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A SEMANTIC SCORING RUBRIC FOR CONCEPT MAPS: DESIGN AND RELIABILITY

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Abstract. At Panama's *Conéctate al Conocimiento* Project there was the need to develop measurement tools to help assess the Project's overall progress towards the goal of implementing the use of concept maps for meaningful learning in the country's public elementary schools. Efforts in this direction led to the development of a taxonomy for concept maps consisting of two components, a topological taxonomy, and a semantic scoring rubric. The topological taxonomy, along with a study of its reliability, was described in an earlier article. The complementary semantic component is presented in this paper. In view of the greater subjectivity involved in the assessment of map content as compared to structure, this tool was expected to be significantly less reliable. Nonetheless, results of our reliability study, conducted among Conéctate Project facilitators, showed an encouraging level of agreement, particularly in the linearly-weighted percent agreement.

1 Introduction

Conéctate al Conocimiento (Tarté, 2006) is arguably the most ambitious education reform project ever implemented in the Republic of Panama. The aim is to fundamentally transform the way children learn in Panamanian public schools, leaving behind the traditional model based almost exclusively on memorization in order to move towards more meaningful modes of learning.

Much of the effort at the Conéctate Project is directed to training teachers in concept mapping, as a means to foster meaningful learning in their students. Facilitators, the heterogeneous group of professionals in charge of teacher training, also visit schools to offer educators support in bringing about the desired changes. During the Project's first year (2005), it was difficult to determine the level of success that was being attained because reports coming in from facilitators were highly subjective. This was aggravated by the fact that the maps created by teachers and students ranged over a very wide spectrum – from the extremely simple to the highly complex – and by the lack of a common language, shared by all facilitators, in which to express all this variety. Thus the Project was in dire need of an objective measurement tool, one that would allow us to gauge more accurately and precisely the extent to which concept maps were actually contributing to meaningful learning processes.

This state of affairs led, in 2006, to an effort to design a tool that would "measure the level of progress in the representation of concept maps, beginning with simple maps, with linear sequences of concepts and texts in nodes, and without linking phrases; all the way to maps with clear propositions, good cross-links, linked to relevant resources and to other maps" (Cañas *et al*, 2006, p. 154). We sought a *taxonomy for concept maps*, similar to Bloom's (1956) taxonomy for cognitive domain skills.

Given that concept maps of novice mappers often could not be read meaningfully, due primarily to the presence of large portions of text and/or absence of linking words, we opted to separate our taxonomy into two components, one topological, dealing with the structure of the graphical representation, the other semantic, dealing with the content.[1] The *topological taxonomy* (Cañas *et al.*, 2006) considers 5 criteria: concept recognition, presence of linking phrases, depth, ramification, and presence of cross-links. The classification consists of 7 levels, ranging from 0-6. Levels 0-2 are considered "poor" topologically speaking due to presence of long texts, absence of linking phrases, and essentially linear sequences of concepts. Level 3 maps are deemed "acceptable," since they show a clear recognition of individual concepts and linking phrases are not missing; however, they show only moderate ramification and depth, and no cross-links. Level 4 maps are essentially "good" maps; their main limitation is that they are missing cross-links. Levels 5-6, both of which include cross-links, are considered "very good" maps topologically speaking. A more detailed description of the taxonomy, along with the results of a reliability study conducted among Conéctate facilitators, may be found in Cañas *et al*. (2006). In this article we present the semantic component.

2 Semantic component of the concept map taxonomy

In keeping with the design behind the topological taxonomy, our idea was to produce a *semantic taxonomy* that would serve to classify concept maps based on increasing levels of semantic complexity and quality of content.

[1] The idea, however, was that as mappers became more skilled in accurately representing their ideas in the form of a concept map, the topological component would become unnecessary.

Not surprisingly, developing a satisfactory tool to categorize maps semantically proved to be considerably more challenging than designing one to classify them by structure. Unlike topology, where there is little room for interpretation, semantics entails dealing with meanings, and meanings are always personal and idiosyncratic. An additional complication was the "one-size-fits-all" design requirement we imposed on the tool, that is, it had to be applicable to all domains of knowledge and adaptable to many levels of expertise.

