COMPULSORY CONCEPT AS INSTRUCTIONAL STRATEGY TO IDENTIFY LIMITED OR INAPPROPRIATE PROPOSITIONAL HIERARCHIES IN CONCEPT MAPS

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Abstract. Concept maps (Cmaps) are powerful graphical organizers that have been used over the last four decades for educational and corporative purposes. Verification of the benefits of using Cmaps to represent and share our ideas depends on the mapper's skills and the general understanding that Cmaps are more than simple diagrams or charts. When these conditions are met, concept mapping is likely to promote changes in teaching, learning, and assessing students. Limited or Inappropriate Propositional Hierarchies (LIPHs), as proposed by Novak, refer to conceptual errors that may occur even when students choose to learn meaningfully. One educational challenge posed in everyday classrooms is convincing students to choose meaningful rather than rote learning. High-quality instructor feedback during the learning process plays a critical role to keep students committed to learning meaningfully throughout the course. This paper presents the use of compulsory concepts (CCs) to make explicit students' LIPHs in Cmaps. Propositions involving the CC(s) can externalize naive messages (limited propositional hierarchies) or conceptual mistakes (inappropriate propositional hierarchies). In both cases, the identification of LIPHs is straightforward and accomplished by checking, at-a-glace, neighbor (NCs) and supplementary (SCs) concepts in the propositional network. Therefore, the use of CC(s) increases the probability of a mapmaker to externalize his or her LIPHs. Making LIPHs visible can help instructors provide precise feedback to students throughout the learning process. We believe this strategy can foster pedagogic resonance between the instructor and students and allow a suitable social interaction to promote the choice to learn meaningfully.

1 Introduction

Concept mapping is a well-established technique for graphical representation of information and knowledge, which makes explicit description of mental models possible. Since its introduction in 1972, concept maps (Cmaps) have often been used for educational and corporate purposes and have changed the way we manage knowledge and information (Coffey et al., 2003; Hoffman et al., 2006; Moon et al., 2011; Nesbit & Adesope, 2006; Novak, 2010). The verification of the benefits of using Cmaps to represent and share our ideas depends on one's skills as a mapper and understanding that Cmaps are more than simple diagrams or charts (Correia, 2012). When these conditions are met, concept mapping is likely to promote changes in teaching, learning, and assessing students (Novak, 2002; 2005).

Cmaps present some unique features that make them more powerful than other graphic organizers: propositions (P), focal question (FQ), recursive revision (RR), and hierarchy (H).

- Propositions (P) are formed by two concepts that are connected through a linking phrase (initial concept + linking phrase + final concept). Reading direction is usually indicated by an arrow. Good propositions have a high degree of semantic clarity and readers can understand clearly the mappers' ideas.
- Focal Question (FQ) is the ultimate goal of the Cmap. It is the critical parameter to drive the selection of the most relevant concepts and linking phrases. The FQ must be addressed by the propositional network from which the readers obtain the mapper's answer.
- Recursive Revision (RR) reflects the dynamic nature of knowledge and information. In other words, Cmaps are never finished and they can be improved over time. It must be stressed that the "right" answer is no longer available; on the contrary, it must be continuously pursued.
- Hierarchy (H) is the fine-tuning of the network structure of the Cmap. The spatial organization of concepts depends on their inclusiveness and the most inclusive concepts must be read first. This hierarchy structure supports understanding through progressive differentiation of concepts (Ausubel, 2000).

Assimilation Theory of Meaningful Learning and Retention refers to the description of the learning process on a continuum between two extremes, called meaningful and rote learning (Ausubel, 2000; Mayer, 2002). The distinction between these extremes is characterized by how new information relates to the relevant aspects within the existing cognitive structure of each learner. In meaningful learning, relationships are established in non-arbitrary and non-literal ways; this process requires more cognitive effort to relate the individual's prior knowledge to the new information. On the other hand, these relationships are established arbitrarily and literally in rote learning and do not require the individual to check the effect of prior knowledge on the new information (Ausubel, 2000; Novak 2010). Meaningful learning is more demanding than rote learning and students must make an effort to learn in this way. Instructor feedback is critical to avoid students shifting from meaningful to rote learning. Finally, meaningful learning depends on the idiosyncrasies of each person (*e.g.,* prior knowledge, experiences, self-efficacy, values, and control beliefs), the instructional strategies used, and learners' intrinsic desire to find meaning (Ausubel, 2000; Novak, 2010; Pintrich, Marx & Boyle, 1993).

