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FROM THEORY TO PRACTICE: THE FOUNDATIONS FOR TRAINING STUDENTS TO MAKE COLLABORATIVE CONCEPT MAPS

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Abstract. Training beginners is critical to avoid the naive use of concept maps (Cmaps) in the classroom. The rewards for using concept mapping can be achieved in the context of appropriate, rather than frivolous, didactic activities. Using the theoretical background of concept mapping, educational methodology and classroom management, we devised a four-session activity for training beginners. Moreover, to foster deep changes in the traditional classroom dynamics, we explored the role of Cmaps as visualization tools for enhancing collaborative knowledge construction. Collaborative Cmaps respond to some of the new educational demands posed by post-industrial society and should be present in the 21st-century classroom. We devised three innovative methodological strategies (half-structured Cmaps, expanded collaborative learning and propositional clarity table) to boost the training session. The favorable result shows that previously naive students could produce acceptable Cmaps after a short period of training (four classes).

1 Introduction

Concept mapping is a well-established technique that allows explicit the description of idiosyncratic mental models. It has been widely used for educational and corporate purposes with a broad variety of goals, including assessing prior knowledge as well as eliciting, archiving and sharing expert knowledge, and fostering collaboration (Novak, 1998; Fischer et al., 2002; Coffey et al., 2004; Coffey, 2006; Novak & Cañas, 2006). The apparent ease of production of concept maps (Cmaps) is attractive for beginners and explains the popularity of Cmaps. However, naive use of concept mapping may produce few (or none!) of the expected benefits, and such experiences may be playful and funny at best. During the closing talk of our last conference in Costa Rica, Cañas and Novak (2006) proposed the re-examination of the foundations for the effective use of Cmaps. They pointed out that many of the difficulties observed with the use of Cmaps derive at least in part from inappropriate use of the technique, inadequate training for users and trainers, and a general failure to recognize the importance of the tool's theoretical foundations.

Mature use of concept mapping in the classroom setting requires a solid methodological background. Insufficient theoretical knowledge makes implementation a troublesome task for the teacher. Naive use of Cmaps may result from the following events (which are generally related to the teacher's classroom routine):

1. The teacher uses the Cmaps to change the classroom dynamics.
2. The students produce various Cmaps in a short period of time because they are fascinated with the new classroom climate.
3. The teacher has difficulties handling the large amount of Cmaps because the textbook does not provide a correct answer for grading.
4. The teacher stops providing feedback to the students authoring Cmaps and Cmaps evaluation is restricted to simple verification of Cmaps production.
5. The teacher does not realize the benefits of concept mapping, makes unfavorable judgments about it, and avoids future use.

This undesirable sequence arises from the inadequate balance between the theoretical and practical aspects that must be considered to allow a mature use of concept mapping in the classroom. Experienced teachers pay less attention to the Cmap underlying theory but their own experiences may be inadequate for successful implementation. Moreover, the complex social interactions and dynamics of the classroom necessitate teaching skills independent of the understanding of the theories supporting Cmaps. Suitable use of concept mapping in classroom also requires familiarity with educational methodology and classroom management (Jones & Jones, 2003; McLeod et al., 2003), as schematically shown in Figure 1.

Training is the critical aspect to guaranteeing rewards from concept mapping. As a trainer, the teacher should be a skilled mapmaker in order to support the students during the training period. Moreover, training must be intentionally designed with a basis in the triple theoretical foundation presented in Figure 1. Appropriate training is fundamental for creating a safe path for introducing Cmaps in the classroom and for overcoming implementation challenges. In response to the warning posed two years ago, we propose a four-session activity sequence specially designed for training beginners to make collaborative Cmaps.

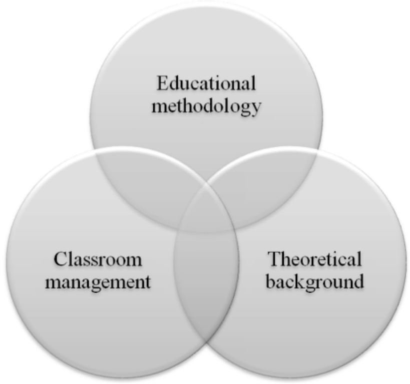


Figure 1. Triple theoretical foundation required for avoiding a naive use of concept mapping in classroom.

