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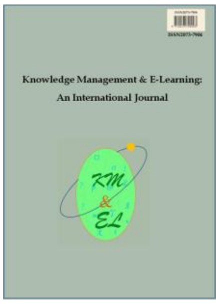

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How good is my concept map? Am I a good Cmapper?

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How good is my concept map? Am I a good Cmapper?

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Abstract: There have been many efforts reported in the literature to score or rate the quality of concept maps. In many cases the objective was to standardize procedures for grading student concept maps, but other efforts have served a variety of purposes, including guiding workshop participants to construct better concept maps or monitoring the advances in concept mapping techniques on a large population of users. We examine some of the criteria used by others for rating or scoring concept maps as "good" and propose a scheme that takes into account both graphical structure criteria and semantic or subject matter accuracy that we propose can lead to better, "excellent" concept maps. It has been said that presentations that are concise but capture the complexity of the content involved are elegant—and producing these kinds of concept maps should be our goal.

Keywords: Concept map; Good concept map; Scoring; Assessment; Criteria; Rubric; Excellent concept map

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1. Introduction

Concept Maps are used widely throughout the world by people of all ages to express their understanding of all knowledge domains. As a result, one finds in papers, on the Web, on CmapServers, and in all types of media, concept maps of all types and of all topics. (Although, as we discussed in Novak and Cañas (2010), we do not run into concept maps as a popular means of expression as often as we would have liked or expected). The IHMC Public CmapServers alone store several hundred thousand concept maps (Cmaps) written in a diversity of languages. As one looks at this large collection of maps, one sees that, unfortunately, many are not Novakian concept maps at all – the authors, for example, used CmapTools to draw some diagram for which the tool seemed useful but they bear no resemblance to what we regard as a concept map. Good concept maps are based upon a solid theory of learning and theory of knowledge (Cañas & Novak, 2008a). On the other extreme, one encounters some carefully designed concept maps that clearly convey their key ideas. In between, there is a whole range of maps, some good, some bad, and some really bad, as with any other media one might examine.

The large variety of Cmaps led us to ask ourselves the question, “What is a good concept map?” Actually, this question comes up often. During concept mapping workshops, participants often call on us and ask, “Is my concept map good?” While commenting on Cmaps being displayed via a projector during a workshop, we find ourselves commenting, “That is a good concept map”. And in education, where concept mapping is most used, teachers and professors are constantly confronted with the assessment of students’ concept maps, which basically consists of determining the ‘quality’ of the concept map. What is, then, a good concept map? We attempt to present a perspective on good concept maps in this paper. We go further and also discuss what makes *a good Cmapper*, borrowing the term from the Cmappers community (Cañas & Novak, 2008b) to refer to the ability of the person to construct good concept maps.

2. Criteria for good concept maps

Back in 2000 while we were developing at IHMC a module for CmapTools which we called “Joe in a Box[1]” which intended to provide automatic advise during the construction of a Cmap, Novak prepared a list of criteria for a good concept map, that would be of use for a novice user learning to build maps. The following is the list of criteria relevant to the quality of the map:

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[1] This module was never included in the public versions of CmapTools. The ideas evolved into the research presented by Brenes and Valerio (2006).

a) A context for the concept map should be defined, commonly with a stated explicit "focus question".

b) Concept labels in maps should be only one or a few words labeling a specific concept.

c) Linking lines should be labeled with one or few words, and not contain concept labels important to the map's conceptual content. They specify the proposition or principle formed by the concepts and linking words.

d) Cmaps should have hierarchical organization, with the most general, most inclusive concepts at the top, and progressive more specific, less inclusive concepts at lower levels.

e) In general, no more than three or four sub-concepts should be linked below any given concept.

f) Crosslinks should specify significant interrelationships between two concepts in different sub-domains of knowledge shown in the map. These are best added when the map is nearing completion.

g) Concept labels should not appear more than once in a given map.

With time we found these were necessary but not sufficient criteria for a concept map to be considered "good". That is, concept maps could satisfy the above conditions and still be terrible maps. However the list illustrates that there are two aspects to a map that need to be considered: its structure and its content. For example, having no more than three or four sub-concepts linked below a given concept is a structural condition. Having the more general concepts at top and the more specific concepts further down is a condition on the content of the map. Good concept maps must therefore have good graphical structure and good content. But this is not enough: we must look at the overall quality of the concept map.

