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MAKING INTERDISCIPLINARITY VISIBLE USING CONCEPT MAPPING

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Abstract. Interdisciplinarity can be considered an alternative way to reorganize the content taught during courses to recover the loss of meaning caused by the exponential growth of knowledge. Despite its importance, interdisciplinary activities in classrooms are still rare because of difficulties faced by instructors involving curriculum design and teaching method selection. The literature does not present a reliable procedure to help instructors identify possible connections between courses. The aim of this paper is to propose a procedure using Cmaps to make visible the concepts that can foster interdisciplinarity, as well as the productive dialogue involving instructors. The interdisciplinary propositional interface (IPI) highlights the core concepts responsible for merging course content and helping instructors focus attempts to connect their courses. A case study involving the courses Natural Sciences (NS) and Psychology, Education and Contemporary Issues (PECI) is presented. These courses represent the two-culture isolation, considering NS and PECI courses are from the scientific and humanities fields, respectively. Despite a seemingly difficult task, the collaborative efforts involving the instructors confirmed that the conceptual frameworks of courses can be connected. The more promising concepts to overcome the two-culture barriers are “complexity”, “religion”, and “technology”. The concepts and propositions presented in the IPI offer an excellent starting point for instructors to collaborate on concrete actions to promote interdisciplinarity in their classrooms, such as teaching methods and instructional materials. Making interdisciplinarity visible is only part of the way to make our courses more connected. The next step will be to explore the information obtained using Cmaps to make the interdisciplinarity visible to students.

1 The need of interdisciplinarity

The explosion of scientific knowledge and the paradigms of contemporary society have brought new challenges to formal education, which are not adequately addressed using the traditional curricular configuration. The integrated understanding of content from different disciplines is a key aspect that should be considered in higher education to prepare professionals who are capable of dealing with the complex challenges of our contemporary society (Ford & Forman, 2006; Moran, 2010; UNESCO, 2005). Therefore, interdisciplinary approach should be intentionally adopted and curriculum should facilitate an inter-relationship among disciplinary content. Despite its importance, interdisciplinary activities in classrooms are still rare because of difficulties faced by instructors that involve curriculum design and teaching method selection.

Organizing the curriculum into disciplines was a solution to account for the enormous amount of information accumulated by humanity and facilitated and standardized the transmission of expert knowledge. For this reason, disciplines play a critical role in the development and organization of the academic curriculum. Additionally, the fragmentation of knowledge into disciplines is employed to organize and systematize the knowledge necessary to educate students. Despite all attempts to organize a non-disciplinary curriculum, the disciplines are the preferred way to transmit knowledge in formal education (Klein, 1996; Lattuca, 2001; 2002).

In comparison to traditional practices, interdisciplinarity can be considered a response to the exponential growth of knowledge, which assumes the organization of content in terms of contemporary issues that require the articulation of concepts from various fields of knowledge (Klein, 1996; Weingart & Stehr, 2000; Lattuca, 2001). Moreover, interdisciplinarity also fosters innovation and creativity and breaks the paradigm of standardization; thus, better connecting scholarly contexts with new demands of our contemporary society (Sawyer, 2006).

The literature related to the organization of interdisciplinary curricula in higher education reveals a gap that hinders the establishment of links between concepts from different knowledge fields. There is no robust procedure to help instructors identify possible connections between their courses. The experience of our research group with Cmaps indicates that this technique can be used to graphically organize and represent the conceptual content of disciplines to search by interdisciplinary connections. Further, Cmaps can support the meaning negotiation among instructors through collaborative knowledge construction (Crandall, Klein & Hoffman, 2006; Fischer et al., 2002).

2 Concept mapping and collaborative knowledge construction

2.1 Historical development of concept mapping

Concept mapping was developed by Novak and colleagues in 1972 at Cornell University. At that time, Cmaps were used to represent the conceptual network established by students throughout elementary and high school, which resulted in a 12-year longitudinal study of conceptual change in science education (Novak & Musonda, 1991). Audio from taped interviews with students was the primary source of empirical data and because of difficulties in fully transcribing them, Cmaps were used to represent part of student's cognitive structure by organizing concepts into a propositional network. This graphical form of representing the concepts mentioned by students during the interviews allowed the researchers to observe, with detail and accuracy, conceptual changes that occurred over the years (Novak & Musonda, 1991; Novak and Cañas 2006, 2010).

