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CONCEPT MAPS AS TOOLS FOR SCIENTIFIC RESEARCH IN MICROBIOLOGY: A CASE STUDY

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Abstract. In scientific research there is often the need to increase the organization of data and to optimize communication of results either in a conference or as a scientific article. Researchers should be able to externalize their critical thinking, their problem solving skills and their ability to interconnect knowledge. Concept maps are pedagogical tools that help researchers to structure their practical ideas and results in useful ways. Concept mapping were used extensively to communicate and clarify ideas, help researchers see the relationships and the organization among concepts, solve problems, and support the design of their work. In this study, concept maps were used as a research tool by a team of research scientists. Our intent is to provide a rationale and explain the practical approach underlying our use of concept maps. A distinctive aspect of our use of maps is that rather than being only a tool for clarifying the ideas and results obtained, concept maps are tools that researchers can use to support their diary work. A case study is described using three different projects: the first approach concerns the use of concept maps to analyse and review a scientific article, the second is the use of concept maps to design a scientific work and the third one is the use of concept maps in protocols or detailed methods section for laboratory work.

1 Introduction

In accordance with the constructivist learning theory, learning is a process that consists not only in memorizing new facts but also by the assimilation of information into pre-existing framework of knowledge (Ausubel et al., 1978). It is therefore of utmost importance the use of powerful meta-cognitive learning tools that enable the construction of structural representations of knowledge. Researchers are supposed to be lifelong independent active learners and problem solvers (Dolmans & Schmidt, 1995) that can successfully analyze data and carry out comprehensive planning and delivery (Novak & Gowin, 1984; Baugh & Mellott, 1998; Schuster, 2000). Scientists are experts that should be considered for their richer knowledge structures, considering not only the relevant declarative information stored, but also the interconnections between knowledge. It is therefore important for science research to use concept mapping as a learning aid and evaluation tool of science work (Ruiz-Primo & Shevelson, 1996; Iuli & Helldén, 2004). Concept mapping is a tool that can promote problem solving and critical thinking (Dabbagh, 2001), thus enabling researchers to organize complex data, to process complex relationships and to measure important aspects of the researcher evolving skills. To create a map a researcher cannot rely only on fragments facts of the work but must have a general view of the entire situation, which requires logical, unambiguous and orderly presented data (Wilkes et al., 1999). Moreover, a researcher needs to construct correct and logically connected explanations of previous described concepts in a specific domain (Ellis et al., 2004). Meta-cognitive tools may be therefore useful not only to construct knowledge based on the enhanced understanding of the experimental events but also to externalize knowledge and thinking processes (McAleese, 1998; Sánchez-Quevedo et al., 2006). These processes will increase communication between individuals and teams allowing knowledge preservation in large complex domains. However, there are few studies in the microbiology and infectious disease domain literature (Fonseca et al., 2004) about the use of concept maps to analyze and review scientific articles, to design experimental work, and elaborate detailed protocols for diary laboratory work. As such, the purpose of this study was to present the case study of a research team that uses concept mapping as a tool for science research using three different projects as examples.

2 Procedure

This work reports the experience of a team of researchers that have used concept mapping since 1998 until present. Our team has developed a number of methods and processes that were useful in helping to formulate research projects and help the members of the team to initiate the use of concept maps as tools for scientific research. One PhD thesis (2007), two master thesis (1999 and 2006), two final graduation projects (2003 and 2005) and ten scientific articles (1998-2008) have been designed and prepared using concept maps. We used three different projects to describe our case study; one of the scientific articles of the PhD thesis and one section of the same thesis were used as representatives (Fonseca & Sousa, 2007; Fonseca, 2007). All the concept maps presented were constructed using the SmartDraw software (version 6.0).

Works	Author	Year	Domain
PhD Thesis	Fonseca AP	2007	Human Biology
Master Thesis	Fonseca AP	1999	Biomedical Engineering
	Extremina CI	2006	
Final Graduation Project	Extremina CI, Costa G	2003	Medical Microbiology
	Bento M, Martins M	2005	
			Journal or Book
Scientific article	Fonseca AP, Extremina CI	2008	*To be submitted*
	Fonseca AP, Granja PL, Nogueira JA, Oliveira DR, Barbosa MA	2001	J Mat Sci: Mat Med
	Fonseca AP, Extremina C, Fonseca AF, Sousa JC	2004	J Med Microbiol
	Fonseca AP, Sousa JC, Tenreiro R	2006	Rec Res Develop Microbiol
	Fonseca AP, Sousa JC	2007	J Applied Microbiol
	Fonseca AP, Sousa JC	2007	Int J Antimicrob Agents
	Fonseca AP, Correia P, Sousa JC, Tenreiro R	2007	FEMS Immunol Med Microbiol
	Fonseca AP, Correia P, Extremina CI, Sousa JC, Tenreiro R, Barros H	2008	*Under revision*
	Extremina CI, Fonseca AF, Granja PL, Fonseca AP	2008	*Submitted*
	Fonseca AP, Extremina CI	2008	*Submitted*