Thus, although our original intention was to produce a classification system by levels of increasing semantic complexity, preliminary testing of the categorization we had come up with proved unsatisfactory. Given the specific semantic criteria we had selected, as well as the levels we had defined based on these criteria, we found that semantic complexity did not necessarily progress in an even fashion across all criteria for all learners, as was generally the case in the topological arena. In any given concept map, some semantic aspects might be quite advanced or well-developed, while others remained at a basic level.

Given the context of our work and the rather urgent need for the tool, we decided to go forward with a point-based evaluation scheme or rubric. Such a scheme had the advantage of not penalizing learners for their asymmetric progression towards semantically more complex concept maps. A correspondence was then set up between score ranges and overall content quality, thus yielding the required categorization. Nonetheless, the question remains as to whether it is possible to come up with a reliable classification system based on increasingly complex semantic levels, akin to our topological taxonomy, valid for all learners, independently of the different paths their concept mapping learning process follows.

There exist in the literature numerous systems for the evaluation of concept maps. These are essentially of three types: *component-based scoring* (e.g., Novak & Gowin, 1984), *comparison to expert or criterion maps* (e.g., Ruiz-Primo & Shavelson, 1996), and *hybrids* or combinations of the previous two systems (e.g., Rye & Rubba, 2002). Perhaps the most widely known is Novak & Gowin's component-based scoring model which assigns points based on 1) number of valid relationships, 2) number of valid conceptual hierarchy levels, 3) number of valid and significant cross-links, and 4) number of valid examples (ibid, p. 37).

Our own semantic scoring system, described in the following section, belongs to the component-based category. However, it includes criteria not considered in Novak & Gowin's rubric, some of which stem from our own experience with Panamanian teachers and students at the Conéctate Project, as well as from recent theoretical considerations put forth by Cañas & Novak (2006), directed at making better use of the representational power of concept maps. It also draws from ideas found in Derbentseva, Safayeni, & Cañas (2004); Safayeni, Derbentseva, Cañas (2005); and Novak & Cañas (2008).

We wish to call attention to the fact that we do not consider this rubric a "finished" instrument; as most measurement tools, it will require redesigning and calibration in order to improve its accuracy and reliability. Modifications are being considered as of this writing. Nevertheless, the tool (as presented in this paper) was applied (Miller, 2008) to a sample of more than 500 concept maps produced by teachers being trained at Conéctate, with a number of interesting results (see Miller & Cañas, 2008; Beirute & Miller, 2008); hence, our interest in making it public as used.

3 The semantic scoring rubric

The semantic scoring rubric developed at the Conéctate Project is intended to be applied only to concept maps containing sufficient structural and semantic elements to be read meaningfully. This essentially means that individual concepts predominate over undifferentiated texts, and that propositions are not missing linking phrases. Roughly, concept maps with a topological level of 3 or greater meet these requirements.

Our semantic rubric takes into account the following six criteria: 1) concept relevance and completeness, 2) correct propositional structure, 3) presence of erroneous propositions (misconceptions), 4) presence of dynamic propositions, 5) number and quality of cross-links, and 6) presence of cycles. In what follows we discuss each of these in turn.

In deciding concept relevance and completeness, external, contextual factors such as the author's personal background (including age, education level and culture) play an important role. For instance, what one would consider a fairly complete list of concepts on the topic of, say, photosynthesis, is not necessarily the same for a 4th grade student as for a teacher. A second aspect to consider is the source or sources of the map's content. A map may be based entirely on previous knowledge; or it may use a specific pedagogical experience, such as a reading, a film, an experiment, or a school visit, to build upon previous knowledge.

Additionally, within the map itself various elements can guide the evaluator in assessing relevance and completeness of concepts. First and foremost, the root concept. One can be fairly certain that this element is always available since at Conéctate teachers are taught to construct maps stemming from a given root concept; thus, it is never the case that a map contains no root concept. A second guiding element is the focus question. This element is less reliable though, since sometimes the question is omitted, or ends up bearing no relation whatsoever to the root concept or the map's content. One may also consider those concepts nearest the root concept. This can be helpful if there is no focus question or the question is not related to the root concept. Though all these elements can certainly help, there is no way around the fact that this criterion involves a great deal of subjectivity,[2] and hence one would expect it to contribute much of the variation among evaluators.

