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COGNITIVE MAPS FROM INTERVIEWS AS A PROCEDURE TO ANALYSE SCIENCE TEACHERS' CONCEPTIONS OF THE NATURE OF SCIENCE

Maria Luisa Bermejo, Teodoro González & Vicente Mellado
Faculty of Education. University of Extremadura,. Badajoz, Spain

Abstract: In this paper we describe the use of cognitive maps from interviews as analytical procedures of a secondary preservice science teacher's conceptions of the nature of science.

The philosophy of science has for many years been absent both from science curricula and from science teacher education (Mellado, 1998b). One of the causes of the failure of many science teaching courses and programs lies in the ambiguity of their philosophical standpoints, which generally leads to implicit assumption of immature and uncontrolled conceptions about the nature of science. From a constructivist perspective (Hewson & Hewson, 1989), the study of science teachers' conceptions thus gains a particular importance as a first step to generating more suitable conceptions and practices in the teachers themselves. Lederman and O'Malley (1990) argue for qualitative research methods and consider that questionnaires give oversimplified results which do not correspond to the richer orientations manifest in interviews.

We used cognitive maps in an investigation of a secondary preservice science teachers at the end of their education at the University of Extremadura (Spain) during the 1992-93 academic year (Mellado, 1996, 1997, 1998). En this paper we describe the use of cognitive maps from interviews as analytical procedures of a preservice science teacher's conceptions. The preservice teacher analysed, who we shall call David, is a Physics graduate who was doing a brief postgraduate pedagogical course dealing with psychopedagogy and science teaching methods, and a short period of teaching practice in secondary education centres.

In the 273-question interview, a preservice secondary teacher was asked about academic background, the nature of science, the science teaching profession, and science teaching/learning. This interview was taped and transcribed. The preservice teacher participant was then able to review and reflect on his own interview.

Conceptual maps were developed by Novak and col. (Novak & Gowin, 1988; Novak, Gowin & Johansen, 1983) to represent scientific concepts graphically. They have been extensively used and convalidated in representing students' knowledge of all subjects at different levels, in designing instructional units and curricular material, in problem solving, as a study technique for students, and to generate attitudes (González, Morón & Novak, 2001). Conceptual maps have also been used in research on science teachers (Mellado *et al*., 2002). Novak & Gowin (1988) also used cognitive maps to analyse student's interviews. Cognitive maps from interviews as analytical procedures of a preservice science teacher's conceptions relate, in a partially hierarchical manner, units of information in a broader sense than the concepts used in conceptual maps. A cognitive map presents an overall and unfragmented picture of a teacher's beliefs.

In a qualitative investigation, the process of analyzing the data is related simultaneously to its collection, reduction, and representation (Miles & Huberman, 1984). To construct David's cognitive maps from the interview, each phrase implying a unit of information was coded, followed by classification into six categories: (a) academic history, (b) the science teacher (the profession, professional knowledge, and teacher education), (c) the nature of scientific knowledge, (d) the school science curriculum, (e) the learning of science, and (f) the teaching of science (planning, organization of the class, classroom instructional tasks, resources, and assessment). Then the information units of each category or subcategory were related graphically forming the cognitive map. For example, question no. 58 given to David was classified into five information units:

> (The had previously been asked if there were rational criteria to decide whether a theory could be considered scientific...)
> Question David-58: Are the criteria universal and objective or do they depend on other factors?
> Response D-58: [There are extrascientific factors which lead to one theory being accepted and another not.]$^{58.1}$ [For instance, the heliocentric theory was not accepted for such a long time because of factors that had nothing to do with science.]$^{58.2}$ [Just the same, it ends up being accepted if it really is good.]$^{58.3}$ [For example, what we were saying before about the theory of relativity which was a long time in being accepted because of a small matter of tradition. Because it meant dumping what there had been before and that is pretty hard.]$^{58.4}$ [It is not a strictly scientific criterion.]$^{58.5}$

The numbers in cognitive maps correspond to the codes assigned to each response in the interview. The cognitive maps were drawn up by the researcher, although later they were analyzed and checked by David. In the following we shall summarize the most relevant results on David's conceptions of the nature of science, including some responses to the interviews.

David considered that scientific theories only reflect our knowledge of reality, not reality itself (figure 1). Although the fundamental is experimental proof, he believed that the progress of scientific knowledge is a complex process arrived at by an interaction between thought and reality, and in which extrascientific factors also intervene:

"There are extrascientific factors which lead to one theory being accepted and another not" (D-58.1).

For David, theories change when a crucial experiment is found to fail, i.e., as claimed by Popper (1983), theories are not tested by verification but by falsification (figure 2):

"A theory is true until they show us it is a lie. Until there is an experimental fact which does not fit in with yours" (D-66.2). "Some experiments are crucial " (D-68.1).