2 New educational demands and collaborative Cmaps

The knowledge explosion, information technology development and globalization have dramatically affected our society (Hobsbawn, 1996; Friedman, 2007). As a result, new social paradigms have emerged and attested the end of industrial society. The new society that has shaped our contemporary way of life is identified with such labels as knowledge, post-modern and post-industrial. While industrial society was based on work and goods manufacturing, post-industrial society is centered in free time, creative idleness, and service production in the form of symbols, information, values and esthetics (De Masi, 2000). The power in industrial society depended on the possession of manufacturing resources (e. g., factories). In contrast, the power in post-industrial society depends on the possession of information (e. g., mass media) and ideation resources such as research labs.

In contrast with the pronounced social changes involved in the transition to a post-industrial society, schools have not changed at all. The education designed for industrial society still prevails at most schools. Schools resemble an industrial factory in that all classrooms are identical, their teachers have a standardized discourse, and all students are expected to answer the same questions in the same way (Menezes, 2000). Such standardization, one of the industrial society's main features, affected the educational system by allowing only one model to satisfy teachers' and students' diverse expectations.

Traditional schools were formed under industrial paradigms, and their methodological procedures must be revised to respond to the new demands of post-industrial society. In addition to transmitting disciplinary knowledge, 21st century education requires the development of skills related to life-long learning, teamwork, creative thinking, and collaborative knowledge construction (Fischer et al., 2002; Sawyer, 2006). The powerful combination of these cognitive and communicative skills with confidence, which is related to emotional behavior, can foster students' empowerment in classrooms. The new educational demands can be described as follows:

1. Life-long learning = metacognition + self-evaluation.
2. Confidence = self-evaluation + motivation.
3. Teamwork skills = motivation + creativity.
4. Creative thinking = creativity + metacognition.

Any methodological change in classroom activities in order to fit the needs of post-industrial society must pursue a truly collaborative and empowering environment that involves both teachers and students (Mintzes et al., 1998). The ultimate lesson to be taught in post-industrial classrooms is to learn how to learn (Georghiades, 2004; Novak & Gowin, 1984). In this context, collaborative concept mapping can be considered a methodological strategy capable of adapting traditional classroom dynamics to the new educational demands of the 21st century.

2.1 Creation, collaboration and concept mapping

Creation is a central value for the post-industrial society. The increasing demand for innovation and creative thinking can be addressed more easily when a collaborative group is formed. As collaboration and creation require extensive practice, students should work together and collaborate in creative groups throughout their formal education. Opportunities for practicing creativity and collaboration in schools must be devised by teachers using innovative methodological strategies.

The creative process that takes place in collaborative groups can be described in three steps. Externalization and elicitation of task-relevant knowledge precede consensus building, which can be conflict- or integration-oriented (Fischer et al., 2002). As visualization tools, Cmaps foster the collaborative knowledge construction process by making idiosyncratic mental models explicit for revising (intrapersonal activity) and sharing ideas (interpersonal activity). Both purposes are important during collaborative knowledge construction because all participants can visualize, interpret and organize their own ideas (intrapersonal) before beginning conflict-oriented and/or integration-oriented consensus building (interpersonal). Figure 2 shows the role of visualization tools (Cmaps) at each step of collaborative knowledge construction.

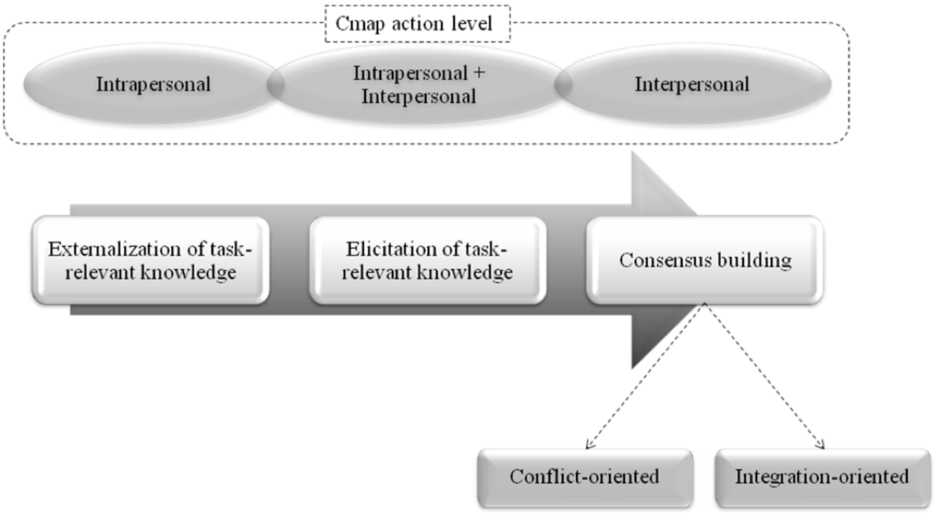


Figure 2. Visualization tools (Cmaps) and their relationship with the collaborative knowledge construction process.