Table 1: Scientific works that have been designed using concept maps

2.1 Analysis of a scientific article

In scientific research the work is usually published in scientific journals, which have instructions for authors that they have to fulfill. In literature review and in the preparation of articles is important the analysis of published literature in various different journals with different instructions. It may seem that analyzing many articles using concept mapping as a tool it is time consuming, but the mapping process of a few indispensable articles allow to identify important theories and concepts (Kinchin, 2005a,b). One way to organize, clarify and unify the ideas is to transform the important sections of an article in concept maps.

The first project to be described was the analysis of an article published in 2007 in Journal of Applied Microbiology entitled: Effect of antibiotic-induced morphological changes on surface properties, motility and adhesion of nosocomial *Pseudomonas aeruginosa* strains under different physiological states (Fonseca & Sousa, 2007). Three different maps of each section were constructed: introduction, materials and methods and conclusions. According to classification of cognitive structures (Kinchin et al, 2000; Hay & Kinchin, 2006) Figure 1 represents a network, which is an indicative of a deep learning.

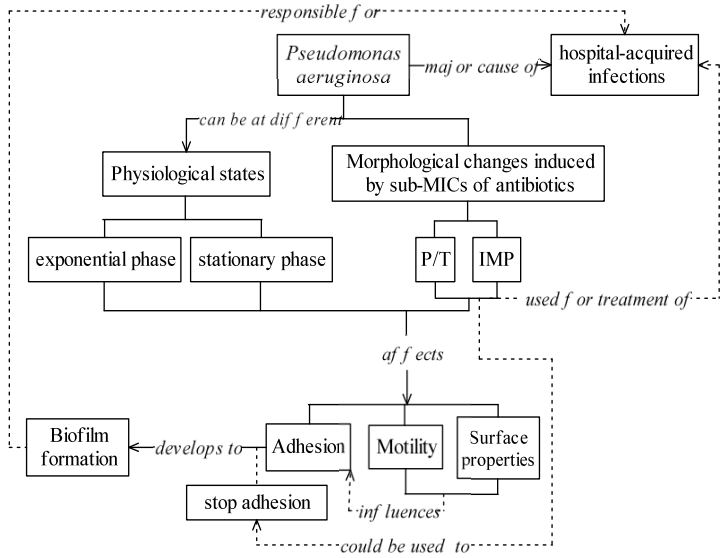

Figure 1. A concept map from the Introduction section (Fonseca & Sousa, 2007).

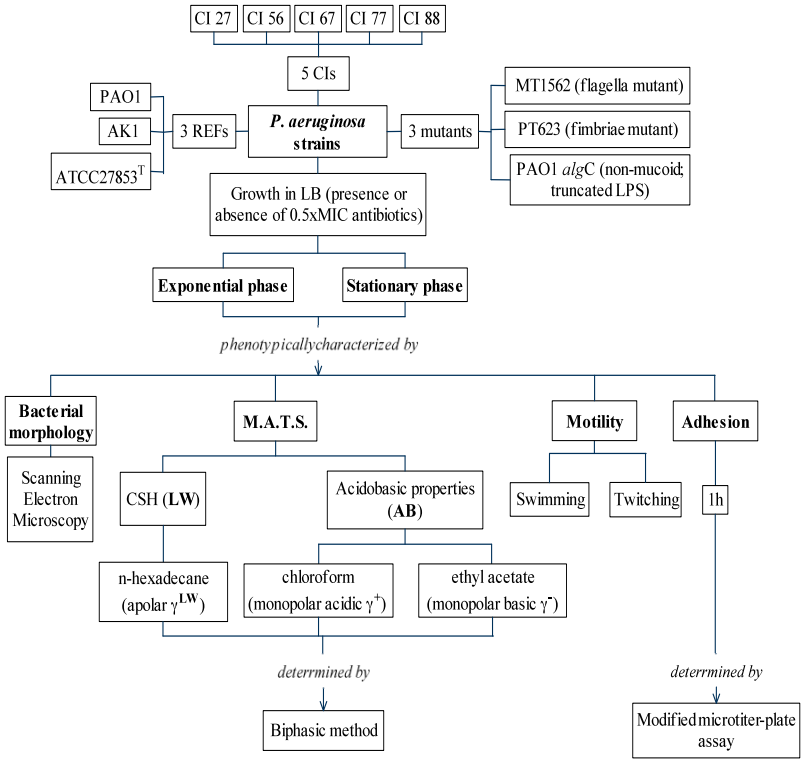

Figure 2. A concept map from the Materials and Methods section (Fonseca & Sousa, 2007).