Meaningful learning does not imply the absence of conceptual mistakes (Novak, 2002; Novak & Musonda, 1991). On the contrary, the literature refers to them as misconceptions, alternative conceptions, naive notions, and pre-scientific notions. Novak (2002) proposed Limited or Inappropriate Propositional Hierarchies (LIPHs) to refer to these types of conceptual errors. The identification of LIPHs in Cmaps is straightforward as the lack of semantic clarity of some propositions may reveal the presence of mistakes or limited understanding. For example, poorly chosen linking phrases constrain the accuracy of messages embedded in the propositional network. Novak (2002) proposed LIPHs as suitable starting points to foster meaningful learning. Therefore, instructors can consider LIPHs to intentionally plan and revise upcoming learning activities to continue to foster meaningful learning.

LIPHs can be the result of meaningful learning and changing them is a difficult task. Students must gradually revise the relevant structures of their own knowledge and build new propositions over time while trying to gain a deeper understanding of the mapped topic. For instance, students must create new meaning from the instructor's comments about their original Cmaps to gain awareness of the propositions that need to be revised. If students choose to use rote rather than meaningful learning to overcome their LIPHs, the resultant knowledge will not be appropriately retrieved after long period and will not be used in contexts that are different than the one used during the learning process.

One educational challenge posed in everyday classrooms is convincing students to choose meaningful rather than rote learning. High-quality instructor feedback during the learning process plays a critical role to keeping students committed to learning meaningfully throughout the course. The achievement of pedagogic resonance (Kinchin, Lygo-Baker & Hay, 2008) and the development of self-regulative skills (White & Frederiksen, 1998) are desirable side effects in supporting meaningful learning. For these reasons, we believe that there is a need for a procedure that allows rapid identification of LIPHs in Cmaps.

2 Research goal

The aim of this paper is to propose the use of compulsory concepts (CCs) to make explicit students' Limited or Inappropriate Propositional Hierarchies (LIPHs) in Cmaps.

3 The role of compulsory concept(s) in concept mapping

The instructional strategy underlying this study is to ask learners to use one or multiple compulsory concepts (CCs) to prepare their Cmaps. This task involves analysis (breaking material into its constituent parts and detecting how the parts relate to one another and to the overall structure or purpose), evaluation (making judgments based on criteria and standards), and creation (putting elements together to form a novel, coherent whole or an original product). These tasks are sophisticated cognitive processes, as described by Bloom's revised taxonomy of educational objectives (Krathwohl, 2002).

The selection of CC is critical to allow students to expose the limits of their understanding of the subject. Some criteria to choosing CC include:

- Selection of threshold concepts (Meyer and Land, 2005, p.373) that may be transformative (occasioning a significant shift in the perception of a subject), irreversible (unlikely to be forgotten, or unlearned only through considerable effort), and integrative (exposing the previously hidden interrelatedness of something).
- In-depth discussion of the CC during learning activities in classroom.
- Usefulness of the CC to address the focal question appropriately.

Concepts in a Cmap can be classified, according to their location from the CC(s), before reading the propositional network. Specifically, all concepts that are directly connected to CC(s) are classified as neighbor concepts (NCs); supplementary concepts (SCs) are not directly linked to CC(s) (see Figure 1). This at-a-glance check allows to analyze the relevance that mappers conferred to the CC(s) by counting the propositions from or to CC(s).

The relevance of the CC(s) to address the focal question is predictable from the number of propositions from or to CC(s). Many propositions are a sign of high relevance (Figures 1a and 1c), whereas few propositions could indicate a student's difficulty in connecting the CC(s) to his or her own conceptual knowledge (Figures 1b and 1d). Curiously, the number of propositions from or to CC(s) is not a good indicator of students' understanding of the mapped topic. In some cases, students may choose to follow the exam instructions without any concern for the usefulness of the propositions they create. The expected result is a Cmap with many (but meaningless) propositions from or to CC(s). Despite using the CC(s), the bureaucratic approach that is adopted by some students is easily detected (Cicuto & Correia, 2012).