3. Concept map: Graphical structure and content

A concept map consists of a graphical representation of a set of concepts, usually enclosed in ovals or rectangles of some type, and relationships between concepts indicated by a connecting line linking two concepts. Words on the line, referred to as linking words or linking phrases, specify the relationship between the two concepts. The two concepts with the linking phrases that join them form propositions. Propositions are statements about some object or event in the universe, either naturally occurring or constructed. Propositions contain two or more concepts connected using linking words or phrases to form a meaningful statement. Sometimes these are called semantic units, or units of meaning (Novak & Cañas, 2008). Concept maps therefore consist of "graphical structure" and "content".

When examining a concept map to determine how good it is, we need to look at both the content and the structure. Fig. 1, where the x-axis determines the quality of the content of the map, and the y-axis the quality of the structure of the map, shows that a good concept map should have both good content and good structure (in this paper we will use the term "structure" to refer to the graphical structure of the concept map).

The formal evaluation of the quality of concept maps takes place primarily with the purpose of assessing students' maps. When evaluating these maps, teachers and professors are basically determining "how good is the concept map". This usually requires establishing predefined criteria or rubrics by which all students' maps are measured. We use these rubrics as examples of gauges used by the community for defining good concept maps. Of course the quality of concept maps is also relevant in other contexts. For example, good maps are essential to clearly express an expert's knowledge during knowledge elicitation. And concept maps prepared for communications purposes must be clear and easily read. But because of the nature of the work, the evaluation of the quality of maps in other applications is not done in as formal a way as in education. Thus, the diversity of contexts, domains, and purposes lead to the question, "Good concept map for what?" We deal with this question at the end of the paper.

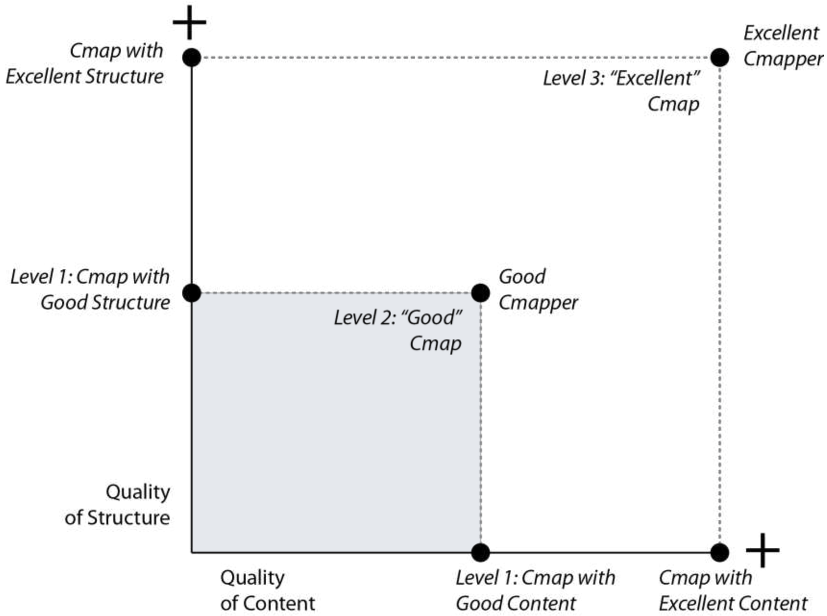

Fig. 1. A good concept Cmapper creates concept maps that have a good graphical structure and good content

3.1. Concept map's graphical structure

We have stated that a good concept map must have a good graphical structure. The graphical nature of concept maps provides the possibility of an objective *evaluation* through a topological or structural analysis of the map. There are structural characteristics that are generally accepted as indicative of a good map. The first is based on the hierarchical structure of knowledge in a particular domain, which usually leads to a hierarchical structure in concept maps, with more general concepts at the top and more specific concepts at the bottom. A well-organized cognitive structure (which is necessary for meaningful learning) usually leads to graphically well-organized concept maps; in turn, building good concept maps helps to build a good knowledge structure. We do need to clarify that the hierarchical structure may lead to other representations, such as a cyclic concept map (Safayeni, Derbentseva, & Cañas, 2005). That is, a conceptual hierarchy of concepts does not necessarily lead to a hierarchical structure of the map. Another important characteristic of concept maps is the inclusion of *cross-links*. These are relationships or links between concepts in different segments or domains of the concept map. Cross-links help us see how a concept in one domain of knowledge represented on the map is related to a concept in another domain shown on the map. In the creation of new knowledge, cross-links often represent creative leaps on the part of the knowledge producer. These two features of concept maps are important in the facilitation of creative thinking: the hierarchical structure that is represented in a good map and the ability to search for and characterize new cross-links.