The second criterion involves recognition of propositions as independent semantic units. Propositions are characterized first, by their structure, generally triads of the form *concept – linking phrase – concept*; and second, by being meaningful and transmitting a complete idea. Not all triads constitute propositions. A triad fails to be a proposition if 1) it lacks the proper structure; 2) it does not make logical sense; or 3) it is not autonomous, i.e., it is a fragment or continuation of a larger grammatical structure such as a sentence, and has no meaning independently of this bigger structure.

This emphasis on correctly structured propositions is not simply a groundless whim. Propositional structure is essential to concept mapping. Requiring a person to make explicit relationships between concepts, be they previously known concepts, newly acquired, or a combination thereof, can foster a process of higher order thinking, essential to meaningful learning. Following the evolution of propositions over a given time span, furthermore, can help visualize the process of meaningful learning as revealed by subsumption, progressive differentiation and integrative reconciliation of concepts; link reworking; and overall map reorganization.

The third criterion deals with erroneous propositions, that is, propositions that make false assertions relative to some objective standard – misconceptions. In the present scheme, the occurrence of erroneous propositions is not penalized; their absence is rewarded. In applying this criterion, it is important to distinguish between relations that result in false statements due to misconceptions – true conceptual errors – and those that may arise from incorrect propositional structure. The tool is designed to give learners the benefit of the doubt by first requiring correct propositional format in order to assess truth value. Additionally, in applying the scoring rubric to a concept map, the evaluator must take into account the nature of a map's content: objective versus subjective. This consideration is essential since propositions in maps whose content is subjective usually can not be judged by objective standards.

The next criterion concerns the static/dynamic nature of propositions. Our definition of static and dynamic propositions was inspired by the corresponding notions of static and dynamic relationships defined by Safayeni *et al.* (2005), but we have made certain changes. For us a proposition is considered to be dynamic if it involves physical movement, action, change of state, or it establishes some form of dependency relationship. We consider the presence of dynamic propositions important since "the ability to represent both static and dynamic relationships in a single map may increase the power of the representational system (ibid, p. 2)."

Dynamic propositions may be causative or non-causative. In causative propositions one of the concepts must be associated to the "cause" or "probable cause" while the other must be associated to the "effect." Cause-effect propositions, in turn may be quantified or non-quantified. Quantified propositions explicitly indicate the manner in which a certain change in one concept induces a corresponding change in the other concept. Propositions which are not dynamic are static. Static propositions generally "help describe, define and organize knowledge for a given domain" (Safayeni *et al*., 2005, p. 10). Examples to help clarify these distinctions may be found in the appendix.

Number and quality of cross-links is the next criterion. From a topological perspective, the interest was mainly on the presence of cross-links. Now, from the viewpoint of content, the emphasis is on whether these cross-links establish correct, suitable, and instructive relationships. The number of cross-links, however, is also important. In our view, a good map should have at least three distinct[3] cross-links. In choosing a specific number like 3, we are guided by our experience which suggests that 1 or 2 cross-links can usually be established

[2] It is probably the most subjective of all 6 criteria.
[3] By this we mean that they do not use the same linking phrase.

without too much difficulty, but a more deliberate effort is needed to find more of these horizontal relationships. As for an upper bound, the guiding principle is whether no important and/or evident relations have been left out.

The final criterion concerns the presence of cycles in the concept map. A cycle is a directed circuit in which the direction of the arrows allows traversing the entire closed path in a single direction. As Safayeni *et al.* (2005) observe, cycles enable "the representation of dynamic functional relationships among concepts. A cycle is built from a constellation of concepts, which represents a group of closely interconnected constructs. Cyclic Cmaps [or Cmaps that contain cycles] capture interdependencies or how a system of concepts works together." Though cycles constitute an important element of Cmaps, the presence of cycles does not necessarily imply a better map; moreover, acyclic maps may actually be very good. Thus, in our taxonomy, the distribution of points is such that acyclic maps can still belong to the highest semantic level, provided they attain a sufficiently high score in all other criteria.[4]

Once points are assigned for each of these six criteria, they are added to obtain a raw numeric score, which is then translated into a 6-level content-quality scale with the following categories: *unevaluated*[5], *very low*, *low*, *intermediate*, *high*, and *very high*.