Propositions are the remarkable feature of Cmaps and they are formed by two concepts connected by a linking phrase that states clearly the conceptual relationship. The need to include linking phrases is the main difference of Cmaps compared to other graphical organizers (Novak, 2010). The content of the Cmap is more objective and less idiosyncratic, which facilitates the communication process during collaborative activities (Torres & Marriott, 2009; Moon et al., 2011).

The historical development of Cmaps is represented by a timeline that begins in the 60s (Figure 1). The initial milestone occurred before the birth of Cmaps (1972) when David Ausubel published *Assimilation Theory of Meaningful Learning and Retention* (Ausubel, 2000). Although it is important to use Cmaps appropriately for educational purposes, this theory has been neglected by beginner users who claim the difficulties in getting the promised benefits shown in the literature.

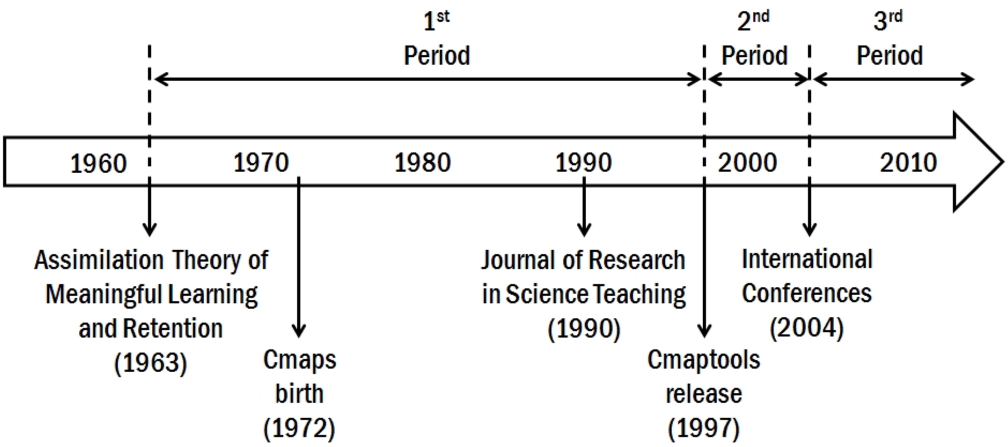

Figure 1. Historical development of the conceptual mapping from the 60s to today.

The first period was characterized by the development of Cmaps (1972) and the widespread use of manuscript Cmaps, especially for science teaching. The difficulty of revising this kind of Cmap hindered the potential of the technique because users had not yet fully explored the recursive revision. Nevertheless, the recognition of concept mapping as a valuable technique to foster conceptual changes throughout formal education was confirmed in 1990 in a publication of a special issue about Cmaps in the *Journal of Research in Science Teaching* (Beyerbach & Smith, 1990; Novak, 1990; Wandersee, 1990).

The release of CmapTools in 1997 was responsible for increasing the use of Cmaps because it made easier to revise and share digital files (.cmap). CmapTools (Cañas et al, 2004) is the result of a collaboration between Joseph Novak and Alberto Cañas and has been developed by the Institute for Human and Machine Cognition (IHMC). The increase in Internet access and the possibility to use this free software toolkit (downloadable at http://cmap.ihmc.us/download/) burgeoned the use of Cmaps for purposes that go beyond educational interests. In addition to the opportunity to review digital Cmaps, as easily as we can edit text using word processing software, synchronous and asynchronous collaboration has become a reality. Today, conceptual mapping is also used in corporations for information and knowledge management (Moon et al., 2011), expanding collaborative and lifelong learning to contexts that extrapolate formal education (Visser & Visser-Valfrey, 2008).