Given the importance of a "hierarchically well organized map" and the presence of cross-links, we fall into the trap of believing that the structural components provide a valid complete assessment of the concept map. By counting structural characteristics such as the number of hierarchical levels, the number of crosslinks, plus other structural elements such as the number of propositions, etc., many rubrics have been developed that assess a concept map based on its structure, often as part of a more comprehensive rubric. Strautmane (2012) provides a comprehensive list of structural measures reported in the literature. These include: number of concepts, number of propositions, number of levels of hierarchy, concepts per level, frequency of branching, number of crosslinks, number of strands, number of examples, diameter of a graph, maximum degree of concept, spanning tree of the map, number of hierarchical segments, ruggedness (unconnected parts), spatial distance, graph connectivity, correspondence to structural patterns, and hierarchiness. Schwendimann (2014) presents a similar list of assessment criteria. The graphical nature of the structure lends itself to additional measures, and a sequence of levels of complexity of structure has been proposed in a topological taxonomy (Cañas et al., 2006). Overall, these rubrics aim at providing a 'score' for a concept map. A high score would imply a "good" concept map.

3.2. Concept map's content

As we mentioned earlier, a concept map consists of structure and content. The content of the map is expressed through its concepts, its linking phrases, and the propositions they form. Not surprisingly, the list of criteria used to assess content reported by Strautmane (2012) is based on these three elements: quality of the concepts, completeness of the concepts used, quality of the concept labels, completeness of relationships, proposition correctness, proposition quality (correctness, validity), proposition's depth of explanation, correct propositions that are not present in the expert's concept map, proposition similarity to expert's concept map, proposition correspondence to a category of relations, proposition relevance, correct placement of concepts and relations, convergence with expert's concept map, and richness of relationships. Many of these criteria assume there is an expert's concept map (most likely the instructor's map) with which the student's map is compared. As with the structural criteria, these rubrics aim at scoring the concept map.

It's worth noting that all of these criteria measure the quality of the concept map either at the concept or proposition level, that is, the assessment is of each concept and/or proposition. None of them look at the overall quality of the content of the map.

3.3. How good is my concept map?

The criteria presented above for assessing the quality of structure and content of a concept map would suggest that a concept map that satisfies these criteria could be a "good" concept map. In Table 1 we present a classification of the quality of concept maps based on the structural and content quality. A concept map that has good structural quality but poor content quality, or poor structural quality and good content quality is anyway considered a *Poor, Level 1* concept map. A concept map with good structural quality and good content quality is classified as a *Good, Level 2* map. We present some examples.

Table 1
Classification of concept maps depending on the quality of the structure, content, and the quality of the concept map

	Quality Level	Structural Quality	Content Quality	Concept Map Quality
1	Poor	√	√	
2	Good	√	√	
3	Excellent	√	√	√

Fig. 2 shows a concept map prepared by a high school student that, according to the structural criteria presented above, would most likely be classified as a "good" concept map by most rubrics Its structure is probably not what most Cmappers are used to considering as a "good" concept map[2], but the criteria do not consider the overall structure. However, the content of this concept map is considered "poor", in particular when considering the quality of its propositions. According to Table 1, a concept map with a "good" structure but "poor" content, as that in Fig. 2, is considered a *Level 1*, *Poor* concept map.