Besides the factors already mentioned that may influence the objective application of the semantic rubric, factors pertaining to the evaluator, variables such as education, personal preferences, knowledge of the map's topic, and attitude toward the evaluation task, can further bias the application of the tool. For all these reasons, we expected rather low agreement amongst facilitators in our reliability study. To our surprise, our study showed an encouraging level of inter-rater agreement.

4 Reliability study for semantic scoring rubric

The reliability study we conducted for our semantic scoring rubric was quite similar to the reliability study carried out earlier for the topological taxonomy (Cañas *et al*., 2006). The study consisted of two stages: the first stage provided valuable feedback that served to refine the instrument; the second stage yielded the reliability statistics we sought, namely, the *percent agreement* and the *kappa coefficient*, unweighted and linearly weighted.[6] Evaluators were Conéctate facilitators, all whom share a common understanding of concept mapping.

4.1 Methods and procedures

Twelve facilitators volunteered to participate in the initial exploratory stage. Given the complexity of the scoring scheme, the tool was discussed with the evaluators prior to beginning; the discussion was followed by a brief practice session during which one map was analyzed semantically. The evaluators were then given 10 concept maps to evaluate. The reason for this small sample size was to avoid fatigue, which we knew had been a factor with the validation of the topological taxonomy, and was even more likely to play a role in this study, where the evaluation task demanded greater cognitive exertion.

Results and evaluator feedback from this first trial indicated the need to clarify descriptions for some criteria and to completely revise others. The revised taxonomy was used in the second phase of the study, which took place in December 2006 with the participation of all available Conéctate facilitators, a total of 33. A second, completely new set of 10 concept maps was used. This set was selected at random from a universe of 25 concept maps, 5 from each semantic level except the "unevaluated" level, that is, maps that do not meet the minimum criteria to be read meaningfully. Once again, the tool was discussed with all participating evaluators prior to beginning the evaluation.

4.2 Results

Results yielded an average percent agreement among evaluators of 47.2%, with a 95% confidence interval of (46.0%, 48.5%). The unweighted *kappa* coefficient was 0.29, (0.27, 0.30), and the linear-weighted *kappa* coefficient was 0.50, (0.49, 0.51), representing *fair* to *moderate* agreement,[7] respectively.

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[4] In the sample of over 500 teacher maps evaluated by Miller (2008), the fraction containing cycles was practically null. Hence, one of the modifications being considered at present is the elimination of this criterion.
[5] This level is assigned to those maps that do not meet the basic requirements to be read meaningfully mentioned earlier.
[6] Percent agreement represents the average, over all possible pairs of evaluators, of their pairwise agreement; the *kappa* statistic attempts to factor out agreement due to chance.
[7] Interpretation of *kappa* values is based on Landis and Koch's (1977) table.

In order to identify the levels between which the greatest dispersion occurred, we considered the distribution of all 5,280[8] possible pairs of evaluations of the set of 10 concept maps by 33 facilitators (table 1). We found that the largest disagreements were between consecutive levels (values immediately below the main diagonal). For instance, 16% of the 5,280 evaluations resulted in one evaluator in a pair assigning a given map to level 1 while the other evaluator assigned it to level 2; between levels 3 and 4, the value was 10%, and between levels 2 and 3, 9%. These percentages help explain the improvement in the linear weighted *kappa* statistic relative to the unweighted *kappa*. Nonetheless, discrepancies by 2 levels (values along the second diagonal below the main one) are non-trivial, which accounts for the overall low *kappa* values.

As table 1 shows 39% of all pairs of evaluations resulted in disagreements by differences of exactly 1 level, while 86% of these pairs resulted in disagreements by differences of at most 1 level. This is quite a good result, considering the inevitable subjectivity involved in the evaluation of content and the complexity of the measurement tool.

Evaluation by facilitator A	Evaluation by facilitator B						
	Level 0	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**
Level 0	**0%**						
Level 1	**1%**	**30%**					
Level 2	0%	**16%**	**6%**				
Level 3	0%	4%	**9%**	**7%**			
Level 4	0%	0%	5%	**10%**	**4%**		
Level 5	0%	0%	1%	3%	**3%**	**1%**	
Level 6	0%	0%	0%	0%	0%	**0%**	**0%**
Subtotal	**1%**	**50%**	**21%**	**20%**	**7%**	**1%**	**0%**

Table 1. Distribution of the 5,280 possible pairs of evaluations of 10 concept maps evaluated by 33 facilitators.