Collaborative concept mapping is an interesting methodological strategy that responds to some of the educational demands posed by post-industrial society. Recent findings presented in the literature confirm that this technique is effective when students have been trained appropriately and can use Cmaps in a mature rather than naive way (Basque & Lavoie, 2006; Novak & Cañas, 2008). In our contemporary context, collaborative concept mapping allows the development of synthesizing and creating minds (Gardner, 2006), as well as teamwork skills, which are formative requisites for 21st-century citizens (De Masi, 2000; Sawyer, 2006). Thus, training activities must include collaborative Cmaps instead of exclusively focusing on individual concept mapping.

3 Half-structured Cmap (HSCmap), expanded collaborative learning (ECL) and propositional clarity table (PCT) for training beginners

We designed and tested a four-session activity based on the theoretical foundations involving concept mapping, educational methodology and classroom management, to train beginners to make collaborative Cmaps (Table 1). The first step in training a student to make maps proficiently was to ensure understanding of Cmap structural aspects. For this purpose, the following central concepts were selected:

1. Proposition: Cmap building block. This must be understood as a semantic unit formed by *"initial concept + linking phrase + final concept"*.
2. Focal question: ultimate goal to be addressed by the propositional network. This must be understood as the critical element for selecting the most relevant propositions and maintaining Cmap clarity.
3. Revision: dynamic characteristic of any Cmap, which is never finished. It must be stressed that the "right" answer is no longer available; on the contrary, it is continuously pursued.
4. Hierarchy: structural fine-tuning of Cmap. It must be stressed that this helps to organize concepts according to their inclusiveness and make the overall Cmap clear for a reader.

The training period was enhanced with three strategies: half-structured Cmap (HSCmap), expanded collaborative learning (ECL) and the propositional clarity table (PCT). HSCmap was inspired by the cyclic Cmap and the experiments on dynamic thinking described in the literature (Safayeni et al., 2005; Derbentseva et al., 2007). The HSCmap demands summarizing capabilities because it restrains the number of concepts used during the Cmap construction. On the other hand, since the HSCmap does not define the maps structure, the author(s) is (are) free to build concept relationships without restrictions. Figure 3 shows the HSCmap adopted in our training activities. The author(s) can reach any of the following structures: linear, hierarchical tree, hierarchical cross-link and cyclic (we will later show that cyclic structures reveal whether the Cmap has a static or dynamic nature).

Table 1: Description of the four-session activity for training beginners ("X" indicates the work's features developed in each class).

		Where?		**Who?**		**Structural parameters**			
Class #	**Activity description**	**Classroom**	**Home work**	**Individual**	**Collaborative**	**Proposition**	**Focal question**	**Revision**	**Hierarchy**
1	• Presentation of a Cmap to students (model) • Discussion about the proposition structure • Discussion about the role of focal question • Negotiation of the focal question for Cmap#1	X	-	X	-	X	X	-	-
2	• Teacher's feedback of Cmap#1 • Preparatory reading assigned: *"Good and bad reasons for believing" (Dawkins, 2004)* • Selection of key concepts from a text • Classroom discussion • Negotiation of the focal question for Cmap#2 • Cmap#2 revision at home	X	X	X	-	X	X	X	-
3	• Preparatory reading assigned: *"The immovable Earth" (Brody & Brody, 1997)* • Cmap#3a preparation ready for classroom discussion • Classroom discussion • Collaborative and half-structured Cmap#3b for sharing ideas and discussing in pairs	X	X	X	X	X	X	X	X
4	• Preparatory reading assigned *"The cosmic egg" (Brody & Brody, 1997)* • Classroom discussion • Peer review and propositional clarity revision of the Cmap#3b • Expansion of the Cmap#3b from the text ideas (preparation for the discipline exam)	X	-	-	X	X	X	X	X

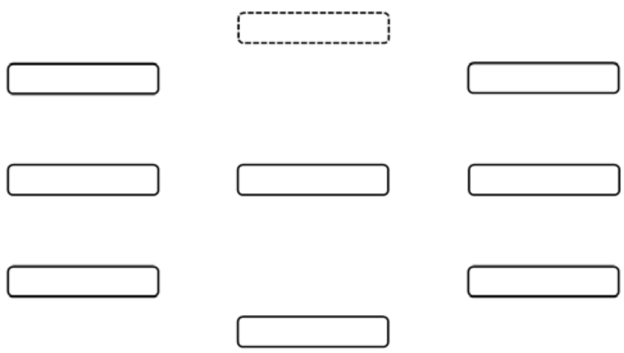


Figure 3. HSCmap with nine concepts used during our training activities. The dashed box highlights the root concept of the HSCmap and the author(s) knows that this is the starting point for the readers.

