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HOW DIFFERENT INSTRUCTIONS AFFECT CMAPS ELABORATED BY STUDENTS? A STUDY INVOLVING CMAP STRUCTURE AND ASSOCIATION OF STUDY MATERIALS

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Abstract. Concept maps (Cmaps) are visual organizers to represent knowledge using propositions. The literature discusses the role of demand in the process of Cmaps elaboration. This work investigated how demand influences the structure and the integration of study materials used during the learning phase. We collected a total of 98 Cmaps elaborated under two different conditions. The first situation was restricted to 24 concepts and the second was restricted to 9 concepts and a pre-established focus question. The analysis of data revealed that the difference in demands changes the structure of the maps and the integration of concepts from the materials of instruction. More restrictive situations lead the mapper to a higher level of synthesis where the structure of the Cmap assumes one more similar to a net structure and leads to integration between different materials.
Keywords: Cognitive Load Theory, Concept Maps, Extraneous Cognitive Load, Instructional Design, Training Methods.

1 Introduction

Concept maps (Cmaps) are graphic diagrams that represent part of the individual's mental models (Novak, 2010). Cmaps are formed by concepts linked to form propositions (initial concept – linking phrases → final concept). The inclusion of linking phrases to clarify concept relationships makes Cmaps more powerful than other graphical techniques used to represent knowledge and information, such as mind and argumentative maps (Davies, 2011; Correia, 2012). In line with Cañas and Novak (2006), our research group advocates that four central concepts must be considered to get all of the benefits from the Cmaps (Aguiar et al., 2014; Aguiar & Correia, 2013). These concepts are summarized below.

- Proposition: Gives semantic clarity to the content of the Cmap and makes it possible to share the represented knowledge.
- Focus question: Keeps the mappers centered on idea and avoids large Cmaps about broad topics, which can be better organized into several Cmaps with specific focus questions.
- Hierarchy: Fosters progressive differentiation when broad concepts are continuously detailed into more specific ones (Ausubel, 2000). This process is useful to organize knowledge and to acquire new information from organized schemas.
- Recursive revision: Reflects the continuous change in our knowledge during the learning process and the consequent need of adjusting the representation we have of it. Cmaps must be revised frequently to keep them up to date with our own knowledge.

The task for elaboration of Cmaps can be planned in different ways. The kind of demand will produce the elaboration of Cmaps with distinctive contents and structures. Cañas et al. (2012) highlights this effect of task configuration on students' Cmaps using a graph to organize typical Cmap tasks into a continuum from total freedom to total restriction of content and structure (Figure 1). This approach provides an insightful connection between instructional design and learning outcomes (student Cmap) usually forgotten by teachers. Our main goal is to further explore this connection and present some empirical data to compare students' Cmaps obtained under two different conditions.

This paper aims to compare the morphology of propositional network (structure) and the way students associate study materials when they elaborate Cmaps following two different instructions. Condition C1 is less restrictive in terms of content and structure, and students make a Cmap as preparation for an exam. Condition C2 is more restrictive in terms of content and structure, and students make a Cmap during an exam, and consult the Cmap prepared under C1 condition. We hypothesized the more restrictive condition (C2) will foster conceptual synthesis during the exam. As a consequence:

- Cmaps elaborated under C2 will present more complex structures than Cmaps elaborated under C1 (hypothesis 1a), and
- Study materials will be more associated in Cmaps elaborated under C2 than Cmaps elaborated under C1 (hypothesis 1b).

Hypotheses 1a-1b will be verified using Cmap analyses developed by our research group (Silva Jr. et al., 2010; Cicuto et al., 2013). These analyses are detailed below.

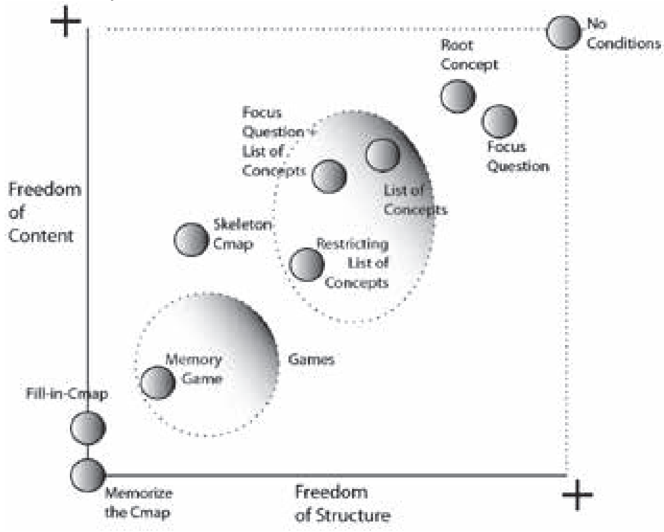


Figure 1. Freedom of structure and content conditions to describe concept mapping task. The instruction to elaborate Cmaps can vary from total freedom (no conditions) to total restriction (memorize the Cmap), which affects students' Cmap (Cañas, Novak & Reiska, 2012).