Once the results were computed, a feedback session was conducted with the evaluators to inform them of the study's outcome and to obtain their impressions regarding the tool. This session led to further revisions of the scoring rubric. The version resulting from these refinements is presented in the appendix to this article.

5 Concluding remarks

This paper discussed the design of the semantic component of a 2-part taxonomy for concept maps. The original goal of coming up with a classification system, akin to the one developed for the topological taxonomy, could not be realized given that, for our particular choice of criteria, we found that our subjects progressed unevenly towards maps of greater semantic quality and sophistication. Hence, practical considerations led us to design a point-based scoring rubric based on the selected criteria. The rubric draws from Novak & Gowin's (1984) original scoring scheme, but also from more recent ideas that seek to increase the representational power of concept maps through the inclusion of dynamic propositions and cycles, as well as from our experience in working with Panamanian schoolteachers. In spite of the complexity and inevitable subjectivity implicit in the tool, our reliability study, carried out with facilitators from the Conéctate Project, indicates a moderate level of consistency among evaluators sharing a common understanding of concept maps.

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[8] There are [(33*32)/2] = 528 distinct pairs of evaluators and 10 maps for each pair to agree or disagree on.

References

Beirute, L., & Miller, N. L. (2008). Interaction between topology and semantics in concept maps: A neurolinguistic interpretation. In: A. J. Cañas, P. Reiska, M. Åhlberg & J. D. Novak, (Eds.). Concept Mapping: Connecting Educators. Proceedings of the Third International Conference on Concept Mapping, Tallinn, Estonia & Helsinki, Finland.

Bloom, B. (Ed.). (1956). Taxonomy of Educational Objectives: Handbook I: Cognitive Domain. New York: Longman, Green & Co.

Cañas, A. J., & Novak, J. D. (2006). Re-examining the foundations for effective use of concept maps. In A. J. Cañas & J. D. Novak (Eds.), Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping, (Vol. I, pp. 494-502). San José, Costa Rica: Universidad de Costa Rica.

Cañas, A. J., Novak, J. D., Miller, N. L., Collado, C., Rodríguez, M., Concepción, M., Santana, C., & Peña, L. (2006). Confiabilidad de una taxonomía topológica para mapas conceptuales. In A. J. Cañas & J. D. Novak (Eds.) Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping, Vol. I, pp. 153-161. San José, Costa Rica: Universidad de Costa Rica.

Derbentseva, N., Safayeni, F., & Cañas, A. J. (2004). Experiments on the effects of map structure and concept quantification during concept map construction. In A. J. Cañas, J. D. Novak, & F. M. González (Eds.). Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping, Vol. I, pp. 209-216. Pamplona, Spain: Dirección de Publicaciones de la Universidad Pública de Navarra.

Landis, J. R., & Koch, G. G. (1977). The measure of observer agreement for categorical data. Biometrics, 33, 159-174.

Miller, N. L. (2008). An exploration of computer-mediated skill acquisition in concept mapping by Panamanian in-service public elementary schoolteachers. Submitted Doctoral Dissertation. Universitat Oberta de Catalunya, Spain.

Miller, N. L., & Cañas, A. J. (2008). Effect of the nature of the focus question on presence of dynamic propositions in a concept map. In: A. J. Cañas, P. Reiska, M. Åhlberg & J. D. Novak, (Eds.). Concept Mapping: Connecting Educators. Proceedings of the Third International Conference on Concept Mapping, Tallinn, Estonia & Helsinki, Finland.

Novak, J. D., & Cañas, A. J. (2008). The theory underlying concept maps and how to construct them. Technical Report IHMC CmapTools 2006-01. Available at: http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm

Novak, J. D., & Gowin, D. B. (1984). Learning how to learn. New York: Cambridge University Press.

Ruiz-Primo, M. A., & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. Journal of Research in Science Teaching, 33(6), 569-600. Retrieved January 27, 2008, from http://www.stanford.edu/dept/SUSE/SEAL/Reports_Papers/all.html#CM4

Rye, J., & Rubba, P. (2002). Scoring concept maps: an expert map-based scheme weighted for relationships. School Science and Mathematics, 102(1), 33-44.

