INTRODUCTION

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Since the middle of the 1970s research has shown that students have intuitive or naïve ideas about scientific phenomena, which have been labelled "misconceptions" in the literature. Since then, many efforts have focused on changing these ideas in ways that can lead students to a correct understanding of science concepts.

Three main findings can be highlighted from current findings. First, radical conceptual change is an effortful, gradual and time demanding outcome. Although instructional interventions are carefully designed to promote it, students' knowledge revision does not automatically occur. Literature has clearly pointed that often teaching practices are not very successful (e.g. Glynn & Duit, 1995; Mason, 2001; Schnotz, Vosniadou, & Carretero, 1999).

Second, it seems that not only purely cognitive aspects are involved in conceptual change processes. For individuals to be able to achieve the deep revision of their prior knowledge that radical conceptual change entails, it seems crucial that they also modify other aspects such as their beliefs about knowledge and knowing, their motivation, affect and achievement goals, and their learning attitudes (e.g. Pintrich, Marx, & Boyle, 1993; Pintrich, 1999).

Third, the social and cultural nature of the contexts in which the change of individuals' conceptions is desired to occur seems to play an essential role. Conceptual understanding and development can be seen as the product of shared social practices within a particular community, in which discourse practices are a cultural tool to construct knowledge (e.g. Kelly & Green, 1998).

More recently, the relevance of intentional learning for conceptual change processes has been pointed out (Sinatra & Pintrich, in press). To achieve a radical conceptual change individuals should be intentional, that is, they should be aware of the need to change their conceptions and beliefs, as well as be willing to change and self-regulate their process of knowledge revision (e.g. Limón, in press; Linnenbrink & Pintrich, in press; Pintrich, in press).

Moving from these findings, the volume aims at giving an account of the state of the art of both theoretical and practical issues that remain open in present day research on conceptual change. It is divided into four parts and each of them is commented by an invited discussant. The two first parts deal with theoretical perspectives on conceptual change. The last two focus more on implications that can

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be drawn from research and practical aspects to foster knowledge construction and re-construction, even if theoretical problems are also underlying in some chapters.

1. A STATE OF THE ART FOR UNDERSTANDING THEORETICAL PERSPECTIVES ON CONCEPTUAL CHANGE PROCESSES

Part I of this volume introduces four different theoretical views of conceptual change. The nature of individuals' prior representations and their characteristics as well as the nature of conceptual change itself have been discussed widely. Nevertheless, the discussion is far from closed as the chapters included in this part show. **DiSessa** points out the limitations of conceptual change research and criticises its current state. He considers that it lacks theoretical accountability concerning the nature of the mental entities involved in the process of conceptual change. The conceptual ecology approach he supports implies hypothesizing that conceptual change involves diverse kinds of knowledge organised and reorganised into complex systems. As an illustration of this approach he presents two very different kinds of mental entities: p-prims and coordination classes.

Vosniadou states that researchers in science education and cognitive science disagree on how to characterize naïve physics. She questions the kind of knowledge naïve physics consists of, how it is organised and how it develops. She argues that naïve physics is a complex conceptual system that includes perceptual information, beliefs, presuppositions and mental representations. Children's knowledge acquisition process starts by organising their sensory experiences, sieved by culture and language, into coherent explanatory frameworks. New information presented through instruction is assimilated to these initial explanatory frameworks creating synthetic models. She presents an empirical study about the development of the meaning of *force* to support the claim that children organise their physical experiences in narrow but coherent frameworks.

Chi also emphasises that even if the nature of misconceptions and conceptual change have been discussed for several decades, the literature only offers a fuzzy picture of what exactly misconceptions are, what constitutes conceptual change, and why it is difficult. She deals with these topics offering her view of these important matters.

Ivarsson, Shoultz and Säljö support a sociocultural view of conceptual change as an alternative to the cognitive view supported by the other three chapters of the section. They argue that to deal with conceptual development questions, it is necessary for researchers to clarify their position with respect to the more general question of how to conceive human cognition. Their paper presents a contribution to this age-old debate. They also present their results of a study on how very young children interpret a map. The authors show that using it as a mediational tool, these children can accomplish rather complicated reasoning about the shape of the earth and gravity, demonstrating the flexible and tool-dependent nature of cognition.

Finally, **Mayer** comments on the four chapters of this section. He compares these four views in terms of what changes during conceptual change, who changes, how the change occurs, where the change takes place, the role of prior knowledge,

and whether there is research evidence to support each one of these views. As a conclusion, he offers a proposal for reconciling alternative views of conceptual change.

2. MOTIVATIONAL, SOCIAL AND CONTEXTUAL ASPECTS

To widen the cognitive perspective from which mainstream research on conceptual change has been carried out, **Part II** of the volume deals with the social, contextual and motivational aspects of conceptual change processes. **Linnenbrink and Pintrich** focus on students' motivation by examining the direct and mediated effects of achievement goal, affect and cognitive strategy use on students' understanding in physics. On the basis of findings from two empirical studies, they highlight the importance of students' purpose of understanding when approaching their schoolwork. Mastery goals appear directly related to the development of current conceptual understandings.

In order to shed light on the controversy between the constructivist and sociocultural approaches, **Halldén et al.** propose an alternative model for conceptual development and change. Their investigation on children's conceptions of the shape of the earth leads them to look at a child's emerging conception as a compound model, which includes facts experienced from different sources contextualized in different models. In this chapter contexts are understood as conceptual contexts, that is, conceptual systems.