2 Research methods

2.1 Participants and data collection

The Cmaps (n = 98) were obtained during an undergraduate course on Natural Science (NS) offered to all first-year students undergraduate students in the School of Arts, Science and Humanities at the University of São Paulo (SASH/USP). The main goal of this course is to provide a broad overview of the influence of scientific and technological development in our society (Correia et al., 2010). Forty-nine students took part into this study in 2013, and each one made two Cmaps following different instructions (conditions C1-C2) during classes 9 and 10 (Figure 2). Both Cmaps were about climate change, the main topic of part 2 of the course. This topic was discussed throughout classes 5 to 9. Class 10 was selected to carry out a formal evaluation of student outcomes using Cmaps (C2). Students could prepare a previous Cmap (C1) to study and consult it during the exam. All of this emphasis on students making their own Cmaps was possible due to the training period on concept mapping we developed and used during classes 1-4 (Aguiar et al., 2014; Aguiar & Correia, 2013; Correia et al., 2008).

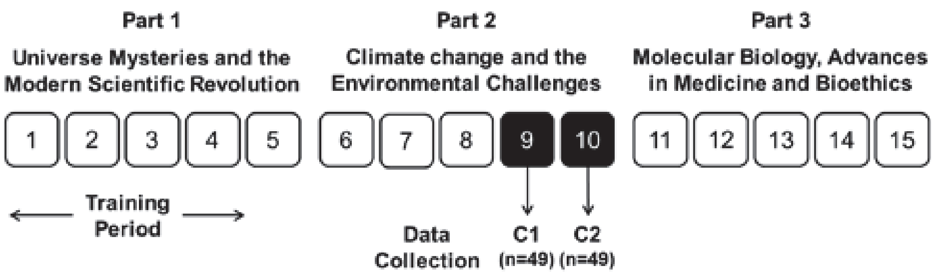


Figure 2. General organization of the 15-class Natural Science Course. Students were trained in the concept mapping technique during classes 1-4. The data collection (Cmaps) occurred at classes 9-10 under different instructions (conditions C1-C2).

The main differences between conditions C1 and C2 are highlighted in Table 1. Condition C1 has more freedom in terms of content and structure compared to condition C2. Moreover, students can consult the Cmaps produced under C1 (during the timespan between classes 9-10) during the exam (class 10) while preparing a Cmap under more restrictive conditions (C2). The full instructions given to students to prepare the Cmaps are presented in Figure 3.

Name:	Code:

[TP2-NS2013] CONCEPT MAP to be used as EXAM PREPARATION

Considering the materials used during the discussion in class 7, 8 and 9. Read the texts, watch the indicated videos, reflect about our discussions, and select the concepts most relevant to each class (max of 4 concept for each instructional material). List your concepts in the following table. You can relate, at most, 24 different concepts. The delivery of Exam Preparation worth 0.5 points in Test 2 of NS-2013

(A) Class 7: Climate change and development. Text of José Goldemberg

A1)
A2)
A3)
A4)

(B) Class 7: Video "Al Gore alerts about the last climate tendencies". TED: Al Gore

B1)
B2)
B3)
B4)

(C) Class 8: Global Questions: crisis or opportunity? Text of André Trigueiro

C1)
C2)
C3)
C4)

(D) Class 8: Video "Conscious consumerism". TED: André Trigueiro.

D1)
D2)
D3)
D4)

(E) Class 9: COP 15: field appointments. Text of Sérgio Abranches

E1)
E2)
E3)
E4)

(F) Class 9: Video "Environmental Racism". TEDxSP: Paulo Saldiva

F1)
F2)
F3)
F4)

FOCUS QUESTION & INSTRUCTIONS

How is scientific-technological development related to climate changes?