Expanded collaborative learning (ECL) is characterized by activities that involve the students' peer review of any material collaboratively produced by them. Peer review is rarely explored as a means of changing traditional assessment procedures; the challenge of students' self-evaluation breaks a paradigm in the classroom and reduces the power asymmetry between teacher and students. Furthermore, since students inhabit a relatively consistent zone of proximal development, peer review offers an opportunity for them to share knowledge with each other; this experience is distinct from interactions with the teacher, who is not in the same zone of proximal development (Novak, 2002; Vygotsky, 1978). Peer review expands the collaborative activities developed by small groups of students, and for this reason, we expect ECL to distinctly shift learning experience and outcomes. This activity can increase the students' awareness of their achievements and failures during the Cmap training period. Moreover, ECL is an assessment exercise that offers a safe road towards the self-evaluation that allows mapmakers to continuously revise their Cmaps.

The propositional clarity table (PCT) was designed to reinforce the Cmap structure, which is based on semantic units. The PCT asks the author(s) to do more than read and check the Cmap as a whole, as the author(s) is (are) asked to pay close attention to each proposition in the map network. A 4-column table is prepared and each row contains one proposition from the Cmap. The first three columns allow the description of the elementary components of the propositions (initial concept, linking phrase and final concept), while the last column is for ranking the clarity of each proposition using a Likert-scale approach varying from 1 to 5 (extreme values: 1= low semantic clarity and 5=high semantic clarity).

The combination of the HSCmap, ECL and PCT allow emphasizing the role of the main aspects related to concept mapping throughout the training session (Table 2).

Table 2: Matching the central concepts (proposition, focal question, revision and hierarchy) and the proposed training booster strategies (HSCmap, ECL and PCT). Plus signals indicate the importance of each strategy to deal with the selected central concepts.

	Proposition	Focal question	Revision	Hierarchy
HSCmap	+ +	+ +	+	+ + +
ECL	+	+	+ + +	+
PCT	+ + +	+ +	+ + +	+

