next we explored the relationship between the type of focus question put forth (independent variable) and the dynamic nature of the propositions present in the concept map (dependent variable). To investigate this relationship analytically we made use of ordered logit regression analysis, since the two categorical variables

have a “natural” ordering. The “goodness of fit” probability was 0.09 on the initial Cmap and 0.00 on the final Cmap. Thus, the null hypothesis – that there is no relation between the type of focus question and presence of dynamic propositions – is rejected in favor of an association between the two variables. The probability values suggest a weaker association in the first Cmap and a stronger one in the final map.

These results can be observed graphically by inspection of figures 3 and 4. If one were to envelope all four categories of focus question under a single bell-shaped curve, one would notice, in the first Cmap, that the center hovers somewhere between the closed/classificatory and the open-static category, and the distribution has a fairly high variance; in contrast, in the final map the mean lies farther to the right, above the open-static category, and there is much less variance in the distribution.

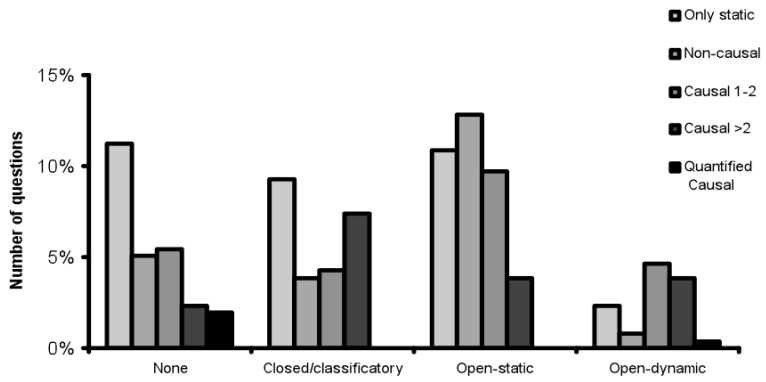

Figure 3. Relation between focus question and propositions present in initial Cmap.

If one looks across the different categories one also notes a certain pattern: the center of imaginary bell curves superimposed over each of the 4 categories moves farther to the right as the category moves to the right. This pattern is more pronounced and evident in the final map. What this suggests is that as the focus question becomes more open and requires more explanation to answer it, the propositions indeed become increasingly explicative.

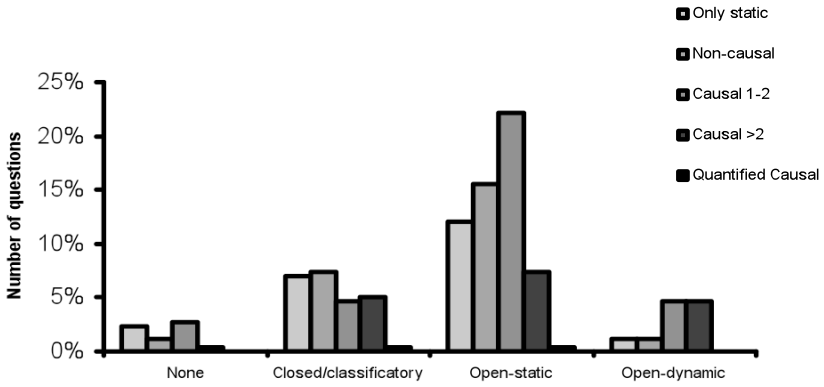

Figure 4. Relation between focus question and propositions present in final Cmap.

Finally, and along the lines of Derbentseva *et al.*’s (2006) study, we compared the presence of dynamic propositions, specifically causative statements, in Cmaps with open-static versus open-dynamic questions. The contingency table in figure 5 shows our findings. What we see is that open-static questions lead to a relatively equal distribution of causative and non-causative proposition; whereas, open-dynamic questions lead to more causative propositions in a ratio of 4 to 1.

		Nature of propositions		
		Non-causal	Causal	Total
Type of focus question	Open- static	71	77	148
	Open-dynamic	6	24	30
	Total	77	101	178

Table 2. Contingency table showing a significant association ($P = 0.005$) between type of focus question and presence of causative dynamic propositions in a concept map.

