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Conceptual changes for and during working life

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ABSTRACT

Rapid and radical changes in science, technology and society may result in new scientific concepts and new workplace practices, which require fundamental restructuring of prior knowledge. Over the years a noteworthy body of research has documented the processes of conceptual change, the learning mechanisms involved, and the instructional methods and strategies that can promote conceptual changes. This research, however, focused young learners in school settings. Conceptual changes in working life go beyond traditional conceptual change consisting of processes and mechanisms that involve the interaction between expertise development and workplace learning processes. This Special Issue investigates whether and how conceptual change research can be extended from learning in schools to learning in professional life.

Introduction

We write this introduction in the middle of the COVID-19 pandemic, a pandemic which has challenged established expertise in medicine but has also resulted in an enormous need for radical changes in knowledge, regulations, and work practices for countries around the world. What we have here is an extreme example of a rapid need for radically new knowledge that can be only partly dealt with by enriching what is already known. Rather, the situation requires a fundamental structuring of prior knowledge and practices (Ohlsson, 2011) and the generation of new strategies to deal with uncertain and ambiguous information (Merenluoto & Lehtinen, 2004).

Already before the pandemic, increasingly fast changes and turbulence in the workplace generated research focusing on the processes needed to cope with and manage change in the workforce. However, change, especially in the case of aging workers, is not easy to come about; there are considerable resistances to change, and some research has attempted to uncover possible reasons (Dent & Goldberg, 1999; Kunze, Boehm, & Bruch, 2013; Oreg, 2006). Resistance to change is found not only in the case of experienced workers, however. Obstacles to change have also been observed when it comes to changing one's ways of thinking in school learning, particularly in the learning of science and mathematics. These problems have been extensively studied in the conceptual change research tradition (Vosniadou, 2013b). The purpose of the present Special Issue is to investigate whether and how conceptual change research can be extended from learning in schools to learning in professional life.

There are various 'change drivers' that require new solutions, work processes and ways to organize individual and collective work (Palonen, Boshuizen, & Lehtinen, 2014). These drivers have been listed in several reports on future development (e.g. Davies, Fidler, & Gorbis, 2011; Redecker et al., 2010; Talwar & Hancock, 2010), highlighting possible challenges, risks and possibilities. Demographic

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and political changes, economic turbulence, changing norms and legislation, new scientific findings, new technologies and environmental challenges, such as climate change, lead to new knowledge and skills to be incorporated in work procedures; they also give birth to new jobs, or hybridize existing jobs (Palonen et al., 2014). The change is so fast that traditional theories and training models are not able to deal with the development of novel professional knowledge and skills (Lehtinen, Hakkarainen, & Palonen, 2014).

Most of the research regarding change in enterprises and public organizations focuses on various aspects of management and leadership (Furst & Cable, 2008), or on how the workforce (or workers) can collectively create new ways to deal with tasks or with organizations in changing environments (Engeström & Sannino, 2010). Many studies address the strategies required to get employees involved in the change and to deal with resistance to change. Remarkably, many of these studies fall back on classical social psychological theories, such as Kurt Levin's change model (Talib Hussain et al., 2018) or Leon Festinger's theory of cognitive dissonance (Hinojosa, Gardner, Walker, Coglisier, & Gullifor, 2017). These theories may explain social phenomena, but they do not provide sufficient theoretical understanding of the individual level learning needed in becoming and being a professional, and particularly in coping with radical changes in the workplace.

Conceptual change research investigates the changes in individual cognition that take place when learners need to revise their prior knowledge in order to learn new and counter-intuitive concepts. Although the beginnings of conceptual change research can be traced to scientific discovery in physics studied by philosophers and historians of science (Kuhn, 1970) and in physics education (Posner, Strike, Hewson, & Gertzog, 1982), it has by no means been restricted to these subject areas. Researchers have applied conceptual change theories and methodologies to understand learning in many areas of knowledge, such as biology (Inagaki & Hatano, 2002; Sinatra, Brem, & Evans, 2008), psychology (Wellman, 2002), history (Leinhardt & Ravi, 2008; Limón, 2002), political science (Voss & Wiley, 2006), medicine (Badenhorst et al., 2016; Kaufman, Keselman, & Patel, 2008; Södervik, Vilppu, Österholm, & Mikkilä-Erdmann, 2017) and mathematics (Lehtinen, Merenluoto, & Kasanen, 1997; Vosniadou & Verschaffel, 2004).