The social and cultural specific contexts in which knowledge construction and re-construction occurs are addressed by **Gorodestky and Keiny**. By dealing with another conceptual framework alternative to that of traditional research in the field, they explore learning and conceptual change processes as participatory processes. Through excerpts from the ongoing discourse in a team of teachers, the authors show the process, continuity and evolution of learning within this community. The dialogical interaction between the "outer" (the social context) and the "inner" (the individual learner) illustrates the construction of common meanings.

Rodrigo, Triana and Simón indicate the importance of considering cognitive variability in a model of conceptual change, that is, people's understanding at a given age does not correspond to a single knowledge stage. Variety of knowledge states are documented through an empirical study on the development of the concept of family. Both transitional and consolidated states as well as changes in distribution of discordant and concordant states are discussed in the light of gradualist and contextualist views of developmental change.

The four chapters of this section are finally commentated by **Sinatra** who identifies three main themes across them, that is, conceptual change involves more than cognition, appears to be an evolutionary rather than a revolutionary process and what it is discovered about it depends on the theoretical perspectives and research methods. She suggests directions for future research and draws implications for pedagogical practice.

3. DOMAIN SPECIFICITY AND LEARNING

Part 3 of the volume illustrates and discusses how the particularities of domain-specific learning and teaching may affect the processes of conceptual change. **Lehtinen and Merenluoto** address some special characteristics of mathematical knowledge that should be considered to understand the processes of conceptual change in this domain. They present a study to examine the difficulties adolescent students experience in achieving the conceptual change that involves enlargement of the concept of *number*. Their results show that students tend to use the logic of the natural numbers and their everyday intuition, even if they are working on more advanced numbers. Nevertheless, the majority of students also had fragmented pieces of more advanced numbers.

Stavy, Tsamir and Tirosh argue that students answer in a similar way some conceptually non-related tasks that differ with regard to either their content area and/or to the reasoning they require, but share some common external features. They have observed this student reaction in both science and mathematical domains. They consider these responses to be instances of a few intuitive rules that lead our responses in many situations, particularly in the domain of science and mathematics. In their chapter they illustrate one of these intuitive rules, "More A-more B", which is described and discussed. Instructional implications for conceptual change and science teaching are developed.

Leach and Lewis deal with the role of students' epistemological knowledge in the process of conceptual change in science. They support that students' conceptual knowledge in science has an epistemological dimension. Thus, they argue that models of conceptual change in science should refer to this epistemological dimension. Based on empirical data from their own research they develop two claims: a) a tendency to over-attribute relevance to empirical processes is manifested by many science students when they justify viewpoints on scientific topics or when they have to explain how to solve scientific disputes; and b) students show different epistemological knowledge in different situations. Thus, students' epistemological knowledge should not be considered in isolation from the context in which that knowledge is used. An agenda for future research on epistemological knowledge and conceptual change in science is outlined.

Limón also emphasises the role of epistemological knowledge and beliefs about history as a discipline and how they affect understanding of history. Her chapter questions the extent to which results from research on conceptual change in science education can be applied to the domain of history. Particular attention is paid to second-order concepts (evidence, cause, explanation, empathy, etc.) that seem to play a crucial role in history understanding. The peculiarities of history as a discipline and their implications for history teaching and learning are also reviewed. Finally, some conclusions for conceptual change in history are developed.

This section of the volume concludes with the commentary by **White**. He addresses two issues that appear in the four chapters. The first regards the discussion of what is idiosyncratic of each topic and what principles can apply across a number of them. The second questions if conceptual change requires a different type of

knowledge that may enable learners to see a subject and the topics within it in a new way.

4. INSTRUCTIONAL PRACTICES TO PROMOTE CONCEPTUAL CHANGE IN THE CLASSROOM

Part IV of the volume focuses on instructional practices to foster conceptual change in the real and complex learning environment of the classroom. The four chapters deal with implications from different lines of research on conceptual understanding and development. **Mason** argues about the relationship between personal epistemologies and knowledge revision processes. Issues from research on students' beliefs in particular domains, i.e. science, maths and history, are introduced to highlight that they may facilitate or impede conceptual change. For each of the three domains an example of an effective instructional intervention, implemented in the learning environment of the classroom, on the refinement of students' epistemological thinking is also introduced. These examples highlight that the development of naïve beliefs is a crucial condition for knowledge re-construction.

Mikkilä-Erdmann examines the role of instructional texts on conceptual change by introducing an empirical study theoretically motivated by research findings on text comprehension and development of conceptions. She compared a traditional text design on photosynthesis with a conceptual text design aimed at producing cognitive conflict in students with varying reading skills, and stimulating their metaconceptual awareness of how to understand this scientific phenomenon. Results highlight that in the complex process of conceptual change, texts play a role more important than we think.

Wiser and Amin focus on the use of computer-based conceptual models in learning physics. They refer to a "situated" approach to understanding in that they refer to the developing conceptualisation of things as a relational construct when thinking about students' sense-making of computer models and internalisation of them as a cognitive tool to construe the physical world. Excerpts from students' protocols illustrate how computer models, as components of students' increasing participation in the scientific practice, are the object of student-student and student-teacher interactions and negotiations of meaning.

Alonso-Tapia deals with assessment of conceptual understanding and its implications for conceptual change. The main characteristics of tools, procedures, contexts and processes to adequately assess students' conceptual representations are introduced. Examples taken from his own research on assessment in high school are given to illustrate how alternative conceptions and knowledge gaps can be identified. Moreover, features and benefits of portfolio assessment for assessing conceptual understanding and development are outlined. The need to pay attention not only to particular aspects of teachers' assessment practices, but to modifying the whole assessment practice is emphasised.

The four chapters of this section are finally commentated by **Boscolo**. He considers them from two perspectives. The first regards the object of change, the second regards the types of interventions that are implemented in the classroom. By

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