Safayeni, F., Derbentseva, N., & Cañas, A. J. (2005). “A Theoretical Note on Concept Maps and the Need for Cyclic Concept Maps.” Journal of Research in Science Teaching, 42(7), pp. 741-766.

Tarté, G. (2006). Conéctate al Conocimiento: Una estrategia nacional de Panamá basada en mapas conceptuales. In A. J. Cañas & J. D. Novak (Eds.) Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping, Vol. I, pp. 144-152. San José, Costa Rica: Universidad de Costa Rica.

APPENDIX

SEMANTIC SCORING RUBRIC FOR CONCEPT MAPS

This semantic scoring rubric is meant to be applied to concept maps that, for the most part, contain no texts nor lack linking phrases. When it is deemed that a map does not meet the requirements to be evaluated semantically, it is given a total score of 0 and assigned to the category of "unevaluated" concept maps. In tailoring the tool to a specific concept mapping task it is important to take into account the author's personal context: age, educational level, cultural background, etc., as well as the instructional setting in which construction of the map takes place (e.g., based on readings, videos, plays, experiments, field trips), and the objective/subjective nature of the content. This is particularly important for criteria 1 and 3.

This tool was designed to provide a reasonable guide to content evaluation in the context of Panama's Conéctate Project. Occasionally, strict adherence to the scoring rubric will not necessarily result in the fairest or wisest evaluation of a map's content. Thus, in applying this rubric it is important to keep in mind the 'spirit' of the various criteria, in addition to their exact wording.

CRITERION # 1: **Concept relevance[1] and completeness**
Note 1: *Relevance and completeness is determined, first, in relation to the* ***root concept****; second, the* ***focus question*** *(if there is one and the root concept corresponds to it); third, the* ***concepts closest to the root concept*** *(if there is no focus question or the root concept is not related to focus question).*
Note 2: *If several concepts appear within a single box, but clearly identified as individual concepts (for instance, separated by commas or marked by vignettes) they are counted as separate concepts.*

- 0 pts. The map contains very few concepts and/or most concepts are irrelevant, redundant or not well-defined (e.g., "characteristics" instead of "physical characteristics"); additionally, there is an excessive use of examples (one third or more of the map's concepts are examples).[2]
- 1 pts. One half or more of the map's concepts are relevant and well-defined, but many important concepts are missing; and/or there is an excessive use of examples (one third or more of the map's concepts are examples.
- 2 pts. Most concepts are relevant and well-defined, but some important concepts are missing. Appropriate use of examples (less than a third of the map's concepts are examples).
- 3 pts. All concepts are relevant and well-defined; no important concepts are missing. Appropriate use of examples (less than a third of the map's concepts are examples).

CRITERION # 2: **Propositions as "semantic units"[3]**
Note 1: *In the case of examples, it is permissible to use linking phrases such as: "like", "for example", "such as", etc.*
Note 2: *If the map contains a small number of propositions (excluding examples) or the map does not contain second level propositions,[4] this must be taken into account in the determining the score. The maximum number of points should only be given if the map provides sufficient evidence that its author truly understands the notion of proposition as a "semantic unit" in the sense previously defined.*

- 0 pts. The author does not understand how to construct propositions (very few propositions are well constructed).
- 1 pts. The author understands somewhat how to construct propositions (some propositions are well constructed).
- 2 pts. The author understands how to construct propositions (all or almost all propositions are well constructed).

CRITERION # 3: **Erroneous propositions**
Note 1: *Only propositions and examples validated under criterion # 2 are considered.*
Note 2: *Erroneous propositions resulting from incorrect use of the CmapTools software are not considered.*

- 0 pts. The map contains more than 2 erroneous propositions.
- 1 pts. The map contains 1-2 erroneous propositions.
- 2 pts. The map contains no erroneous propositions.

CRITERION # 4: **Dynamic propositions[5]**
Note 1: *Only propositions validated under criterion # 2 are considered.*
Note 2: *This criterion is independent of criterion # 3; that is, erroneous dynamic propositions are counted.*

- 0 pts. The map contains no dynamic propositions of any kind.
- 1 pts. The map contains only **non-causative** dynamic propositions.
- 2 pts. The map contains 1-2 **causative** dynamic propositions with **physically separate links[6]**.
- 3 pts. The map contains more than 2 **causative** dynamic propositions with **physically separate links**.
- 4 pts. The map contains **quantified causative** dynamic propositions.