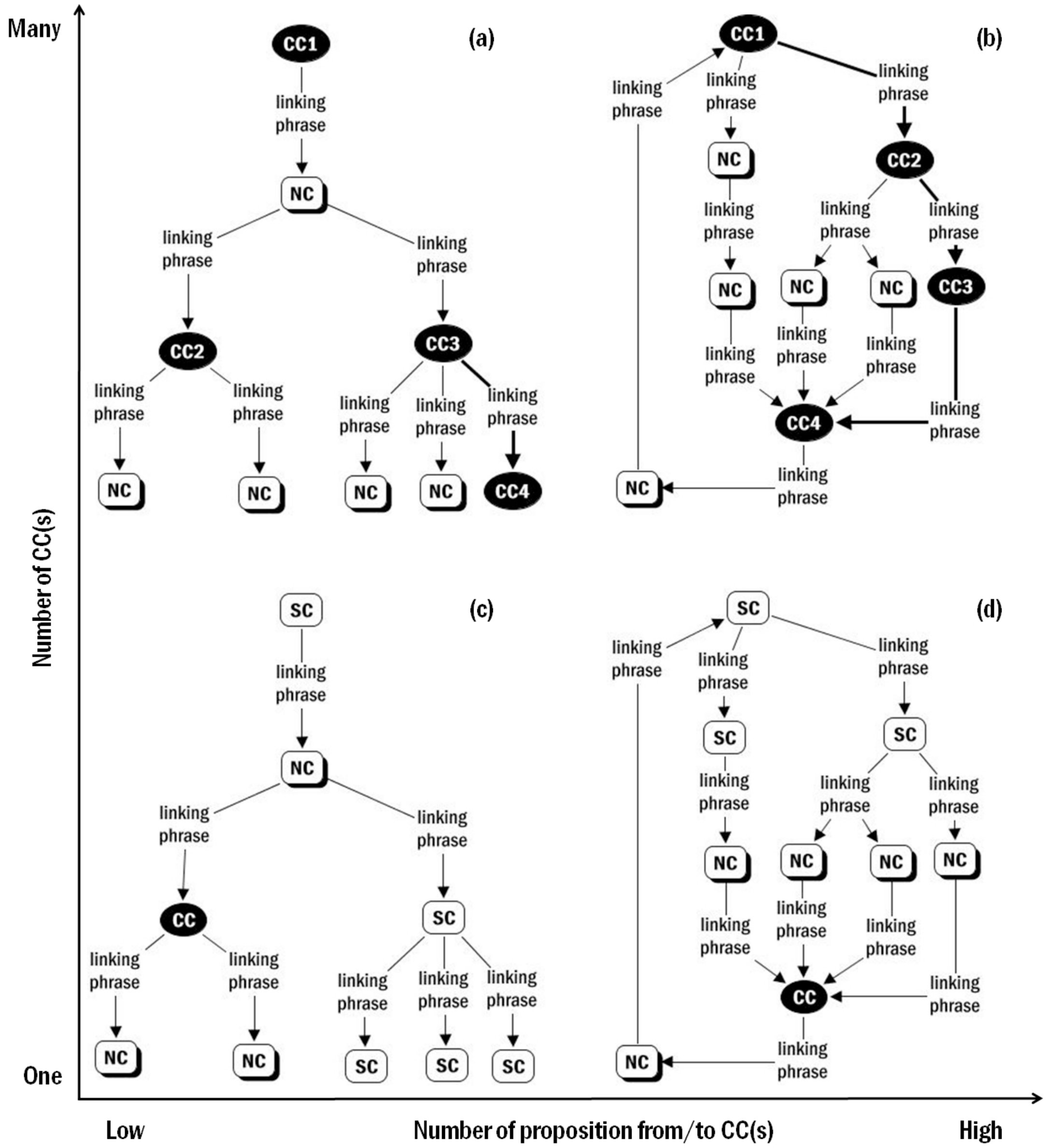


Figure 1. Classification of concepts according to the CCs (black circles): neighbor concepts (NCs, shadowed boxes) are directly linked to the CCs, whereas supplementary concepts (SCs, white boxes) are not. Some patterns can be identified at-a-glance: Cmap with multiple CCs and few propositions from or to them (Figure 1a), multiple CCs and many propositions from or to them (Figure 1b), one CC and few propositions from or to it (Figure 1c), and one CC and many propositions from or to it (Figure 1d). Thicker lines show CC-CC propositions in Figures 1a and 1b.