Over the years a considerable body of research has emerged which has documented the processes of conceptual change, the learning mechanisms involved in the construction of new concepts, and the instructional methods and strategies that can promote conceptual changes. This research has focused primarily on school learning and on the conceptual changes needed when students are exposed to scientific concepts that require major re-organisations of prior knowledge, acquired mainly through everyday experiences in the context of lay culture (Amin & Levrini, 2017; Vosniadou, 2013b).

However, it is becoming increasingly apparent that conceptual changes not only have to take place when there is inconsistency between individuals' knowledge based on everyday experience and scientific concepts and theories; they are also required in working life, when there is a discrepancy between established science and new scientific concepts emerging from rapid changes in science and technology in today's culture. Yet, the investigation of conceptual changes in working life involves going beyond traditional conceptual change research and understanding processes and mechanisms involved when expertise development interacts with workplace learning processes. For example, conceptual changes may be required when formal, school learning is applied in practice. It also calls for understanding the reflection processes and mechanisms needed to transform tacit everyday learning into metacognitive and explicit conceptual knowledge. While school learning focusses on conceptual understanding applied to well-defined problems, learning in practical settings and working life is often ill-defined and encoded in formats that enable rapid performance (Boshuizen, Gruber, & Strasser, 2020). The latter semi-autonomous processes may make it more difficult to be revised in the face of radically new scientific knowledge and techniques. The question addressed in the special issue can thus be formulated as follows: **Can conceptual change research contribute to our understanding of the learning that takes place in the different phases of individuals' professionals' career, and if so how?**

Professional learning is typically a career- or lifelong process including several phases taking place in various situations and environments and is affected by sudden and continuous change that can only be partly predicted, as shown in Fig. 1.

Graduates moving from school learning to learning and working in professional practice may encounter a huge divide between the two contexts. Conceptual changes during school learning are usually accomplished through deliberate instruction, often guided by cognitive conflict, self-explanation, and reflection. The targeted correct conceptual understanding is usually clearly defined and presented in instruction. Learning and performance at higher levels of expertise, on the other hand, not only involve learning new concepts and theories but also new ways and tools needed for the application of these concepts, and meta knowledge about the relations between concepts and tools and actual practice. Particularly during rapidly occurring new challenges, such as the COVID-19 pandemic, it is typical that there are no experts who already know what solutions are needed and who can explicitly guide the learning of other professionals (Ohlsson, 2011).

Learning in practice settings is initiated and structured differently from learning in school-based situations. Such learning is no longer sanctioned by a formal curriculum but is self-directed or happens as part of work processes within a community. It can be triggered by conflict between prior knowledge and present experience, and it requires reflection on conflicts and errors. This extension of learning to professional practice is further complicated by the continuous changes that are taking place in the content and context of work. Such changes are, for example, the introduction of ICT and serious games in teaching, the regulations for the reduction of nitrogen emission in farming, the introduction of new imaging techniques in medicine, and the massive introduction of working from home. Over a professional career that may last for at least 40 years, many of such changes in roles and contexts will take place (see Fig. 1). One might wonder if these learning processes can be considered as requiring conceptual changes and how these take place.

The studies brought together in this Special Issue share the focus of conceptual changes in professional knowledge and/or in professional life. They concentrate on different periods and on different professions; they are ordered chronologically, that is, along the line of a developing professional career.