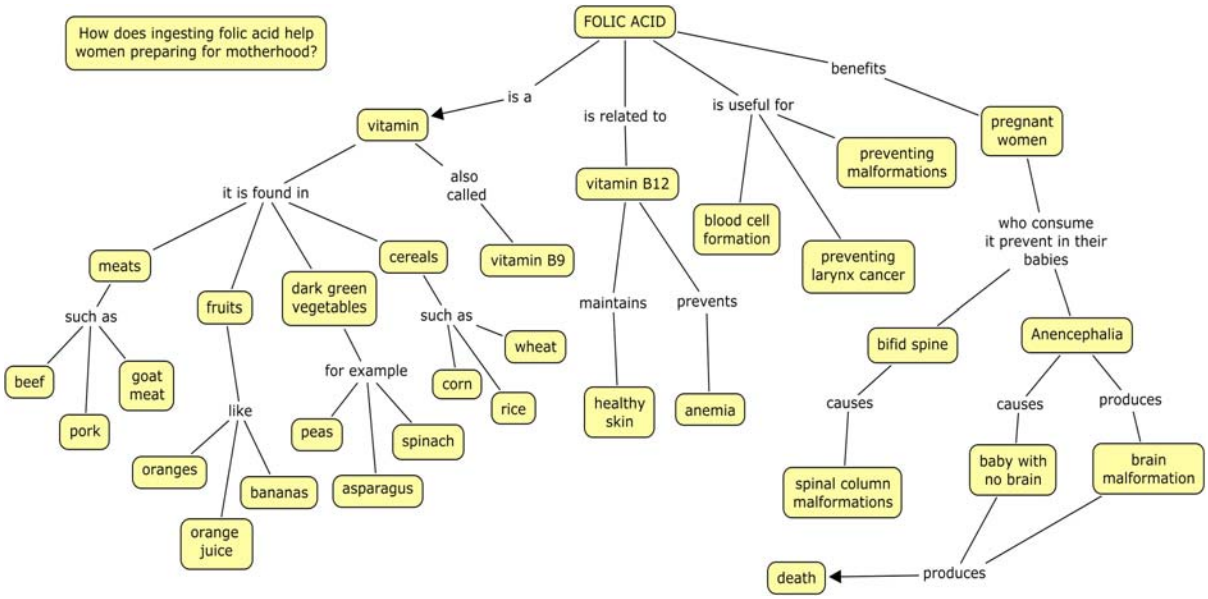

Figure 5. Concept map associated to an open-dynamic focus question: *"How does ingesting folic acid help women preparing for motherhood?"*

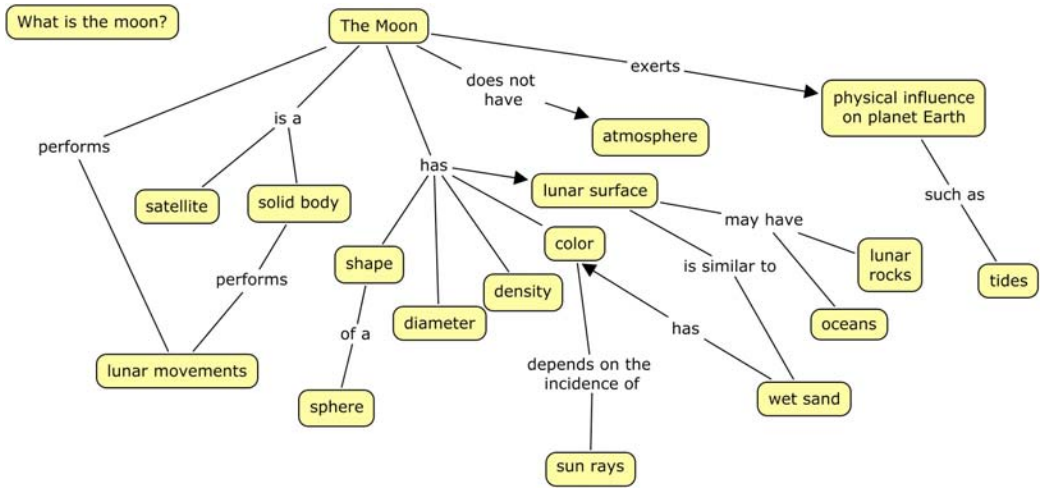

Figure 6. Concept map associated to an open-static focus question: *"What is the Moon?"*

Figures 5 and 6, respectively, show examples of rather typical Cmaps associated with open-dynamic and open-static focus questions. In the map corresponding to the open-dynamic question, of a total of 20 propositions (examples excepted), there are 12 causative dynamic propositions. In contrast, in the map associated to the open-static question, of a total of 18 propositions (there are no examples) there is only one that is causative.

6 Discussion

Concerning the type of focus question, results indicate a significant decrease in the number of maps containing no focus question and a corresponding increase in those with open-static focus questions. These findings were to be expected given the emphasis placed by facilitators on the importance of including focus questions in concept maps, and the encouragement given to considering topics outside the school curriculum, and closer to personal experience.

Results also reveal changes in the nature of questions, in particular the decrease of static propositions and parallel increase of causative propositions. Unlike changes in focus question, these results can not be attributed to facilitator intervention. As pointed out earlier, though most facilitators have been exposed to the notion of dynamic propositions, this is not a topic they are intimately familiar with, and it is not one that is covered in the workshops. Furthermore, the classification of propositions in terms of their explanatory nature was not known to them. In view of this, the distribution of propositions both in the initial and final maps, as well as any change in this distribution between the two maps, must follow, at least in part, from the type of questions guiding the construction of the maps.

We have seen that there is a clear positive association between the type of focus question and the nature of the propositions. In particular, the more open to personal experience and the more demanding of explanation a focus question, the more explicative the resulting propositions in the corresponding concept map. This finding confirms the result obtained previously by Derbentseva *et al.* (2006). However, it goes a bit beyond as well. Derbentseva el al.'s (2006) experiment compared two specific questions, a "what is..." question with a "how does..." question, which belong to our open-static and open-dynamic categories, respectively. In our setting, 258 virtually different questions[5] posed by an equal number of subjects were considered. Thus, our data essentially generalizes the previous result, showing that it holds true, independently of any particular question.

7 Conclusions

In this paper we have presented results confirming and generalizing an earlier result by Derbentseva *et al*. (2006) concerning the effect of the focus question on the dynamic nature of propositions in a concept map. We have shown that the more open to individual input and the more demanding of explanation the focus question, the more dynamic (explicatory) the nature of the resulting propositions.

If we are to take full advantage of concept maps as a tool for meaningful learning, especially with regard to the sciences, we must promote explicative maps, containing numerous dynamic propositions. The significance of this result rests in the possibility of achieving this increased representational power of concept maps. It demonstrates that by simply posing a certain kind of question, one that demands both an explanation and an evocation of personal experience, concept maps will naturally tend to incorporate more dynamic propositions. If this is accompanied by additional questions, particularly dynamic questions, concerning the relationships between pair of concepts, the explanatory potential of concept maps and their value as a Mindtool may be significantly increased.

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