[1] The doted rectangle shows the initial concept of Cmap. [2] "INCREASE OF LOCAL ACTIONS" is the obligatory concept and it must be part of your Cmap. [3] Put the number in the propositions to indicate the order of reading. [4] Put the source of each concept in the circle next to rectangle, considering the codification used to elaboration of **TP**.

(A) "Climate change and development" (Text, José Goldemberg)	(B) "Al Gore alerts about the last climate tendencies". (Video, Al Gore)
(C) "Global Questions: crisis or opportunity?" (Text, André Trigueiro)	(D) "Conscious consumerism". (Video, André Trigueiro)
(E) "COP 15: field appointments." (Text, Sérgio Abranches)	(F) "Environmental Racism". (Video, Paulo Saldiva)

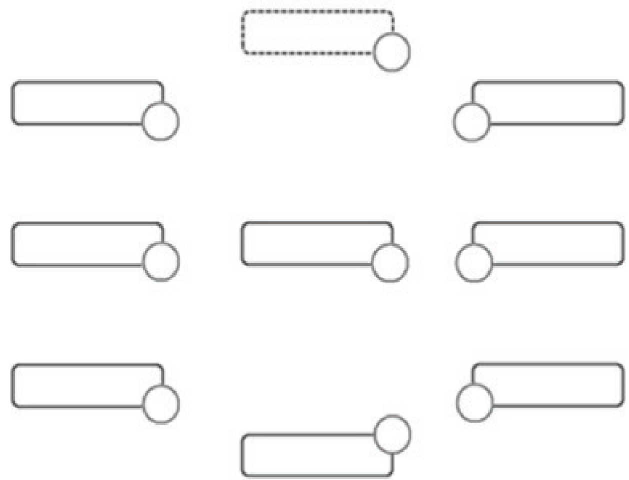


Figure 3. Instructions to students to prepare their Cmaps under condition (a) C1 and (b) C2. The Cmaps made under C1 could be consulted during the exam (C2), which involved the elaboration of a Cmap under more restrictive conditions.

Table 1: Comparison of conditions C1 and C2 to students elaborate Cmaps in class 9 and 10, respectively.

	Condition C1 **Study/Preparation to the exam**	**Condition C2** **Exam of Natural Science course**
Material to be consulted during the elaboration process	Texts and videos used in classroom (classes 5-9).	Cmap produced by students to study for the exam (condition C1).
Number of concepts (structural restriction)	**Mild.** 24 (maximum) to be selected by students, considering the texts and videos used in classroom.	**Moderate.** 9 concepts, one of them is compulsory and defined by the teacher ("increase of local actions")
Focus question (content restriction)	**Mild.** To be defined and declared by students.	**Moderate.** Defined by the teacher. A how-type question to foster dynamic thinking/ propositions.
Time limit	**Mild.** One week between the demand and the delivery date. There is virtually no time restriction.	**Moderate.** Time controlled and limited to 60 minutes.

2.2 *Structural Analysis of Cmaps*

Our research group developed a quantitative structural analysis of Cmaps to capture all morphological features of the propositional network (Silva Jr. et al., 2010). This approach was inspired by the qualitative study proposed by Kinchin et al. (2000) and a quantitative rubric reported in the literature (Cañas et al., 2006). We consider that Cmaps are formed by three types of building blocks: J, K, and L (Figure 4). Each one represents concepts that may be involved in one or more propositions as initial concepts (p) or final concepts (q). Using this information, we can describe all morphological features of the propositional network of a Cmap.

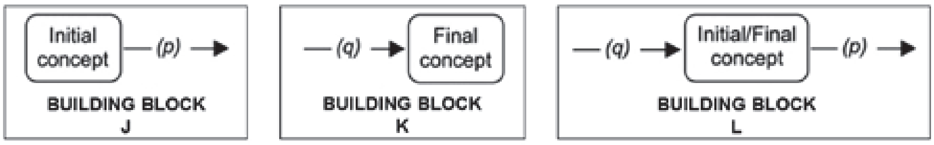


Figure 4. Fundamental building blocks (J, K, and L) of Cmaps' considered for structural analysis (Silva Jr. et al, 2010).

Table 2 presents the parameters of the structural analysis and their computations from the building blocks. The size difference involving Cmaps elaborated under C1 (24 concepts) and C2 (9 concepts) was compensated by calculating relative values for the parameters of the structural analysis. These relative measurements allowed us to compare the morphology of Cmaps obtained under C1 and C2 without considering the size difference. Averages and standard deviations were obtained for each parameter (absolute and relative). SPSS (v. 22.0, IBM, USA) was used to run Student's *t*-test to compare these results.