Propositions CC-CC and CC-NC can be considered to evaluate the occurrence of progressive differentiation (Figures 1a and 1c) or integrative reconciliation (Figures 1b and 1d). In the former, inclusive concepts present in the student's cognitive structure subsume the newer information. Frequently, beginners on the mapped topic prefer to express their knowledge using this approach. Integrative reconciliation (Figures 1b and 1d) is typically applied by experts on the topic. This approach reflects a deeper understanding of the concepts involved by identifying patterns among less inclusive concepts to other concepts (called as superordinates). The rapid analysis of the structure of Cmaps, when CC(s) are required, allows for classification into two groups according to the amount of integrative reconciliation. The pedagogic resonance (Kinchin, Lygo-Baker & Hay, 2008) between the instructor's conceptual knowledge and the students' Cmaps can take place and increase the precision of the instructor's feedback throughout the learning process.

4 Compulsory concept(s) to identify Limited or Inappropriate Propositional Hierarchies

We hypothesize that the use of CC(s) increases the difficulty of making a Cmap because the CC(s) is not chosen by the map-makers themselves. Consequently, the mapper must find appropriate NCs and linking phrases to express how the CC(s) can be included into the propositional network. This task seems more difficult than establishing propositions using only concepts selected by the author of a Cmap.

It is possible that the CC(s) will not be familiar to some students who studied the topic without considering its threshold concept(s) appropriately (Meyer & Land, 2005). In this case, the externalization of LIPHs, due to the CC(s), is likely to occur while students try to use this concept(s) without a clear comprehension about its meaning(s). On the other hand, when the map-makers choose all concepts themselves (there is no CC to be used), the externalization of LIPHs is less probable because the students will prefer to use only familiar concepts and avoid the risk of exposing their conceptual gaps. Therefore, it is more difficult for instructors to identify LIPHs from students' Cmaps and plan further activities to fostering meaningful learning. Our hypothetical generalization can be summarized as follows: propositions involving the CC(s) can externalize naive messages (limited propositional hierarchies) or conceptual mistakes (inappropriate propositional hierarchies). In both cases, the identification of LIPHs is straightforward by checking, at-a-glace, the neighbor (NCs) and supplementary (SCs) concepts in the propositional network. Therefore, the use of CC(s) increases the probability of a map-maker to externalize his or her LIPHs. The comparative evaluation of students under the same instructional conditions and the precise feedback provided by the instructor are critical in the support meaningful learning. Specifically, these can be achieved in everyday classrooms using CC(s), Cmaps, and the proposed procedure to make a rapid evaluation of learning progress.

Figure 2 illustrates Cmaps prepared by the authors to represent the most common patterns identified using CC during a Natural Sciences course (Correia et al., 2010), offered at School of Arts, Sciences, and Humanities (University of São Paulo). Our intention is to present how LIPHs are externalized in Cmaps that contain one or multiple CCs. The Cmaps represented in Figures 2a and 2b show two types of propositions: CC-CC (thicker lines) and CC-NC. The former proposition is only formed when multiple CCs are selected by the instructor, whereas the latter is found with one or multiple CCs.

Figures 2a and 2b allow a close evaluation of CC-CC and CC-NC propositions, which may increase the chance of LIPHs externalization. The CCs for these Cmaps include environment, technology, science, and climate change. This selection aims to confirm the relationships involving science, technology, and society (STS approach), which are critical aspects to promoting scientific literacy (Bybee, McCrae, & Laurie, 2009; Correia et al., 2010; Millar, 2006; Osborne, 1997, 2012; Santos, 2009). Figure 2a illustrates only one CC-CC proposition (climate change – is studied by → science). This proposition has semantic clarity and is correct considering the message expressed. On the other hand, the CC-NC propositions in Figure 2a present limitations or conceptual mistakes. The propositions that involve technology, economic development, and climate change (technology – and → economic development; economic development – with → climate change) were classified as limited (L) because their semantic clarity is hindered by the lack of verbs in the linking phrases. Inappropriate propositions (containing conceptual mistakes) can be found from the concept climate change (climate change – minimizes → clean development; climate change – minimizes → alternative energy use). The verb used in the linking phrases confirms the lack of understanding about climate change and the differentiated concepts (clean development and alternative energy use).