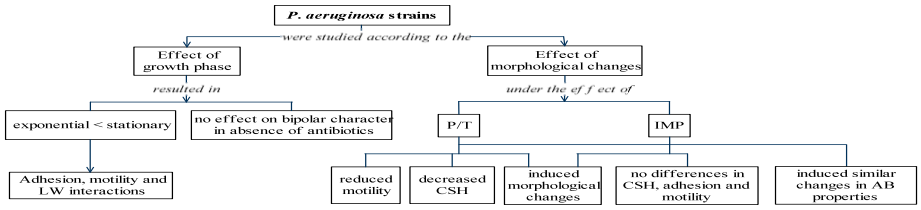

Figure 3. A concept map from the conclusions (Fonseca & Sousa, 2007).

2.2 Design of a scientific work/project

To prepare a scientific work/project it is necessary to organize all the objectives and ideas in a practical and useful way. Our main objectives in this project were to present an example showing how concept mapping can promote higher integration and organization of knowledge during the various stages of the project design. In fact, concept maps can be used to structure a scientific work while constructing it, thus helping to clarify the sequence of an argument. Moreover, these maps can summarize sections of the work and highlight connections being therefore useful for novice team members or by others to increase scientific output (Kinchin, 2005b).

The Aims from the PhD thesis (Fonseca, 2007) used by the research team are exemplified in Figure 4 using concept mapping as a tool. This concept map was constructed in order to work as an advance organizer, which "activates appropriate cognitive structures" and guides the researcher while analyzing the entire work within a context (Kinchin, 2005b).

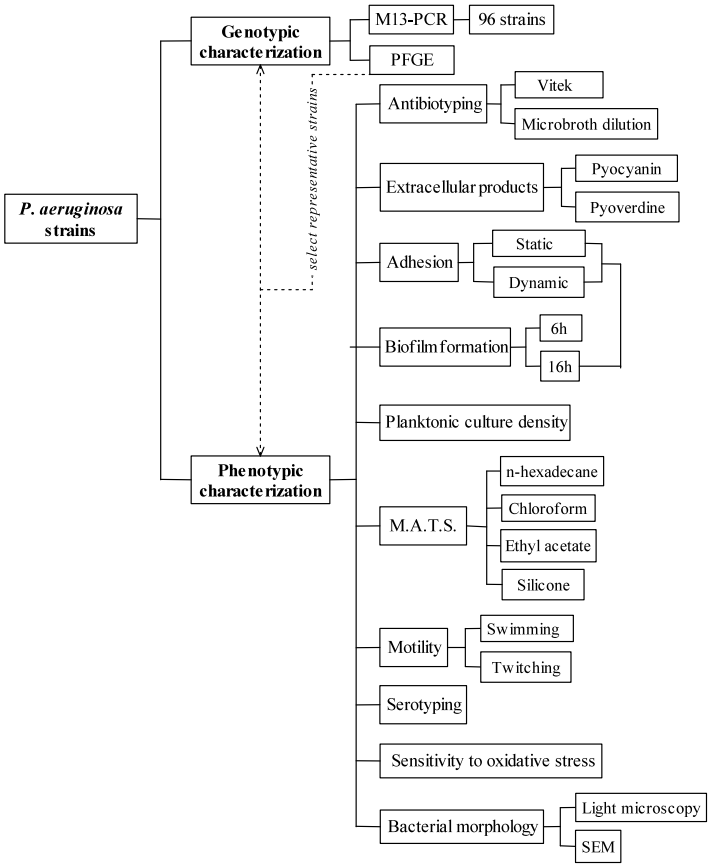

Figure 4. Concept map for the Aims of a scientific work (Adapted from Fonseca, 2007).

2.3 Construction of a protocol for laboratory work

In diary work on laboratories it is crucial to have the protocols organized and available to follow step by step all the procedures. When the researchers are working and at the same time have to look to the procedures it is difficult to follow up the steps of a protocol in Word or pdf format. The link between the writing process and the concept maps is critical because it is necessary to share all the information with others who are not concept map users. The level of detail of the concept map compared with the writing process is dependent of the experience and knowledge of the researcher. The greater the researchers experience in concept map construction the greater the level of detail.