Table 2: Parameters for the structural analysis of the Cmaps.

Parameter for structural analysis		**Correspondence with structural building blocks**	**Computation**	
Description	**Notation**		**Absolute value**	**Relative value***
Concepts (boxes)	C	-	-	-
Propositions (arrows)	P	-	-	-
Propositional density	PD	-	-	PD = P/C
Only initial concepts	OIC	J	OIC = J	OICr = OIC/C
Only final concepts	OFC	K	OFC = K	OFCr = OFC/C
Initial/final concepts	IFC	L	IFC = L	IFCr = IFC/C
Initial concepts	IC	J+L	IC = J+L	ICr = IC/C
Initial concepts with multiples propositions	MIC	Jm + Lm = J+ L, when (p≥2)	MIC = Jm+Lm	MICr = MIC/C
Final concepts	FC	K+L	FC = K+L	FCr = FC/C
Final concepts with multiples propositions	MFC	Km + Lm = J+ L, when (p≥2)	MFC = Km+Lm	MFCr = MFC/C

*The relative values were calculated to compensate the size difference involving the Cmaps elaborated under C1 (24 concepts) and C2 (9 concepts). The absolute values were divided by the total number of concepts to obtain the relative values.

2.3 *Analysis of study material associations*

Six study materials (A-F) were selected by the teacher, and students focused on them to prepare their Cmaps (C1 and C2). They were asked to identify the source of the selected concepts using colors (C1, see Figure 3a) and letters (C2, see Figure 3b) to make visible the connections among the study materials during the process of retrieving and organizing information about the topic (climate change). The association of different study materials by the students was then evaluated using these Cmaps, as additional information was available to the teacher. This approach was proposed and tested by our research group (Cicuto et al., 2013), and it allowed the teacher to check how students processed the selected study materials.

Table 3 presents the categories used to compute the results for the analysis of study material associations. The critical condition was to distinguish propositions involving concepts from the same study material and from different study materials. Relative values were also calculated to avoid interference due to the difference of the size of the Cmaps elaborated under C1 (24 concepts) and C2 (9 concepts). Averages and standard deviations were obtained for each parameter (absolute and relative). SPSS (v. 22.0, IBM, USA) was used to run Student's *t*-test to compare these results.

Table 3: Parameters for the analysis of study material associations.

Parameter for study material analysis		**Computation**	
Description	**Notation**	**Absolute value***	**Relative value****
Propositions involving concepts from the same study material	SM	$SM = P_{SM}$	$SMr = P_{SM}/P$
Propositions involving concepts from different study materials	DM	$DM = P_{DM}$	$DMr = P_{DM}/P$

*SM and DM represent same/different study materials, respectively. **The relative values were calculated to compensate the size difference involving the Cmaps elaborated under C1 (24 concepts) and C2 (9 concepts). The absolute values were divided by the total number of propositions to obtain the relative values.

3 Results and Discussion

3.1 General considerations about conditions C1 and C2

Students used the Cmaps made under condition C1 during the exam (condition C2) to address a focus question about climate change ('How is scientific and technological development related to climate change?') and accommodate a compulsory concept ('increase of local actions') into the propositional network in 60 minutes. The access of a Cmap containing an organized set of propositions about the study material (C1-Cmap) helped students to deal with the restrictive conditions imposed during C2. The major challenge they faced was selecting the most important concepts to include in the 9-concept Cmap. This reduced number of concepts from 24 to 8, considering that the teacher offered one compulsory concept, which imposed a synthesis exercise because they needed to express their knowledge using only the most critical concepts. The number of propositions was not restricted, which allowed them to make as many conceptual relationships as they wanted. The teacher gained two straightforward indicators to evaluate the C2-Cmaps comparatively. Students who grasped the content tended to produce:

- Cmaps with net structure (few concepts embedded into many propositions), and
- Cmaps with a smart concept selection (only critical concepts are present, revealing the capacity to identify the main parts of the topic).

3.2 Influence of instructions on the Cmap structure

The mean for all parameters of the structural analysis are presented in Table 4. The absolute values confirmed the influence of the difference on the Cmap sizes (C1: 24 concepts; C2: 9 concepts). As students could use more concepts in C1, these Cmaps presented higher values to all parameters than C2-Cmaps. In brief, there was a significant influence on the Cmap structure because of difference in the number of concepts used in each condition. Despite being expected and obvious, this fact confirms different instructions to elaborate Cmaps produce different outcomes. Therefore, it seems difficult for a teacher to compare Cmaps produced under diverse conditions (e.g., freedom considering the number of concepts to be used by students).