International conferences on concept mapping have occurred every two years since 2004. Researchers, instructors, and practitioners interested in Cmaps gather at these meetings to consolidate advances in the use of this graphical organizer, which confirm the universality and ubiquitousness of Cmaps (Novak & Cañas, 2010). This is the context, the latest research on concept mapping is discussed (Almeida & Moreira, 2008; Cicuto & Correia, 2012; Correia, 2012; Correia, da Silva & Romano Jr., 2010; Correia et al., 2010; Derbentseva, Safayeni & Cañas, 2007; Hay, Kinchin & Lygo-Baker, 2008; Hay, Wells & Kinchin, 2008; Hilbert & Renkl, 2008; Karpicke & Blunt, 2011; Kinchin, Hay & Adams, 2000; Kinchin, Lygo-Baker & Hay, 2008; Nesbit & Adesope, 2006, 2011; Novak, 2002, 2005; Romano Jr. & Correia, 2010; Safayeni, Derbentseva & Cañas, 2005; Yin et al., 2005).

2.2 *Collaborative concept mapping aiming knowledge construction*

The process of collaborative knowledge construction (CKC) can be understood as a succession of three steps (Fischer et al., 2002). Externalization and elicitation of task-relevant knowledge precedes consensus building, which can be achieved by conflict or integration of ideas (Table 1).

Table 1: Main steps for describing the collaborative knowledge construction and the role of concept mapping to externalize, elicit and build consensus.

Step	Itemized description	Concept mapping	
		Individual	Collaborative
1	Externalization of task-relevant knowledge	Yes	No
	• *Individuals bring individual prior knowledge into the situation* • *Different points of view can be clarified* • *Exchange of individual concepts is the starting point for negotiating common meaning* • *Diagnosis and resolution of misconceptions can take place*		
2	Elicitation of task-relevant knowledge	Yes	Yes
	• *Learning partners express their knowledge related to the task* • *Elicitation occurs frequently in the form of questions, which leads to externalizations in the form of explanations* • *Elicitation could be partly responsible for successful learning*		
3(a)	Conflict-oriented consensus building	No	Yes
	• *Individuals seek a common solution or assessment of the given facts* • *Conflict plays an important role in reaching consensus* • *Different interpretations made by learning partners can led to a modification of knowledge structure*		
3(b)	Integration-oriented consensus building	No	Yes
	• *Consensus can be reached through the integration of various individual perspectives into a common interpretation or solution for the given task* • *Superficial conflict-avoiding cooperation style may be used in this attempt to incorporate individual views in a common perspective* • *There is a tendency on the part of the learners to reach an illusionary consensus*		

Visualization tools can foster CKC. Among other options, Cmaps appear as powerful visualization tools to represent knowledge. They are useful for making idiosyncratic mental models explicit for revising (intrapersonal activity with individual Cmaps) and sharing ideas (interpersonal activity with collaborative Cmaps). Both purposes are important during CKC because all participants can visualize, interpret, and organize their own ideas (intrapersonal) before engaging in conflict-oriented or integration-oriented consensus building (interpersonal). Moreover, collaborative concept mapping can also support discursive meaning mediation and conflict negotiation, even when on-line tools are used.

Elicitation of expert knowledge is a critical issue that can be addressed using Cmaps and naturalistic studies (Crandall, Klein &Hoffman, 2006). This is a sophisticated use of concept mapping and its success depends on the skills of the interviewer (mapper facilitator) to organize and clarify the specialized knowledge by posing questions during a half-structured interview. The dialogue among instructors who aim to find interdisciplinary connections among their courses fits into this description. Therefore, concept mapping can be explored to make interdisciplinarity visible.

3 Research goals

This paper proposes a procedure using Cmaps to increase visibility of concepts that foster interdisciplinary curriculum. A case study involving the courses Natural Sciences (NS) and Psychology, Education and Contemporary Issues (PECI) is presented.

4 Procedures to increase visibility of interdisciplinarity

4.1 Preparation and revision of Cmaps before collaborative knowledge construction (CKC)

One Cmap was created to represent the conceptual framework of each course considered (NS and PECI). Table 2 shows the 4-step procedure followed to revise the Cmaps, which must be carried out before the CKC.