The remarkable feature of the Cmap presented in Figure 2b is the sequence of CC-CC propositions: technology – can minimize → climate change; climate change – is studied by → science; and science – and → environment. This sequence of propositions using only CCs requires a good understand of the topic. Moreover, the student must be confident in expressing his or her ideas, which can be another indicator of he or she understands the topic. This type of Cmap reveals confident students who take a chance to make something special. The price they could pay is externalizing LIPHs, as seen in the last proposition (science – and → environment). However, the instructor's feedback should recognize the mappers' effort to go beyond a naive subject description. The limitation should be identified without compromising the net evaluation of the Cmap (low grades for this mistake may be not justifiable). The deeper understanding shown in Figure 2b can be supported with the use of "environment" as a concept to promote integrative reconciliation. The Figure 2a shows a less complex Cmap that is based only in progressive differentiation.

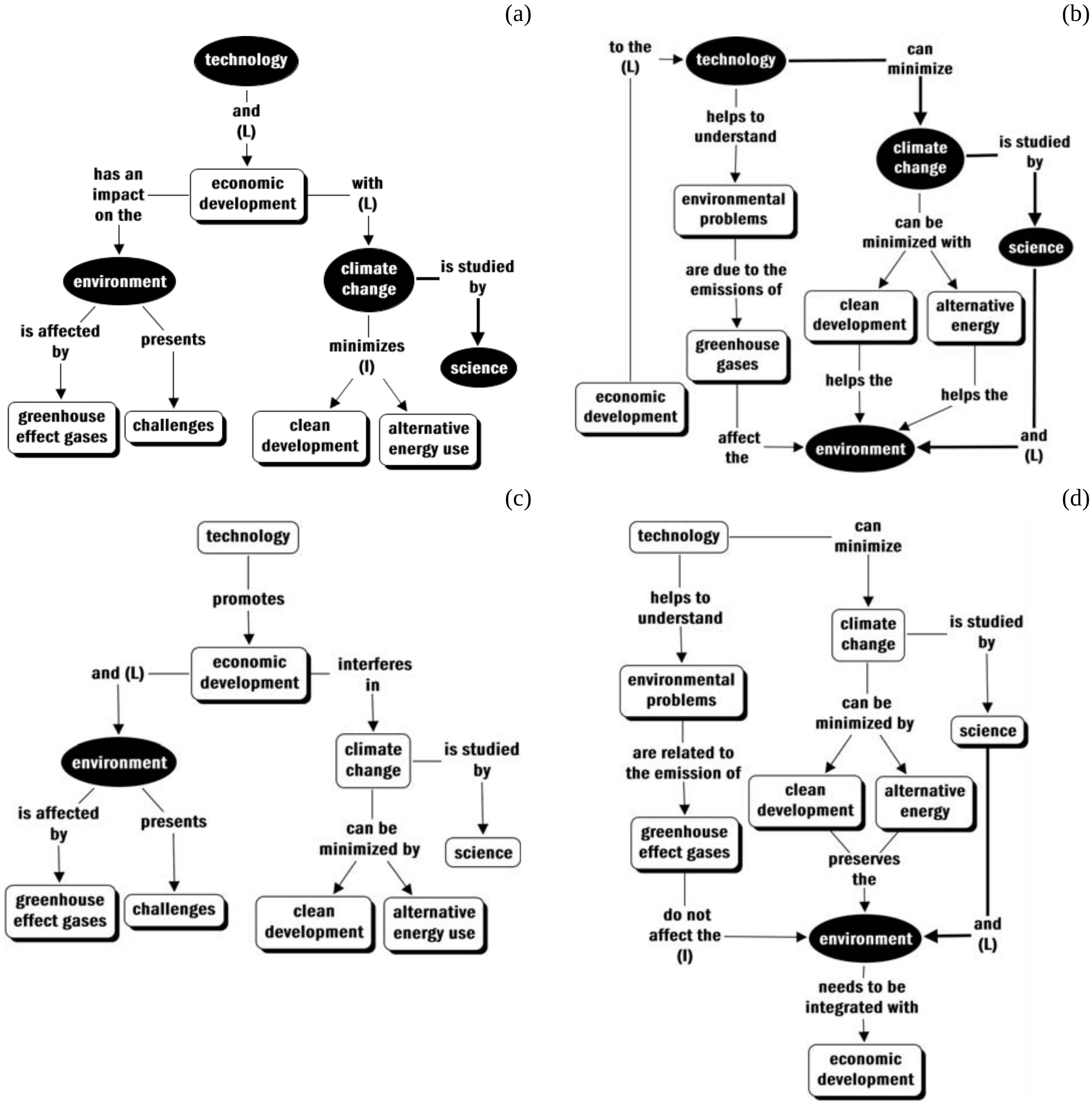
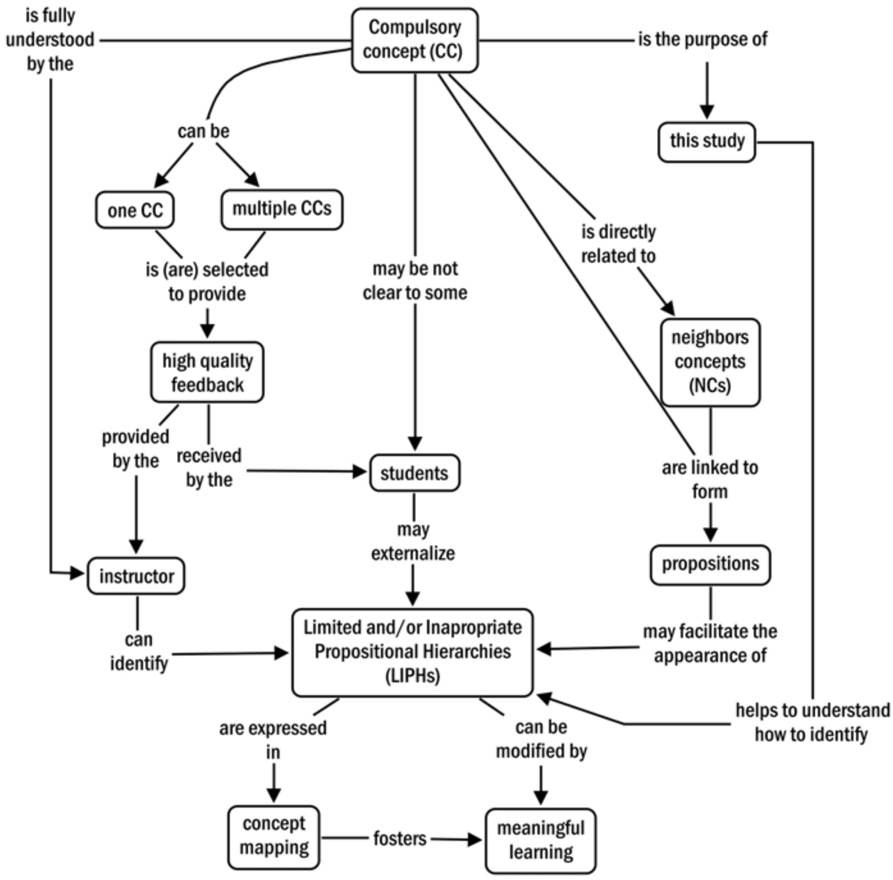