Relative values were critical to comparing the C1 and C2 Cmaps because they eliminated the effect caused by the difference in the size between them. The *t*-test revealed no difference considering PD, OICr, MICr, and FCr. However, a statistical difference remained for the parameters, OFCr, IFCr, ICr, and MFCr. The changes can be explained considering the influence of condition C2, which was more restrictive in terms of structure and content.

Table 4: Parameters of the structural analysis for Cmaps obtained under C1 ($n = 49$, 24 concepts) and C2 ($n = 49$, 9 concepts).

		C1: Study/Preparation to the exam M (SD)	C2: Exam of Natural Science course M (SD)	t-test
Absolute Values	C	22.92 (2.76)	9.31 (0.68)	33.51**
	P	29.24 (9.38)	12.29 (2.62)	12.19**
	OIC	2.76 (2.42)	1.33 (0.92)	3.86**
	OFC	7.31 (3.30)	1.45 (0.98)	11.91**
	IFC	12.86 (4.28)	6.53 (1.34)	9.88**
	IC	15.61 (3.56)	7.86 (1.08)	14.60**
	MIC	6.98 (2.57)	3.18 (1.42)	9.04**
	FC	20.16 (3.34)	7.98 (0.72)	24.98**
	MFC	5.69 (3.57)	3.10 (1.58)	4.64**
Relative Values	PD	1.28 (0.39)	1.33 (0.29)	-0.67
	OICr	0.12 (0.10)	0.14 (0.09)	-0.90
	OFCr	0.32 (0.13)	0.15 (0.10)	6.79**
	IFCr	0.56 (0.17)	0.71 (0.16)	-4.37**
	ICr	0.68 (0.13)	0.84 (0.10)	-6.71**
	MICr	0.31 (0.11)	0.34 (0.15)	-1.33
	FCr	0.88 (0.10)	0.86 (0.09)	0.96
	MFCr	0.25 (0.16)	0.33 (0.18)	-2.41*

**Values differ for $p < 0.05$. **Values differ for a $p < 0.005$.*

- Decrease of 'only final concepts' (OFC) in C2: Students used Cmap made under condition C1 during the exam. They must extract part of the content (expressed in a propositional framework containing 24 concepts) to organize and synthesize nine concepts. This condition created a wish to tell, and the students made many propositions with few concepts. Therefore, OFC (building block K, Figure 4) became 'initial/final concepts' (IFC, building block L, Figure 4).
- Increase of 'initial/final concepts' (IFC) in C2: A consequence of the wish to tell many things using few concepts. The reduction of OFC produced an increase of IFC in C2; these Cmaps have concepts that are more connected to each other (prevalence of building blocks L instead of K, see Figure 4).
- Increase of 'initial concepts' (IC) in C2: A consequence of the increase of IFC (discussed above). IC is the sum of IFC (building block L, Figure 4) + 'only initial concepts' (OIC, building block J, Figure 4), which remained unchanged.
- Increase of multiple final concepts (MFC) in C2: A consequence of the integrative reconciliation caused by the synthesis exercise proposed during the exam. The OFC concept (building block K) presents only one proposition ($q = 1$) and MFC applies when multiple propositions appear ($q \geq 2$). This change implies in high concept integration, especially for Cmaps containing few hierarchical levels.

The morphological changes detected using relative values confirmed the influence of the instructions on the produced Cmaps. Based on the structures proposed by Kinchin et al. (2000), we can say, in general terms that the Cmaps produced under C1 had a spoke structure, and the Cmaps produced under C2 presented a net structure. This observed change in structure confirmed hypothesis 1a.

3.3 *Influence of instructions on association of study materials*

The mean for propositions involving concepts from the same study materials (SM) and different study materials (DM) are presented in Table 5. Again, the absolute values confirmed the influence of the difference on the Cmap sizes (C1: 24 concepts; C2: 9 concepts). The amount of propositions used was much higher in C1 than in C2 and the SM and DM means were statistically different for these conditions. The influence of the instruction on the produced Cmaps was confirmed again, and the number of concepts to be used was a critical parameter.