Table 2: Procedure to prepare and revise Cmaps.

Step	Main goal	Description	Cmap ID
1	*Student's point of view about the course*	*An undergraduate student who knows how to prepare a Cmap (G.B.C.) checks his or her notes about the course. His or her perspective drives the creation of the Cmap (draft version).*	Cmap-1
2	*Semantic clarity revision*	*Cmap-1 is revised during a meeting (90-120 min) between the student (G.B.C.) and an expert on concept mapping (P.R.M.C.). The goal is to check the semantic clarity of each proposition through a dynamic involving questions and answers.*	Cmap-2
3	*Instructor's point of view about the course*	*Cmap-2 is discussed with the course instructor during a half-structured interview (40-60 min) with the undergraduate student (G.B.C.). The goal is to include the instructor's point of view through exclusion, inclusion, and modification of concepts and propositions.*	Cmap-3
4	*Semantic clarity, hierarchy and level of detail revision*	*Cmap-3 is revised during a meeting (90-120 min) between the student (G.B.C.) and an expert on concept mapping (P.R.M.C.). The goal is to check the propositional network considering its semantic clarity, conceptual hierarchy, and level of detail (number of concepts used to describe each course).*	Cmap-4

Steps 1-4 are critical to identify interdisciplinary connections between courses. In this case study, one Cmap-4 was obtained for each course (NS and PECI). All meetings and half-structured interviews were audio recorded.

4.2 CKC and the search for interdisciplinarity

Figure 1 shows the role of preparation and revision steps (Table 1) to the CKC; a final meeting (180-240 min) involving the student (G.B.C.), the expert in concept mapping (P.R.M.C.), and the course instructors is conducted. The goal is to merge the Cmap-4 of each course by connecting the concepts from them through a dynamic involving questions and answers.

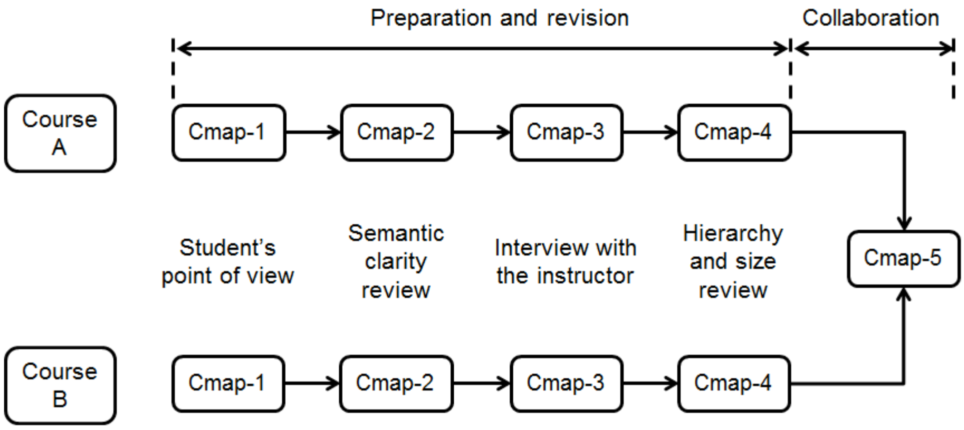

Figure 1. Mapping the conceptual framework of courses to search for interdisciplinarity connections. The CKC aims to produce Cmap-5 after the preparation and revision steps.

Cmap-5 is the most promising representation of prospective interdisciplinary connections. The interdisciplinary propositional interface (IPI) is a new concept proposed in this paper (Figure 2). Specifically, IPI highlights the core concepts that are responsible for merging courses content and helping instructors focus the attempts of interdisciplinary connections.