The contribution by Södervik, Mikkilä-Erdmann, and Chi (this issue) stays closest to original conceptual change research but extends it by trying to address questions about long-term stability of changes, and how conceptual change predicts later professional

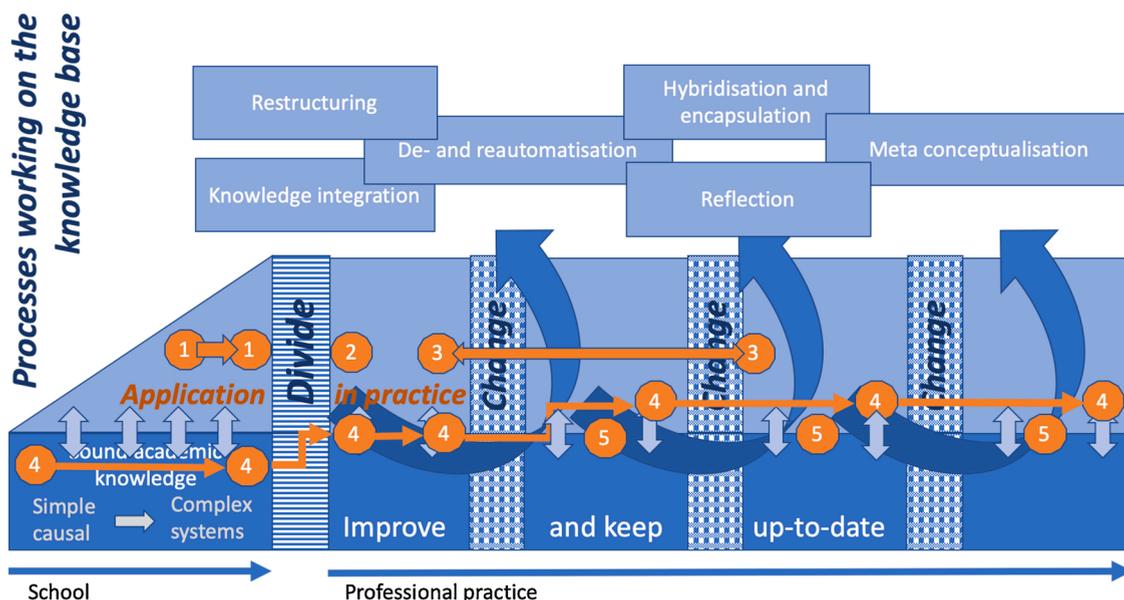


Fig. 1. Learning and conceptual change during school and professional life. The dark rectangle at the bottom depicts scientific knowledge that has to be developed, improved and kept up-to-date. The light blue shaded triangle and rectangles represent application affected by task, role, context, etc. The vertical two-headed arrows represent the cognitive processes at the interface of the two; the curved arrows depict knowledge restructuring processes emerging from knowledge application in professional practice affected by task requirements and change processes. The numbers 1 – 5 refer to the articles listed below.

procedural skills. The study focuses on medical students' conceptual understanding of the central cardiovascular system during the first two years of medical school. The results showed that even the highly selective medical students in the sample had false beliefs as well as deeper misconceptions about the functioning of the cardiovascular system. During the basic course false beliefs decreased, although the number of false beliefs fluctuated between measurement points. In contrast, deeper misconceptions preventing understanding of the system as a whole, decreased only slightly during the course. The researchers concluded that the instruction in the cardiovascular course supported knowledge enrichment and belief revision but did not result in mental model transformation. In addition, there was some evidence that the quality of biomedical knowledge was related to students' later success in a clinical application task.

The work by Vosniadou et al., 2020 focuses on the examination of learning happening at the divide between school and practice learning in teaching. Their study extends conceptual change research from school learning to learning at the workplace. It also extends conceptual change research from students learning in subject matter areas to teachers learning how to teach. Despite many commonalities between the conceptual changes that need to happen in pre-service teachers as they learn how to teach and students as they acquire subject matter knowledge, there has not been much communication between these two areas of research. Educational research has so far documented the importance of teachers' beliefs on their teaching practices but has not tried to investigate in greater detail the nature and structure of teachers' belief systems, the presence and co-existence of conflicting beliefs, and the ways in which such beliefs may interact to influence teachers' interpretation of educational theory and its application in practice. Guided by the framework theory approach to conceptual change (Vosniadou, 2013a), Vosniadou et al. describe a methodology that can provide more information than previous research about teachers' conceptual knowledge and its possible influence on teacher practices (see also Igusti, Vosniadou, Lawson, Van Deur, & Wyr, 2020; Vosniadou et al., under revision).