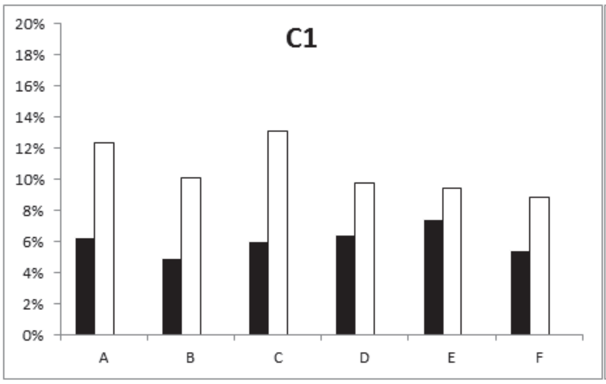
Relative values were considered to compare C1 and C2 Cmaps to eliminate the effects caused by the differences in the size between them. The *t*-test revealed a statistical difference between the means calculated for SMr and DMr. A predominance of propositions existed involving concepts from different study materials (DM) for both conditions (C1 and C2). However, this pattern was intensified under C2, when 76% of all propositions involved different study materials (for C1 this value was 61%). The synthesis exercise presented during the exam (C2) and the possibility to consult the Cmap prepared under C1 (containing the source of the concepts) may explain why students were able to associate concepts from different study materials to set up their propositional networks. This association of concepts from diverse sources is highly desirable in a natural science course, as it is a first step to reach a broad understanding of complex subjects that demand multiple approaches. The restrictive demand proposed in C2 fostered the representation of this association in a Cmap and allowed the teacher to check students' knowledge because it became visible (Hay et al., 2008). The higher level of association of study material verified under C2 confirmed hypothesis 1b.

Table 5: Results for the analysis of the association of the study materials declared by the students in Cmaps obtained under C1 (n = 49) and C2 (n = 49).

		C1: Study/Preparation to the exam M (SD)	**C2: Exam of Natural Science course M (SD)**	**t-test**
Absolute values	SM	10.78 (4.33)	2.73 (1.41)	12.36*
	DM	18.47 (9.80)	9.06 (2.95)	6.44*
Relative values	SMr	0.39 (0.17)	0.24 (0.12)	5.36*
	DMr	0.61 (0.17)	0.76 (0.16)	-4.16*

**Values differ for a p < 0.005.*

Figure 5 shows the distribution of propositions considering each study material for C1 and C2. The difference between SM and DM became clear when comparing Figures 5a and 5b. The association of study materials during the elaboration of Cmaps under C2 (exam) was higher for the first materials used in this part of the course. This fact can be explained because these materials contained more fundamental concepts about the topic, and they can be related to the students' prior knowledge easily. Moreover, students had more time to study these materials compared to other materials (the last text about climate change was presented and discussed one week before the exam). The assimilation of information from the study materials seems critical to activate them during the synthesis exercise that occurred during the exam (C2). Time is needed for assimilation to occur and materials E-F were used less often than their counterparts (Figure 5b). This hypothetical explanation appeared during the interpretation of our results and it deserves further investigation.