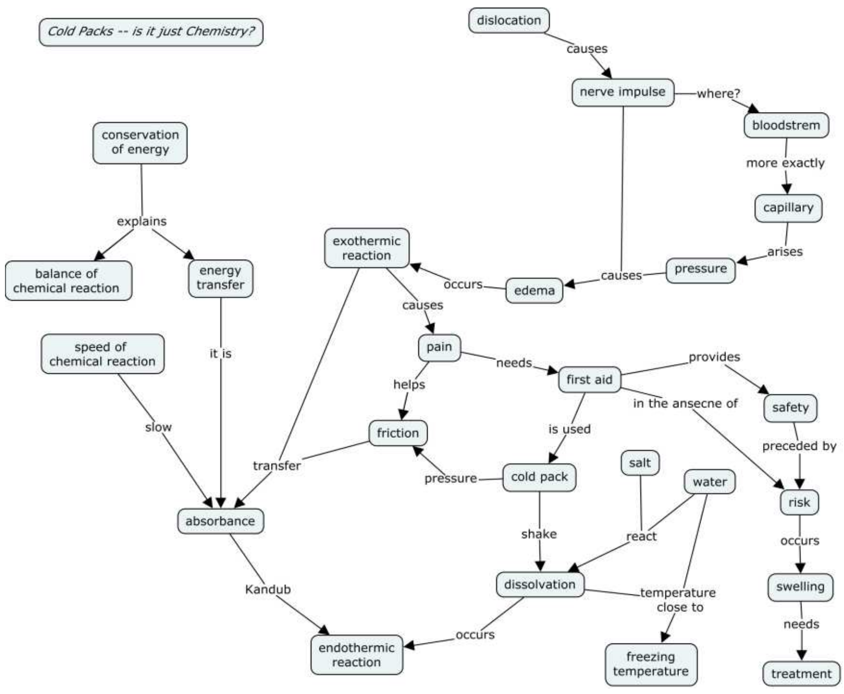

Fig. 2. A *Level 1, Poor* concept map with "good" structure according to rubrics, but poor content. Translated from Estonian from the study reported by Soika and Reiska (2013, 2014)

[2] Interestingly, concept mappers tend to 'agree' on what a 'well structured concept map' is, to the point that experts tend to agree whether a concept map is "good" by just looking at its structure without considering its content (Carvajal, Cañas, Carballeda, & Hurtado, 2006).

Fig. 3 presents a concept map with a low score for its structure (e.g. no crosslinks) but good propositions, generating a good content score. It would also be classified as a *Level 1*, *Poor* concept map.

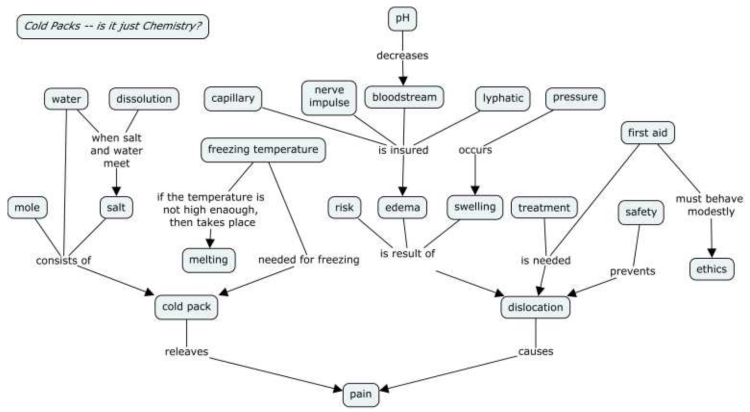

Fig. 3. A Level 1, Poor concept map with "good" content according to rubrics, but poor structure. Translated from Estonian from the study reported by Soika and Reiska (2013, 2014)

Its important to note that depending on the purpose for which the map was constructed, one axis may be more relevant than the other. For example, instructors assessing students' understanding of a topic of study will be generally more interested in the student showing good understanding of the content, and therefore would push the students to the right on the x-axis, encouraging to build better propositions. A concept map being used for communicating an idea would equally need to be of high quality structurally.