Figure 2. Illustrative Cmaps made by the authors to highlight typical patterns from our experience using CC(s) to identify LIPHs. Classification of concepts, according to the CCs (black circles): neighbor concepts (NCs, shadowed boxes) are directly linked to the CCs, whereas supplementary concepts (SCs, white boxes) are not. Limited and inappropriate propositions are indicated using L and I, respectively. Thicker lines show CC-CC propositions (Figures 2a and 2b).

Figures 2c and 2d present Cmaps that contain one CC (environment). Therefore, only CC-NC propositions are available to foster the externalization of LIPHs. Both Cmaps have one limited (L) proposition (economic development – and → environment in Figure 2c, and science – and → environment in Figure 2d); whereas the Cmap in Figure 2d includes an inappropriate proposition (greenhouse effect gases – do not affect the → environment). The latter shows a conceptual mistake, while the former is not clear enough to allow this type of judgment. The comparison among the two allows differentiating, at-a-glance, limited and inappropriate propositional hierarchies in Cmaps (Novak, 2002).

The overall analysis of the four Cmaps presented in Figure 2 supports the use of one or multiple CCs to foster the externalization of LIPHs. Making LIPHs visible can help instructors provide precise feedback to the students throughout the learning process, thus, making the learning progress even more visible (Hay, Kinchin, & Lygo-Baker, 2008). We believe this strategy fosters pedagogic resonance between the instructor and students (Kinchin, Lygo-Baker & Hay, 2008) and allows a suitable social interaction to promote the choice to learn meaningfully.

5 Summary



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