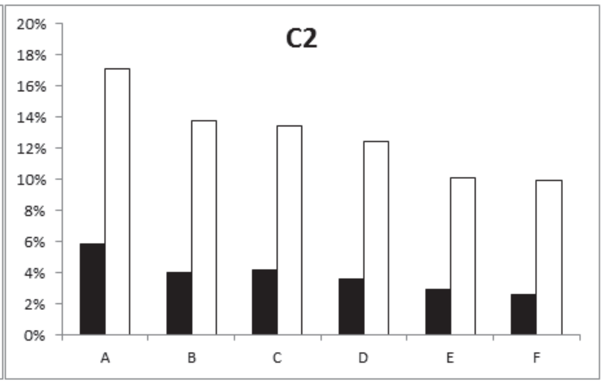


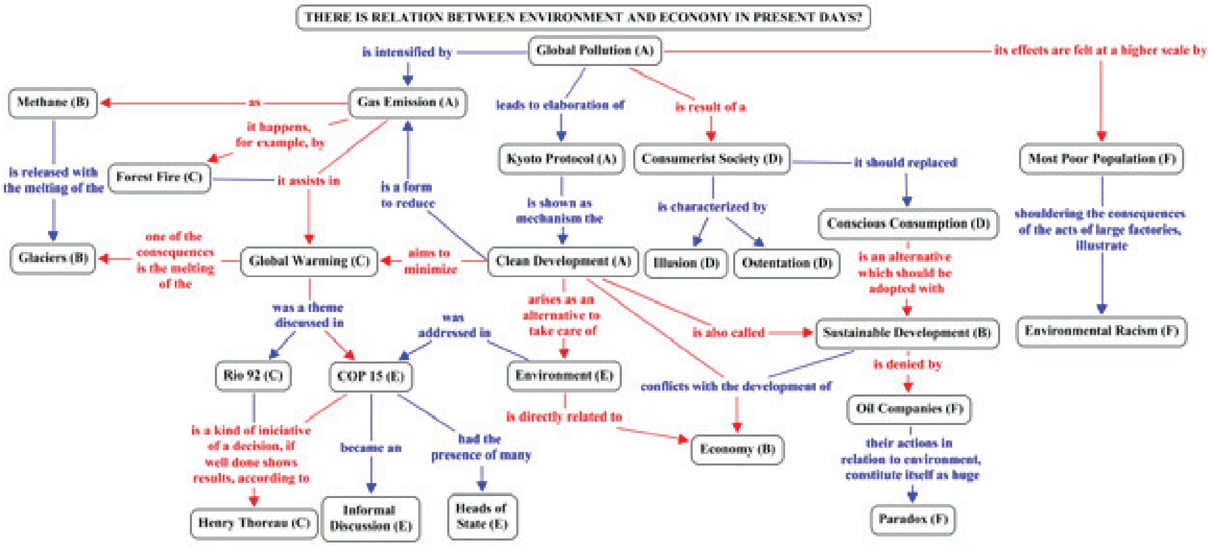
Figure 5. Distribution of propositions according to the study materials (A-F). Propositions involving concepts from the same and different study materials are represented in black and white bars, respectively.

3.4 Student Cmaps

Figure 6 presents Cmaps created by the same student under conditions C1 (Figure 6a) and C2 (Figure 6b). In Figure 6a, we can see how this student used the Cmap as study material by selecting the most inclusive concept (Global Pollution) and demonstrating a progressive differentiation that leads to more specific concepts in the low hierarchy. In this structure, it is easier to see that there is many 'only final concepts' (OFC) and few 'multiple final concepts' (MFC). Also clear is a preference to maintain grouping of concepts, thus, there are a lot of propositions involving concepts from the same material.

Figure 6b represents the Cmap elaborated by this same student under the C2 condition. In this case, the demand is more restrictive, which led the student to higher synthesis; therefore, he used some concepts from the C1-Cmap, but he selected more inclusive concepts. In this example, there is just one 'only initial concept' (OIC) and also one 'only final concept' (OFC), but the presence of many 'initial and final concepts' (IFC), 'multiple initial concepts (MIC), and 'multiple final concepts' (MFC). The process of integrative reconciliation changed the map morphology into a net structure, where it appears that all concepts are more connected. There are more propositions that relate concepts from different instructional materials.

(a)



(b)

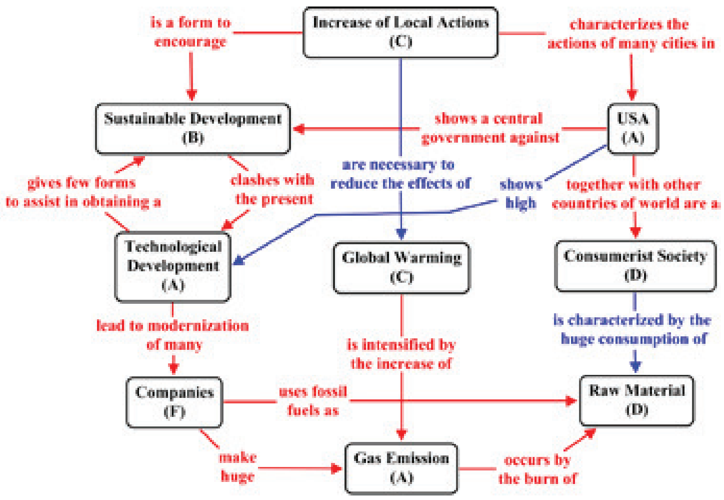


Figure 6. Cmaps elaborated by a student under conditions (a) C1 and (b) C2. The study material related to each concept in shown in parenthesis using the letters A-F (see Figure 3a). Blue and red arrows indicate propositions with concepts from the same and different study materials, respectively.

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