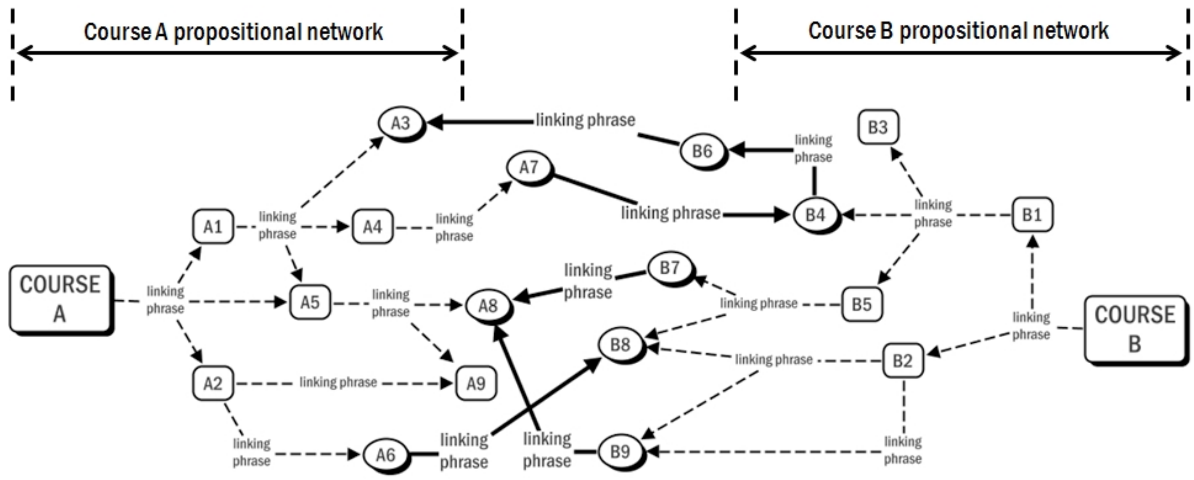

Figure 2. Schematic representation of the interdisciplinary propositional interface (IPI), which can be identified in Cmap-5. The IPI contains the core concepts (shadowed circles linked with thicker lines) from each course that is responsible for prospective interdisciplinary connections. Concepts A and B describe the conceptual framework of courses A and B, respectively.

5 Prospective interdisciplinary connections between the two cultures

C. P. Snow's (1998) thoughts about the British educational system were first revealed in the 60s; however, they are still recalled because they highlight the barriers that isolate scientists and literary intellectuals from each other. The desire to pursue interdisciplinarity can be understood as a movement to bring together these two cultures. The courses chosen for this case study represent this two-culture isolation; considering the Natural Sciences (NS) course and the Psychology, Education and Contemporary Issue (PECI) course are from the scientific and humanity academic cultures, respectively.

Figure 3 shows the Cmap-5 obtained after following the procedures described in the previous section. Despite seeming a difficult task, the discussion during the CKC confirmed that the conceptual frameworks of these courses can be connected. The more promising concepts to overcome the two-culture barrier are "complexity", "religion", and "technology", as shown in the IPI (see shadowed circles and the thicker lines in Figure 3). This insight was the most important result after a 3-hour discussion among the student (G.B.C.), the instructors, and the expert on concept mapping (P.R.M.C.).