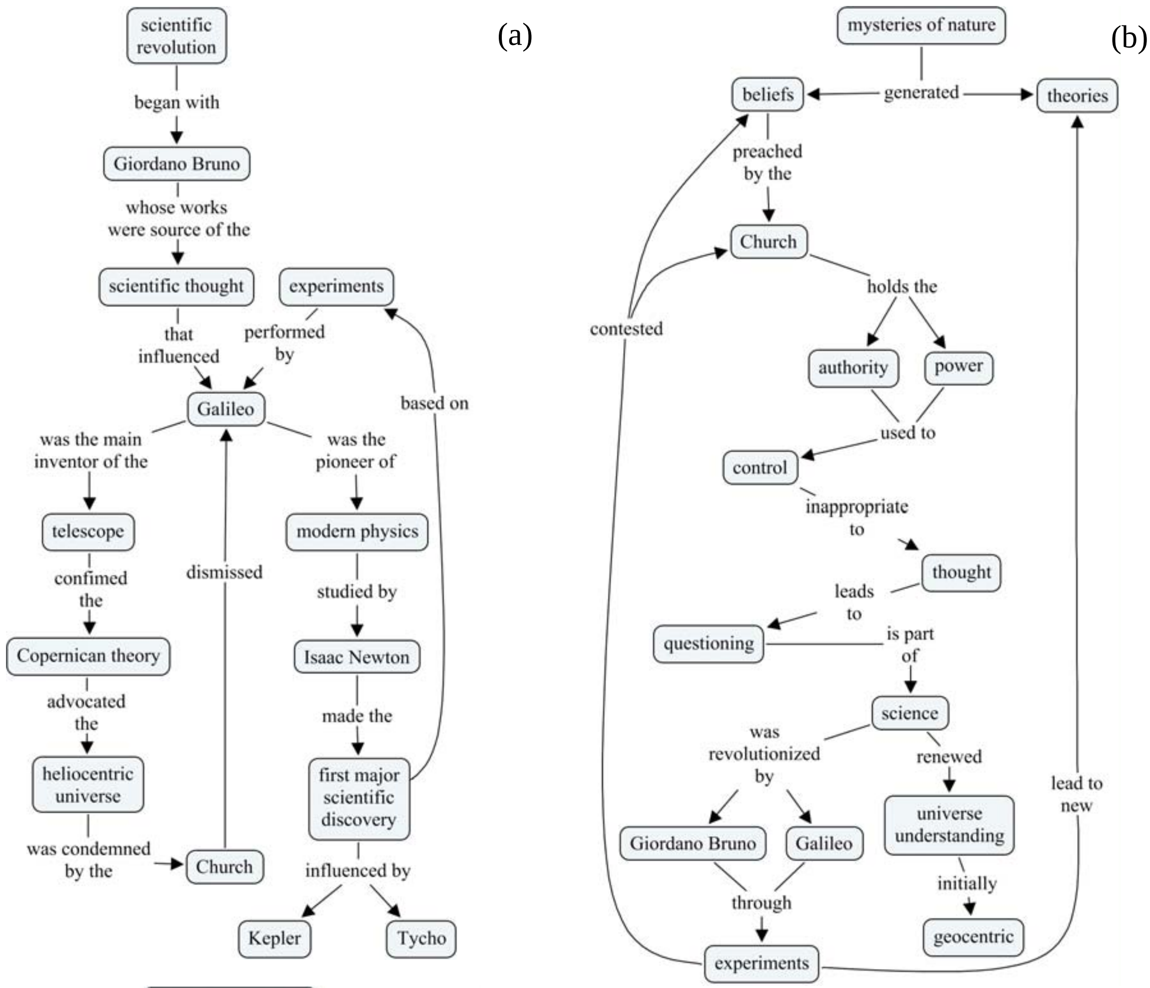
4 Training first-year undergraduate students

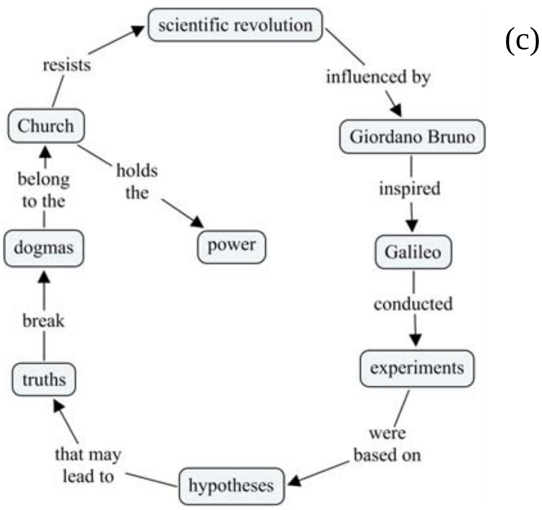
The application of the four-session activity shown in Table 1 occurred during the discipline ACH 0011 Natural Sciences, which is offered for all first-year undergraduate students at Escola de Artes, Ciências e Humanidades (School of Arts, Science and Humanities at São Paulo University). The main goal of this discipline is to provide a broad view of the impact caused by scientific and technological development in our society. Scientific literacy, a new post-industrial demand, is a requisite for an autonomous citizenship. A new contract involving society and science is under negotiation and all citizens must have the right to make their own judgments about ethical aspects of scientific and technological issues (Fourez, 1997; Unesco, 2005). Therefore, scientific literacy needs to be nurtured throughout formal education.

The first part of the 2008 edition of ACH 0011 Natural Sciences discipline was used to apply the devised training sequence for introducing the students to concept mapping and to prepare them for using Cmaps during the final part of the course. The material produced by a three-student group is presented in Figure 4 to support the most relevant findings that were verified throughout the training period. For this reason, our preliminary comments are focused on the activities developed during classes #3 and #4 (Table 1).