Lehtinen, Gegenfurtner, Helle and Säljö (this issue) investigated the cognitive processes in the context of change during mid and late career happening with the introduction of new technology, and compared these changes with early career new learning. The article is based on three previously published studies on visual expertise in medicine, which are reanalyzed from a conceptual change point of view. The studies show that the expertise needed in diagnosing various medical images consists of several layers of knowledge and skills including biomedical conceptual knowledge, illness scripts, knowledge of the affordances of various imaging technologies and disciplinary professional practices. Traditional theories of conceptual change only regarded the biomedical conceptual knowledge but due to rapid technological development, remarkable changes are needed at all levels of this complex system of knowledge and skills.

Boshuizen and Marambe's (this issue) review study focuses on the whole learning trajectory from (pre)school into professional life, and the associated structural changes in professional knowledge in medicine. It asks whether this could be framed as cognitive change during school and the many years of workplace learning following. The results showed that the focus of the articles identified changed according to the level of learning, reflecting the goals of education: from beliefs about health and disease, to scientific biomedical knowledge, to knowledge about (groups of) patients and how to treat them. Remarkably, no studies including further advanced stages of experience could be located. It was concluded that several processes and domain features interact in the creation and sustainment, as well as the prevention and rectification of misconceptions and other knowledge weaknesses. Special attention is called to factors

related to shared misconceptions and blind spots emanating from established research practices, to unintended but potentially harmful side-effects of professional practices, and to the importance of lifelong critical thinking and reflection.

Kainulainen, Puurtinen and Chinn's study (this issue) presents a theoretical analysis of historians' conceptions of their topic 'history' (history as 'the past' vs history as 'human production') and associated different professional practices. They highlight two aspects of knowledge development, which are relevant from a conceptual change point of view. Traditional approaches of conceptual change research have focused on specific topics in various domains. Kainulainen and his colleagues, however, show that in history, some of the most important conceptual challenges are related to changes in the conceptions of the domain itself rather than any particular concept within a field. In addition, the coexistence of multiple expert conceptions of history highlight the importance of metaconceptual awareness, which enables adaptive and flexible shifts between the different views of history.

The contributions in this Special Issue show, among other things, that as we move to higher levels of expertise the phenomena investigated become more complex, regardless of whether they involve perceptual skills, professional practices, or technical skills and values.

Furthermore, meta-concepts and metaconceptual awareness seem to play an increasingly more important role. Conceptual change research has so far dealt with changes that happen mainly in K-12 students and university students and has not studied conceptual changes that happen at higher levels of expertise. The findings of the review study by Boshuizen and Marambe (this issue) regarding the absence of research to investigate conceptual changes at higher levels of expertise suggests that such changes are either less meaningful or harder to document at more advanced phases of people's professional careers. It might be argued that conceptual change theory is too much a theory of early, school-based learning to provide a feasible framework for understanding the changes taking place in workplace and in advanced expertise development. That is not, however, our conclusion. The analyses so far and the conclusions that can be drawn from the present research give some initial answers while at the same time raise new questions that need to be answered; questions such as what are some of the cognitive/conceptual preconditions for later professional learning and good practice, how does the quality of prior conceptual knowledge affect adaptations to changes in science and practices of a profession, or what is the role of conceptual change within the complex system of knowledge, skills, and practices needed in turbulent working life. The contributions presented this Special Issue provide initial answers to these questions while at the same time demonstrate the complexity of the learning processes that happen in professional life.

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