David also showed features of Lakatos's (1978) methodology in defending the idea that theories are reformulated by confrontation with each other. And, lastly, he believed that theories are replaced by others that solve more problems, as indicated by Laudan (1977).

David considered experimental proof to be basic, and would keep the theories which solve more problems and are more elegant and more general. In any case, he came down in favour of the principle of parsimony (expressed by William of Occam in the 14th century as "It is vain to do with more what can be done with fewer") to choose the simplest theories from amongst those that fulfill the required conditions.

"When one has two confronting theories, I would stay with the one which solves most problems" (D-62).
"Of two theories which have experimental validity, one chooses the one with simplest arguments" (D-57.1).
"As global a theory as possible" (D-93.1).

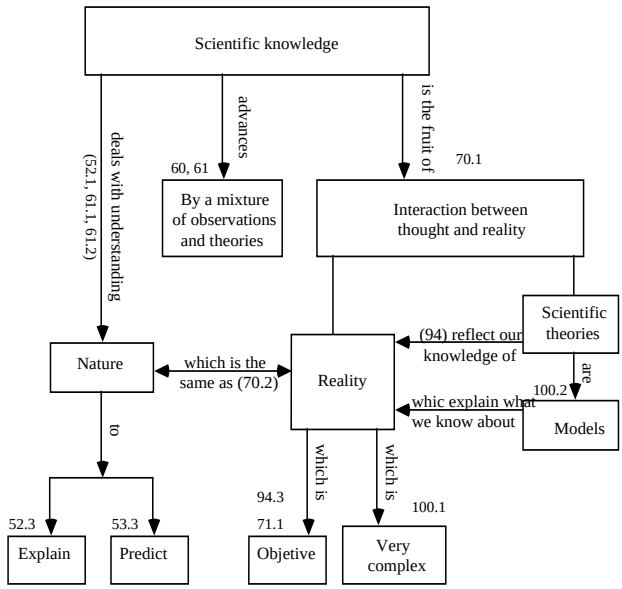

Figure 1. *David's cognitive map on scientific theories*

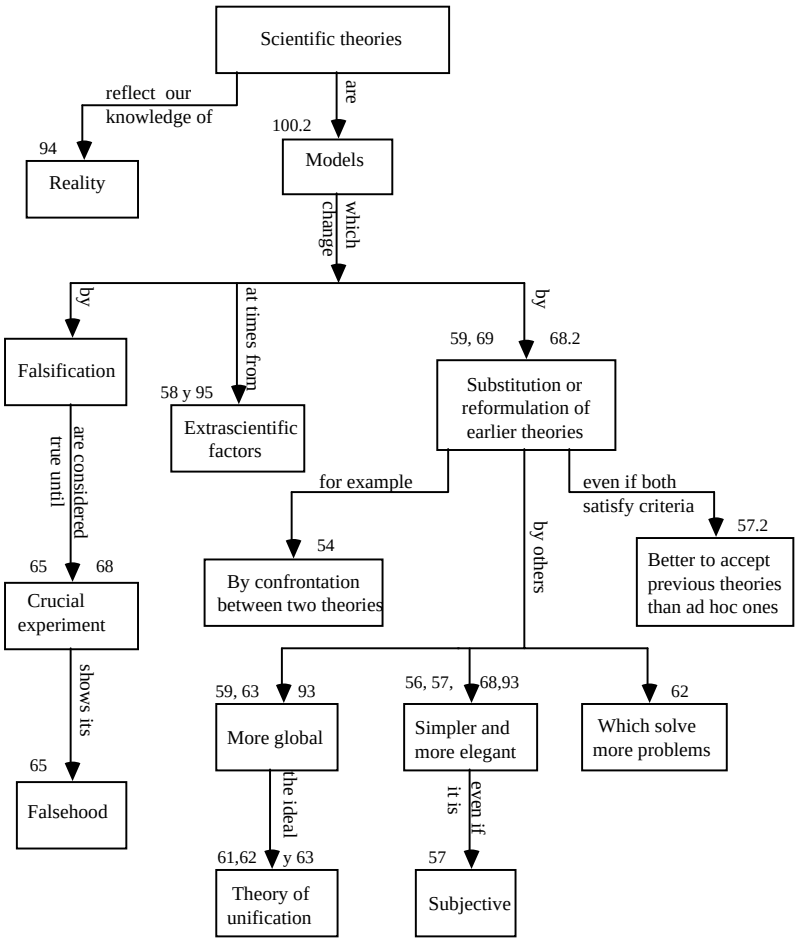

Figure 2. *David's cognitive map on scientific change.*

David showed marked contradictions between an empirical verificationalist scientific philosophy and other more constructivist methodologies in which previous ideas and theories condition observation (figure 3). He himself recognized that he had hardly reflected at all before then on the nature of science:

"These are things which, despite having done a degree in science, I had never set myself to consider" (D-79.3).