In this project the protocols were constructed as concept maps which made them more useful as an individual tool or for sharing with others. It is presented one of the examples in Figure 5, which is composed of a series of chains that indicate goal-orientation, as can be expected in an experimental protocol (Kinchin et al, 2000; Hay & Kinchin, 2006).

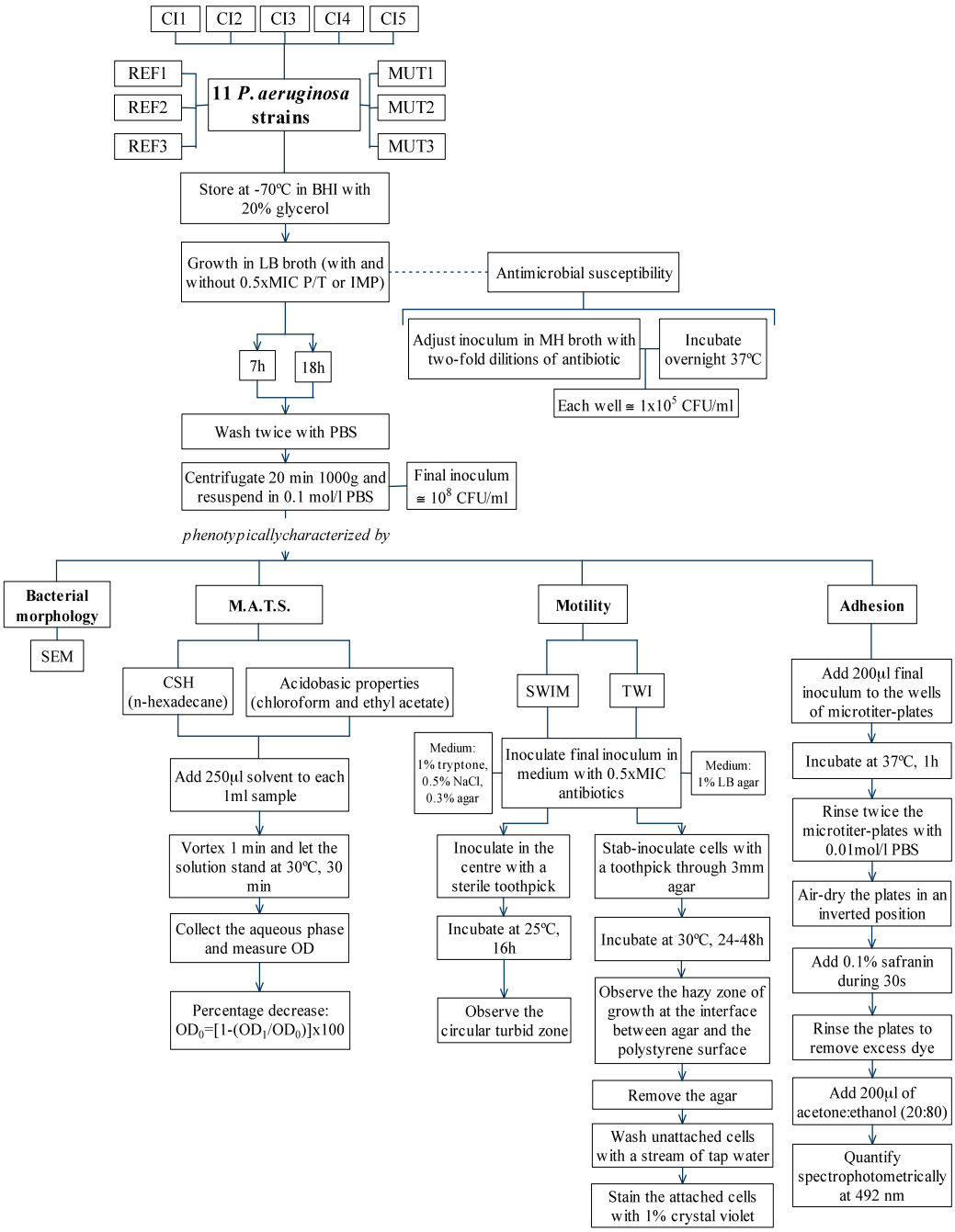

Figure 5. Protocol as a concept map for laboratory work.

3 Summary

This article reports a case study describing three projects involving the use of concept maps to clarify, organize and integrate ideas and information in a specific scientific research domain. Our research team concluded that concept mapping provides a useful way to share knowledge and information and to see connections in different works/projects and scientific articles. Concept maps that result from the analysis of a scientific article, the design of a project or from a construction of a protocol are useful tools for communication and share of knowledge between individuals and the research team. These meta-cognitive tools can facilitate knowledge understanding, retrieval and application promoting therefore the increase in scientific output for all the team members and the optimization of the presentation skills by new research team members.

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