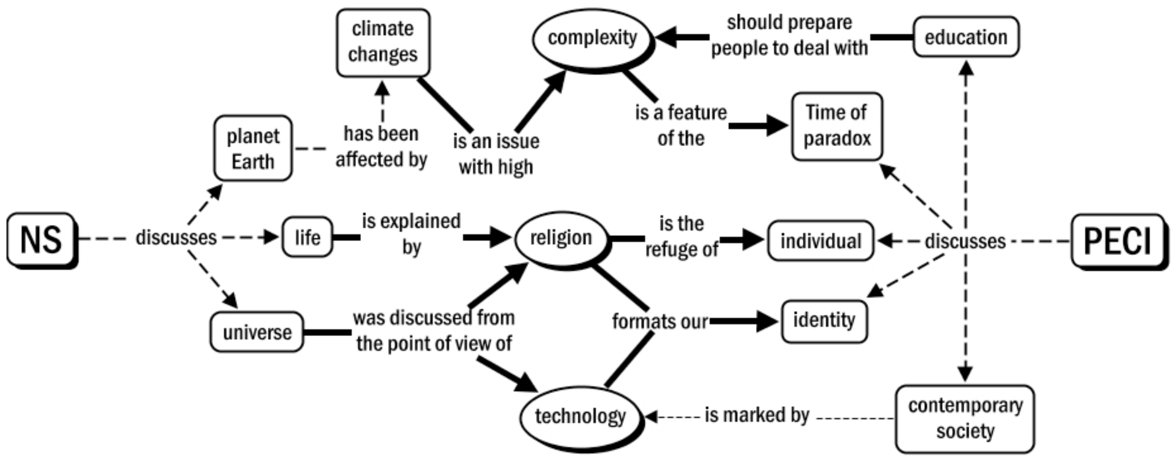

Figure 3. Cmap-5 obtained for our case study, involving two courses that express the apparent isolation of the two cultures. The interdisciplinary propositional interface (IPI) shows that "complexity", "religion", and "technology" (shadowed circles) are promising concepts to prospective interdisciplinary connections. Instructors can visualize interdisciplinarity in this Cmap and start a discussion about teaching methods and conceptual approaches to let students visualize these connections in the classroom.

Latent information that was not considered by the instructor was made visible by using concept mapping as a graphical organizer to manage knowledge and information. The concepts and propositions presented in the IPI offer an excellent starting point to instructors think about concrete actions in terms of teaching methods and instructional materials. Making interdisciplinarity visible is just part of the way to better connect courses. The next step is to explore the information obtained using Cmaps to make the interdisciplinarity in the classroom visible to the students. The ultimate goal is to let students note the relevance of connecting disciplinary knowledge to understand the high-complexity problems of the 21st century. We agree with the literature that suggests the interdisciplinary approach can encourage students to choose meaningful rather than rote learning (Lattuca, Voigt & Fath, 2004).

6 Summary

The summary of this paper is presented using a Cmap (Figure 4).

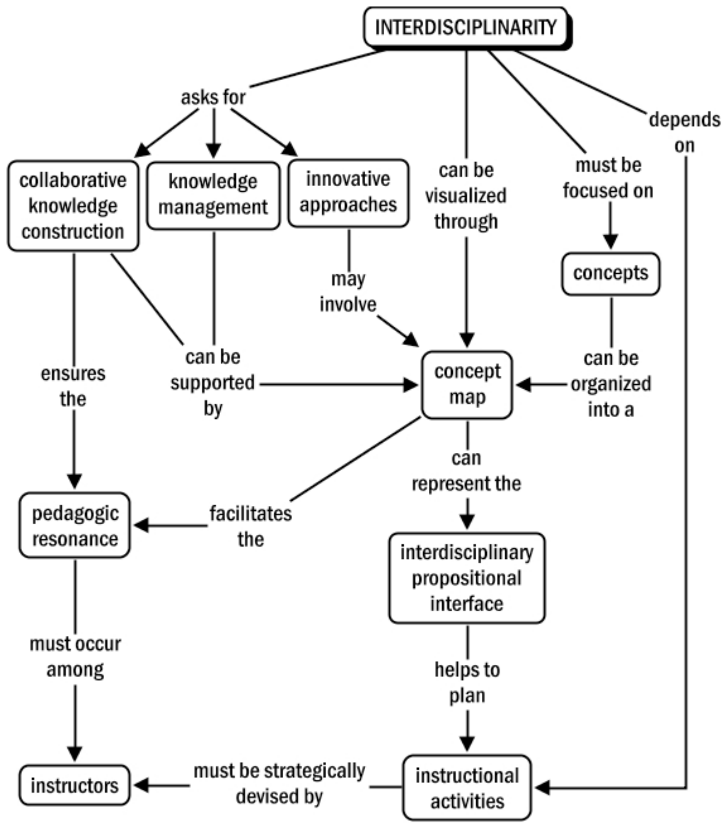

Figure 4. Cmap to summarize this study. Focal question: What are the key ideas related to our study? The root concept is highlighted in a shadowed box and serves at starting point to read the propositional network.

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