Individual Cmaps were prepared by the students after reading the preparatory text entitled "The immovable Earth" (Brody & Brody, 1997), assigned as homework. This text discusses the scientific revolution from a historical perspective and highlights the impact of Galileo's investigative work during the 16th century. This activity prepares students for the classroom discussion, because they can make their idiosyncratic mental models explicit through a visualization tool (Cmaps). Therefore, they can visualize, interpret and revise their own ideas before starting a discussion with their counterparts in the classroom. Figures 4a and 4b show two individual Cmaps, in which authors' idiosyncratic features can be verified. Two different approaches were used to address the proposed focal question (How can we relate the main events that led to scientific revolution?). One student focused on the philosophers who were responsible for this endeavor and used information from the assigned text (Figure 4a). The other student also included information provided by the assigned reading for class #2, entitled "Good and bad reasons for believing" (Dawkins, 2004), which discusses the differences between scientific and religious thinking (Figure 4b). The latter student developed a broader approach, while the former focused on the scientific domain.

These individual Cmaps show beginner fingerprints and both can be improved. There is a big concept (first major scientific discovery) and a conceptual imprecision involving the beginning of the scientific revolution (see the proposition: scientific revolution began with Giordano Bruno) in Figure 4a. The proposition “universe understanding initially geocentric” in Figure 4b presents structural and conceptual problems. On the other hand, it should be stressed that each of these students had previously produced only two Cmaps each. The Cmaps are well organized and present an interesting overall structure. Moreover, these Cmaps prepared the students for the collaborative concept mapping using half-structured Cmap (Figure 4c).





(d)

Initial concept	Linking phrase	Final concept	
scientific revolution	influenced by	Giordano Bruno	4
Giordano Bruno	inspired	Galileo	2
Galileo	conducted	experiments	5
Experiments	were based on	hypotheses	4
Hypotheses	that may lead to	truths	4
Truths	break	dogmas	3
Dogmas	belong to the	Church	3
Church	resists	scientific revolution	5
Church	holds the	power	4

Figure 4. Material produced by a three-student group during the training activity. Individual maps (Cmap#4a) prepared before the classroom discussion during class #3 (Fig 4a and Fig 4b). Collaborative half-structured map (Cmap#4b) prepared after the classroom discussion during class #3 (Fig 4c). Propositional clarity table and students’ evaluation (made during the class #4) using a Likert-scale approach (Fig 4d). Focal question for the presented Cmaps: How can we relate the main events that led to scientific revolution?

After discussing the assigned text in the classroom, the students were organized in groups to prepare a collaborative version of their individual Cmaps. In addition to collaborating between pairs, they must synthesize their ideas because the HSCmap required the use of nine concepts as a challenging boundary condition. The intrapersonal activities required for the collaborative knowledge construction (Figure 2) intensified the group discussion and the result was a clear Cmap (Figure 4c) that offered a direct response to the focal question. The interpersonal elicitation and consensus building developed from the idiosyncratic contributions of prepared participants, confirming the importance of the visualization tools for supporting collaborative knowledge construction. Some groups spontaneously used cyclic structure; this structure usually highlights cause and effect relationships among the concepts. In these cases, students made a more dynamic Cmap than those kept at a descriptive level (static Cmaps).

The fourth class was reserved for revising the collaborative Cmaps. The propositional clarity table (PCT) was used to let the authors check the clarity of each proposition in order to be sure that the Cmap clearly presented the authors' ideas. The PCT for the collaborative Cmap shown in Figure 4c is presented in Figure 4d. The authors ranked each proposition using a Likert-scale approach (extreme values: 1= low semantic clarity and 5= high semantic clarity). The students noted both the importance of revising their Cmaps and the absence of the right answer that is frequently present in the traditional strategies used for evaluation purposes.

5 Summary

This work proposes a response to the re-examination of the foundations for the effective use of Cmaps (Cañas and Novak, 2006). To ensure experience of the rewards of concept mapping, training is critical and intentional activities should be designed for this aim. A four-session activity for training beginners was set up and applied in the higher education context. Half-structured Cmaps (HSCmaps), expanded collaborative learning (ECL) and propositional clarity table (PCT) are innovative approaches that enhance the training period. Their effects on Cmaps may highlight the key structural features of concept mapping (proposition, focal question role, revision and hierarchy) that allow beginners to make acceptable Cmaps in a short period of time (four classes). The training activities may avoid the naive use of concept mapping and take advantage of the theoretical background available in the literature to overcome the difficulties that arise during the process of changing the classroom environment. After this first pilot trial, the authors will keep evaluating the results to refine and adjust the training procedures until 2010. More practical interventions during the ACH 0011 Natural Science discipline are scheduled to 2009, 2010 and 2011.

Despite the preliminary results seem positive, there is room for further investigation into the development of methodological strategies that ensure effective training. Different contexts may require different solutions that can be developed from the triple theoretical foundations discussed here.

6 Acknowledgements

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