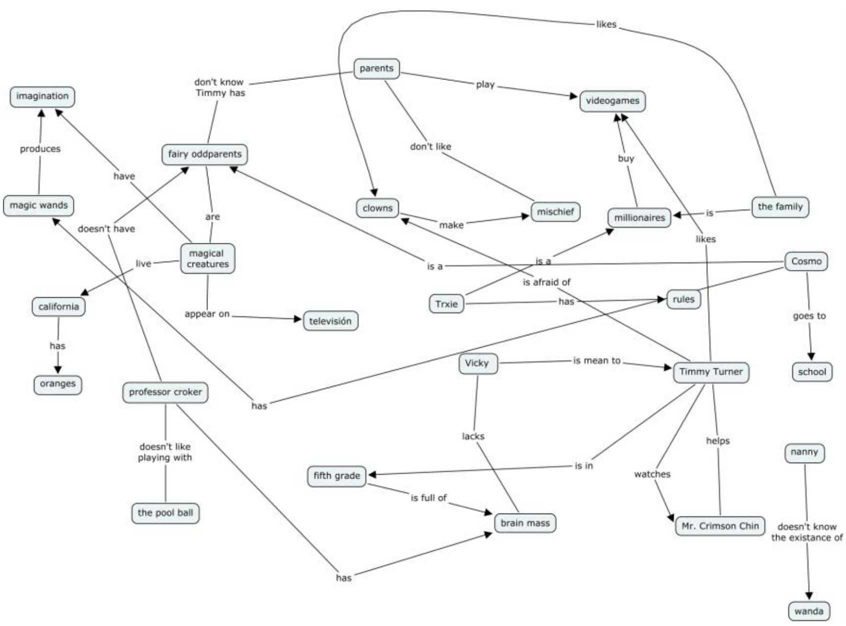

Fig. 4. Cmap constructed collectively by the experimental group playing the conceptual card game. Adapted from Giovani et al. (2008)

Fig. 4 presents a concept map prepared by elementary school children in Panama's Proyecto Conéctate al Conocimiento (Tarté, 2006) while playing a game of memory to learn how to construct propositions (Giovani et al., 2008). The map was prepared piecewise, proposition-by-proposition. Because of the nature of the game, all propositions are valid and relevant, and therefore the quality of content is high. The resulting network structure will satisfy most of the structural criteria presented earlier. Therefore according to our classification this is a *Good, Level 2* concept map, which would fall close to the Good Cmap point in the chart of Fig. 1. However, from an "overall concept map" point of view this concept map is a mess, typical of maps that are built as an aggregation of propositions. The literature would consider it a Good map, we do not.