CRITERION # 5: **Quantity and quality of cross-links**
Note: *Only propositions validated under criterion # 2 are considered.*

- 0 pts. The map contains cross-links, but they are all erroneous (false).
- 1 pts. The map contains no cross-links.

2 pts.	The map contains cross-links and these establish correct (true) relationships. However, they are redundant or not particularly relevant or adequate.
3 pts.	The map contains 1-2 correct, relevant and adequate cross-links with **physically separate links**. However, based on the concepts present in the map, important and/or evident cross-links are missing.
4 pts.	The map contains more than 2 correct, relevant and adequate cross-links with **physically separate links**. However, based on the concepts present in the map, important and/or evident cross-links are missing.
5 pts.	The map contains more than 2 correct, relevant and adequate cross-links with **physically separate links**. Based on the concepts present in the map, no important or evident cross-links are missing.

CRITERION # 6: **Presence of cycles**[7]

0 pts.	The map contains no cycles.
1 pts.	The map contains at least 1 cycle, but **some propositions in the cycle do not satisfy criterion # 2**.
2 pts.	The map contains at least 1 cycle and **all propositions in the cycle satisfy criterion # 2**.

Levels:

Unevaluated	0	Intermediate	9 – 11
Very low	1 – 5	High	12 – 14
Low	6 – 8	Very high	15 – 18

NOTES

[1] A concept is considered irrelevant if: 1) it is not related to the topic under consideration; or 2) it is related to the topic, but does not contribute substantially to it. One way to decide whether a concept is irrelevant is to think of removing it from the map and ask ourselves if this alters the map's content significantly (in relation to the root concept and the focus question). If our answer is "no", it is quite likely that this particular concept is not relevant to this map.

[2] Examples are specific instances or occurrences of concepts. For instance, "Chagres River" is an instance of the concept "river". Examples are usually joined to concepts by the following linking words: "for example", "like", "such as", among others.

[3] A triad is **not a proposition** if 1) it lacks the required structure CONCEPT + LINKING PHRASE + CONCEPT; 2) it does not make logical sense, either because its meaning depends on previous propositions, or due to grammatical mistakes, incorrect use of CmapTools, or some other reason; 3) it is not autonomous, i.e., it is clearly a fragment or continuation of a larger grammatical structure.

[4] A **second level proposition** corresponds to the second linking phrase counted from the root concept.

[5] **Dynamic propositions** involve: 1) movement, 2) action, 3) change of state, or 4) dependency relationships. They are subdivided into **non-causative** and **causative** dynamic propositions. In causative propositions, one of the concepts must clearly correspond to the cause while the other one clearly corresponds to the effect. Causative propositions, in turn, may be **quantified**. Quantified propositions explicitly indicate the manner in which a certain change in one concept induces a corresponding change in the other concept.

- Examples of non-causative dynamic propositions: *Roots absorb water*; *herbivores eat plants; digestive system breaks down food product; living beings need oxygen*.
- Examples of causative dynamic propositions: *Electric charge generates electric fields*; *reproduction allows continuity of species*; *cigarettes may produce cancer*; *independent journalism strengthens credibility*; *exercise decreases risk of developing diabetes*; *rule of law attracts foreign investment*.
- Examples of quantified causative dynamic propositions: ***Increased** transparency in public affairs **discourages** corruption*; ***under-activity** of the thyroid gland (hypothyroidism) **decreases** body metabolism*; ***increased** quality of education contributes to **greater** national development*.

Static propositions, on the other hand, serve only to describe characteristics, define properties and organize knowledge. They are generally associated to linking phrases such as: "is", "are", "have", "possess", "are made up of", "are classified into", "are divided into", "contain", "live", "are called", "is located in", "likes", etc.

- Examples of static propositions: *Sun is a star*; *means of transportation include land transport means*; *Panama is located in Central America*; *animals may be vertebrates*.

[6] By propositions with "**physically separate links"** we mean propositions that use distinct linking entities (boxes) to join one concept to another. However, the linking words within these separate boxes may be repeated.

[7] A **cycle** is a directed circuit in which the direction of the arrows allows traversing the entire closed path in a single direction.