In general, he showed himself to be more on the side of the empiricist scientific method which begins with observation, and in which the role of experiment is one of testing (O-H-E-T: Observation - Hypothesis - Experiment - Theories).

"I believe that one begins by observing" (D-75.3). "There is previous observation" (D-78.1). "I believe that observation is the first thing" (D-79.1).
"The role of experimentation is, above all, testing" (D-92).

Although he recognized he had doubts about this methodology:

"You are making me wonder whether there is always observation or not! Let's say that the most traditional method is to start by observing, formulating hypotheses, experimenting, and giving results" (D-76).

At other times he expressed his disagreement with the ingenuous inductivist method:

"The researcher is conditioned by previous theories" (D-86.1).
"I think that the researcher's previous ideas condition observation" (D-88).

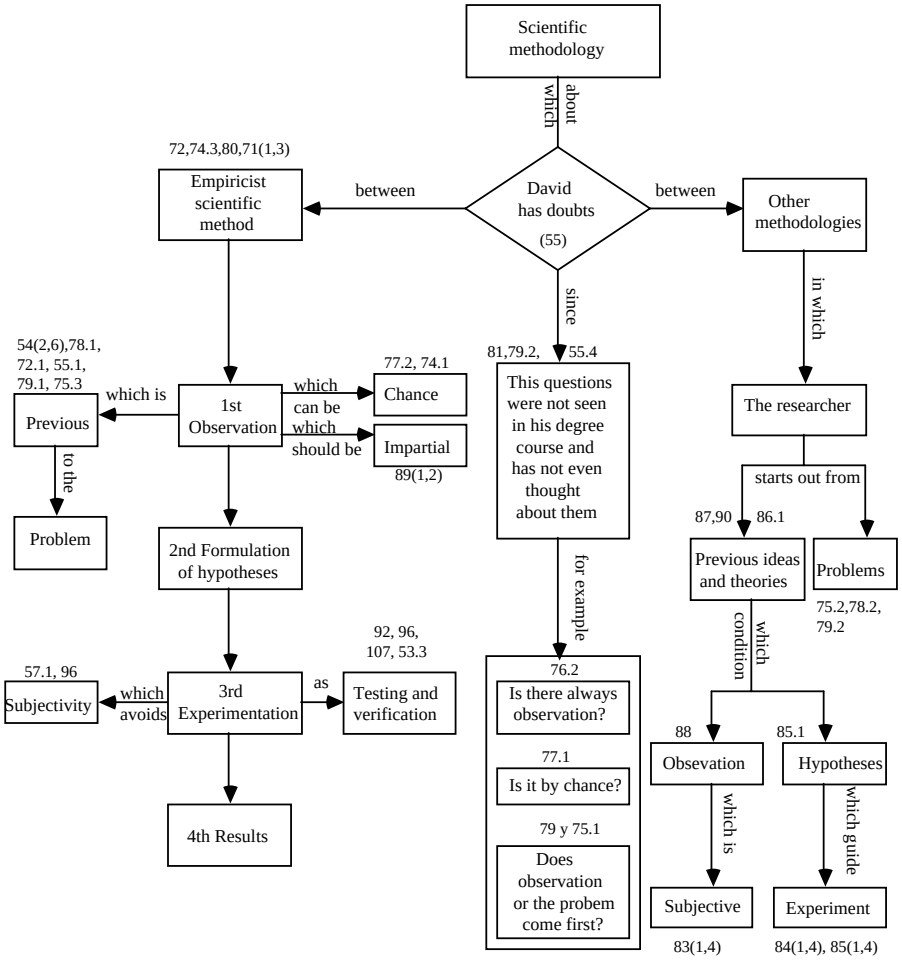

Figure 3. David's cognitive map on scientific methodology.

1 Conclusions

Firstly, we would say that cognitive maps from interviews are a good analytical procedure for a preservice science teachers' conceptions. The research project participation itself has made David reflect on and evaluate many of his conceptions. In this sense, cognitive maps are a tool for pedagogical intervention and a first step to generating more suitable conceptions and practices in teachers.

Secondly, our investigation showed a more complex panorama than earlier studies which assigned positivist empirical conceptions of the nature of science to science teachers. A lack of previous reflection on the nature of scientific knowledge was detected, and he recognized not having dealt before with aspects of the philosophy of science. This lack of reflection led him to fall into clichés and contradictions in their ideas. David did not have a conception of scientific knowledge which was coherent in all its aspects. Rather than a single conception we should refer to dominant tendencies or orientations.

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