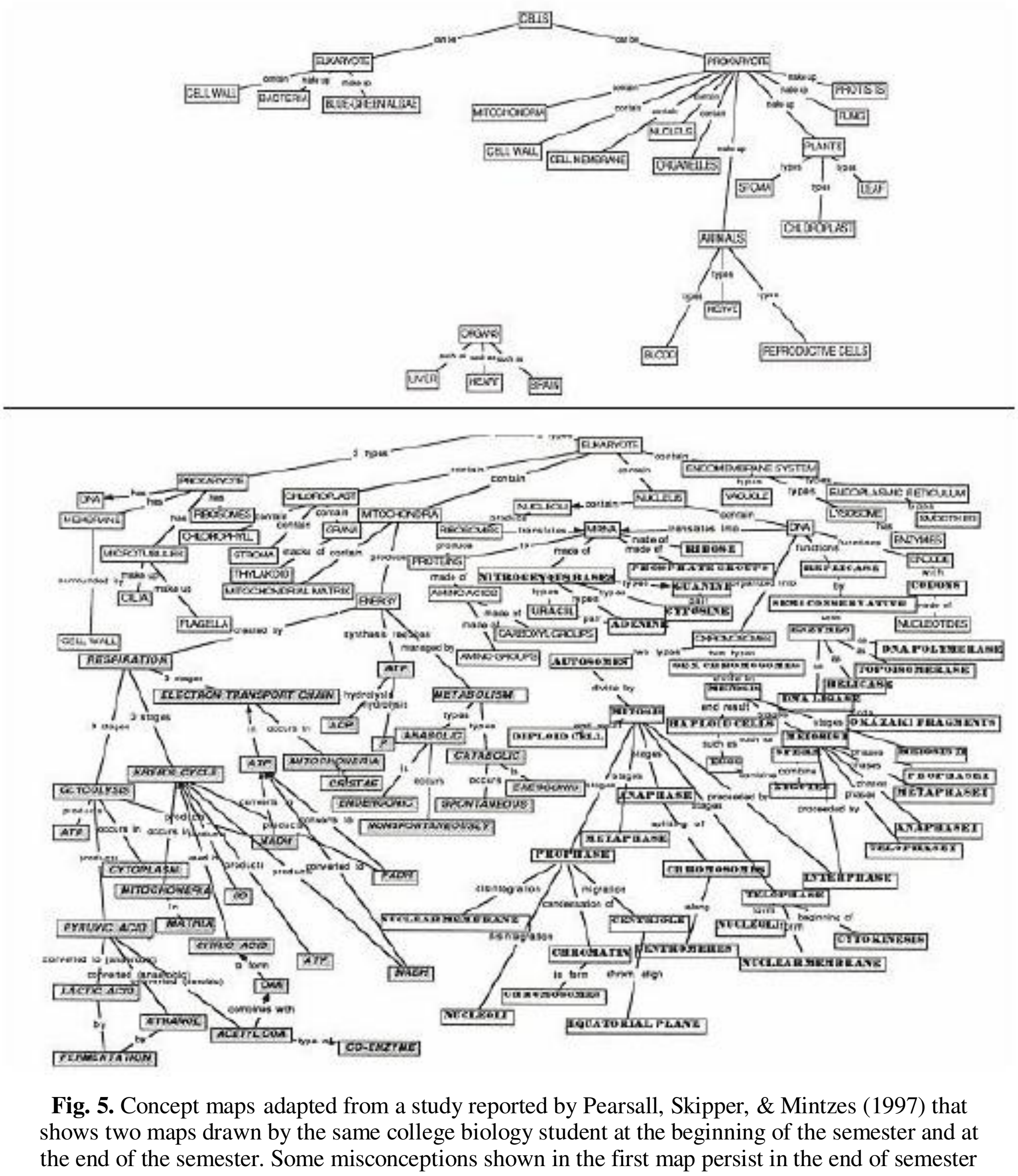

Fig. 5. Concept maps adapted from a study reported by Pearsall, Skipper, & Mintzes (1997) that shows two maps drawn by the same college biology student at the beginning of the semester and at the end of the semester. Some misconceptions shown in the first map persist in the end of semester map.

We present one more example. The two maps in Fig. 5 come from a study reported by Pearsall, Skipper, and Mintzes (1997) and shows two maps drawn by the same college biology student at the beginning of the semester and at the end of the semester. Given the assessment criteria above, the first map would probably be scored as a *Level 1*, while the second map would most likely be scored as *Level 2*, showing an increased understanding on the part of the student. But let's look at the maps in more detail. The first map is very simple, but it shows very clearly that this student has confusion about prokaryotes and eukaryotes, for the reverse of what is depicted is true. It is common for students who learn primarily by memorization, as do most high school students, to get the meanings for concepts confused, as clearly shown in this map. So even though it is a simple map, it carries a clear message. An additional problem shown is that cell walls are a characteristic a plant cells, rather than prokaryote or eukaryote cells. Concept map two shows that this student has learned much about cells, but we see on the left side that she is still confused about the differences between prokaryotes and eukaryotes and differences between plant and animal cells. Thus we see that a map that superficially looks impressive really contains a number if misconceptions and incomplete conceptions. While this map might score as a *Level 2, Good* map according to the rubrics, it is far from the kind of map we would describe as elegant or comprehensive. Moreover, the map lacks clear definition of several major concepts, nor does it show any crosslinks integrating key ideas in different parts of the map. While this second map looks impressive superficially, it is deficient in important ways from being a truly good concept map.

Kinchin (2014b) discusses Good and Poor concept maps (with a different, but analogous classification to that presented here), and additionally describes situations where concept maps that would be considered "good" by the community would qualify as *Poor* by most assessment criteria, and warns us of the tendency towards scoring maps. As can be seen, the criteria used for evaluating concept maps as reported in the literature, and that are commonly used based on our experience, do not do a good job at determining whether a concept map is *really* a "good" map. So, what is a *really* "good" concept map? We go further than Kinchin (2014b) and describe what we refer to as an *excellent* concept map.

4. Quality of concept map

Anyone can write lines of verse, but that doesn't make a poem. Likewise, it's not difficult to construct a concept map that has correct and relevant propositions and a good graphical structure that may qualify as a "good" map according to the content and structure criteria. But that does not make it an *excellent* concept map. As Table 1 shows, an "excellent" concept map also has high "quality of the concept map".

Every concept map should respond to a *focus question* that provides the reference or context for the map. The main question that we ask ourselves when assessing a concept map is, "Does it respond the focus question?" A good map will respond to the focus question. An *excellent* concept map not only responds to the question, it explains the response in a *clear* fashion. Additionally, the epistemological stance taken in class can influence the quality of the concept maps and their value in learning: concept maps made in a classroom context where most facts are memorized lead to very different outcomes from concept maps made in a classroom where the meaningful learning of key concepts is the central objective. The epistemological stance, in conjunction with good focus questions on the part of the instructor can lead to explanatory concept maps as opposed to descriptive maps (Cañas & Novak, 2006; Derbentseva, Safayeni, & Cañas, 2006).

An *excellent* concept map is *concise*. All concepts and propositions should be relevant to the topic of the concept map; it should not include "unnecessary" concepts, propositions or crosslinks, and should not be missing any key, relevant concepts, propositions or crosslinks. Geoff Briggs, when describing the construction of the concept maps presented in Briggs et al. (2004), commented that his problem wasn't an inability to find which concepts to link, but rather determining which propositions provided a clear explanation, and only those that contributed to the explanation. Beginners tend to make complex concept maps that include a large number of concepts, propositions and linking phrases that are completely irrelevant to the focus question. In fact, they often construct a "good" concept map that does not respond to the question. Structural and content criteria tend to reward maximizing each criterion (i.e. a large number of relevant propositions), while an "excellent" map has an optimal number. More complex concept maps do not necessarily provide greater insight into a learner's thinking, as shown in Fig. 5. Measures are often taken independently, e.g. proposition quality is assessed for each proposition without considering the coherence with other propositions. Note the importance of evaluating the relevance of each proposition to the topic of the map. There are rubrics in the literature that evaluate whether the proposition is 'true' or 'false', independent of the relevance to the topic of the concept map (Reiska, 2005).

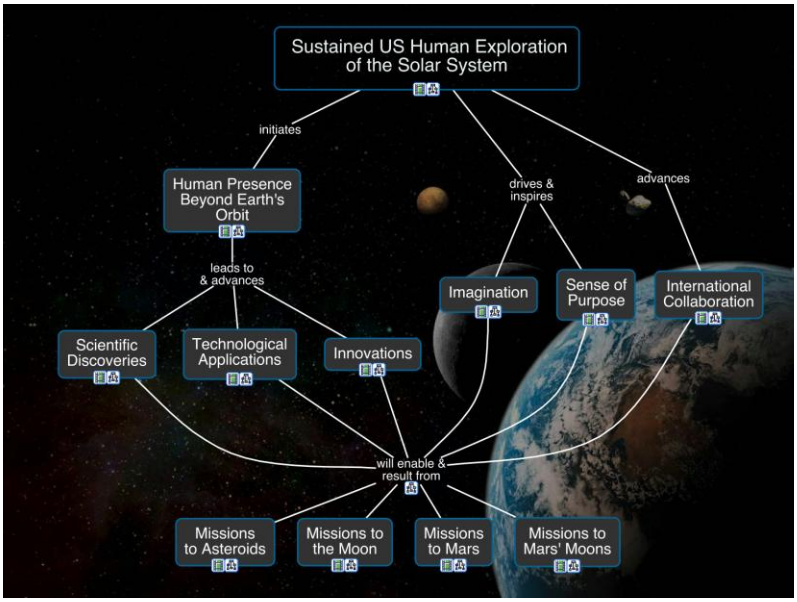

Fig. 6. Concept map on the rationale for Human Space Exploration (Cañas, Carff, & Marcon, 2012), answers the focus question "Why does the U.S. have a human space exploration program?"

An *excellent* concept map has *high clarity*, a *clear message*, and *communicates key ideas*. Fig. 6 and Fig. 7 clearly show these qualities. Both concept maps are also *well balanced*, *well structured* and *demonstrate understanding*. *Excellent* maps are *explanatory*, not descriptive (Cañas & Novak, 2006). Users should be asking themselves, not whether they are "good" Cmappers, but whether they are "excellent" Cmappers. An "excellent" Cmapper is one who has achieved the level of maturity, dexterity, experience and understanding of concept maps to construct "excellent" concept maps. The concept map in Fig. 8 was handed out by Kinchin (2014a) during an oral presentation. Its clarity and message clearly convey the presentation's intent without having to attend it, an example of its explanatory nature.

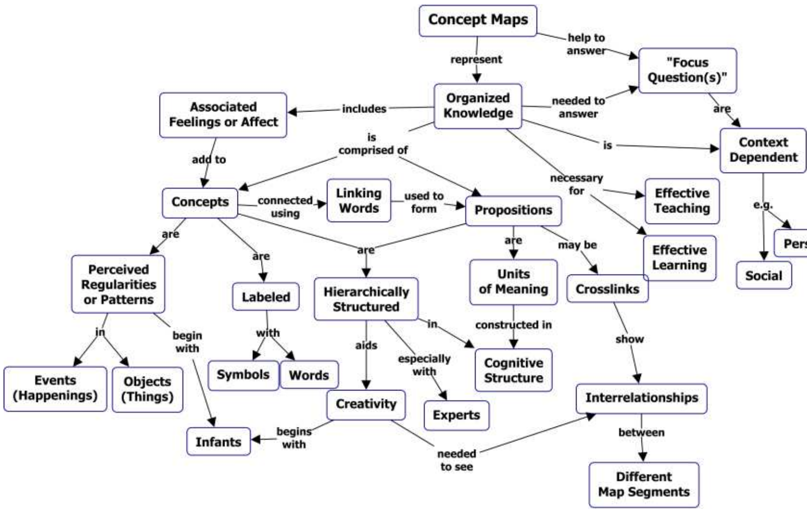

Fig. 7. Concept map about concept maps (Novak & Cañas, 2008), answers the focus question "What is a concept map?"

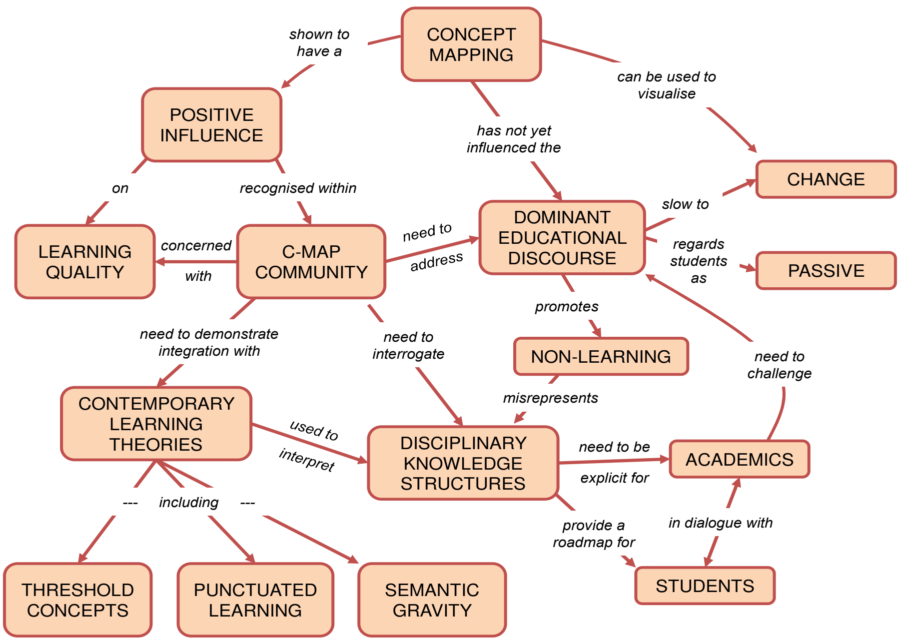

Fig. 8. Concept map on "What is Next for Good Cmapping?", part of an oral presentation by Kinchin (2014a).

One could argue that one's concept map is "good enough" for its intended purpose. For example, if one prepares a concept map as a guideline on the process of writing a manuscript, or if a student is drawing a concept map as part of preparing for an exam, it may not be worth the effort to refine it to the point where it is an *excellent* map. On the other hand, a concept map that may be a good map for one audience may not be "good enough" for another audience. Derbentseva and Kwantes (2014) present cases where "good" concept maps prepared by and considered useful by a working committee were not acceptable or considered of use by their supervisor, and go on to describe aspects of layout and flow that can lead to increased clarity and understanding of concept maps.

5. Conclusion and discussion

Assessing the quality of a concept map is a complex issue. Even if we are able to assess very many different single criteria (measures), we are not able to determine whether a concept map is "excellent". We have automated tools to assess whether a concept map is good or not (Level 1 or 2), e.g. CmapAnalysis (Cañas, Bunch, Novak, & Reiska, 2013), but we are still discussing how to define in a quantitative manner an "excellent" concept map (Level 3). Educators need to be aware that rubrics, whether automatic or manual, tend to determine whether a concept map is "good" (Level 1 or 2,), but not whether it is "excellent".

An "excellent" concept map is like a good poem, we know when we have read one, but we can't quantify the reason. Professional Cmappers can recognize them, but it's hard to teach how to construct them.

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