Chapter 1

THE NATURE OF CHEMICAL KNOWLEDGE AND CHEMICAL EDUCATION

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INTRODUCTION

Almost half a century ago, Joseph Schwab had argued that science teaching should nurture themes that characterise a science as a distinct way of knowing (Schwab, 1958). While Schwab's insight on significant goals for science education has been recognised and promoted (e.g. Duschl, 1990), several decades later overwhelming evidence suggests that science education is not doing enough to align science teaching with contemporary perspectives in philosophy of science. Despite numerous international reform efforts (e.g. National Research Council, 1996), science teaching continues to reinforce a 'rhetoric of conclusions' (Schwab, 1964), a tradition that perpetuates the learning of conceptual outcomes while neglecting the learning of strategies that enable knowledge growth in different fields of scientific inquiry. For instance, in terms of a contrast of physics and chemistry, school science makes little differentiation beyond the obvious conceptual variation between the disciplines. Whereas the tendency in physics is mathematisation, chemistry relies on classification schemes such as chemical models which explain more the qualitative aspects of matter (Scerri, 1996). Such treatment of science in schooling fails to communicate to students those disciplinary emphases which might play an important role in the processes of inquiry as well as knowledge growth.

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In this chapter we investigate how the teaching and learning of chemistry can be improved through an understanding of the structure of chemical knowledge. We use arguments from the emerging field of philosophy of chemistry (Scerri & McIntyre, 1997; van Brakel, 2000) to highlight the significance of domain-specificity in the characterisation of science. Our thesis is in contrast to educational research that promotes the improvement of chemistry teaching through an emphasis on, for instance, problem solving (e.g. Gable & Bunce, 1984; Lythcott, 1990), concept learning (e.g. Cros, Chastrette & Fayol, 1987; Nussbaum & Novak, 1979) and learning of science-process skills (e.g. Heeren, 1990; Yarroch, 1985). In particular, we advance the position that the exclusion of philosophical perspectives in chemistry education is a significant deficit which hinders the teaching and learning of the nature of chemical knowledge. We believe that the application of themes from philosophy of chemistry will begin to address this deficit and enhance effective teaching and learning of chemistry. In this chapter, we apply some issues raised by Scerri & McIntyre (1997) where the authors presented the case for the autonomy of philosophy of chemistry. Specifically we concentrate on the role of reduction, explanations, laws and supervenience as salient themes that provide a foundation for philosophy of chemistry. In so doing, we argue that chemistry education will benefit from discussions that detail the nature of chemical knowledge. The implication of our work will necessitate a reconceptualisation of chemistry education to be more inclusive of philosophy of chemistry. In particular, we will consider the ramifications of our discussion for theories of learning, curriculum design and teacher education.

ATTEMPTS TO IMPROVE SCIENCE EDUCATION THROUGH HISTORY AND PHILOSOPHY OF SCIENCE

In recent years, there has been renewed interest in the application of history and philosophy of science (HPS) in science education as a strategy to improve science teaching and learning (e.g. Finley, Allchin, Rhees, & Fifield, 1995; Herget, 1989, 1990; Hills, 1992; Winchester, 1997). Popularisation of the notion 'cognitive ontogeny recapitulates scientific phylogeny' through Thomas Kuhn's (1962/1970) *The Structure of Scientific Revolutions* has contributed substantially to this renewed interest. The ongoing debate on the relationship between theory change in science and children's cognitive development has played a key role in the formulation of the conceptual change theory of science learning (Hewson, 1981; Posner, Strike, Hewson, & Gertzog, 1982).

Contemporary applications of HPS in science education (Duschl, Hamilton, & Grandy, 1992; Hewson & Thorley, 1989; Matthews, 1994; Shortland & Warwick, 1989) follow earlier arguments (Conant, 1948; Connelley, 1969; Klopfer, 1969a) which were predominantly justified on the grounds that science needs to be connected to its social and historical roots. Since science teaching has traditionally embraced little or no reference to the cultural, personal and historical contexts in which science occurs, learners of science do not develop an appreciation of science as a human endeavour. HPS has thus been advocated as an instrument for humanising science and a catalyst for motivating students' interest in science (Ihde, 1971; Wicken, 1976).

What remains as a common theme between earlier (Bent, 1977; Klopfer, 1969b) and contemporary (Gallagher, 1991; Lederman, 1992) arguments for the inclusion of HPS in science education is the importance of students' engagement in scientific inquiry. Schwab (1958) had argued that the science curriculum needs to be faithful to the nature of scientific inquiry and should provide students with experiences that are similar to scientists' experiences in science. Subsequent recommendations for promoting scientific inquiry (Duschl, 1994; Wandersee, 1992) drew closer attention to examining the conditions that can sustain scientific inquiry in the classroom. Increasingly, there has been a shift in focus from teaching science process skills, such as hypothesising and experimenting, to a stronger emphasis on students' construction of scientific theories, models and explanations (Schauble, Klopfer & Raghavan, 1991).

Current reform efforts acknowledge arguments for the integration of HPS in science education in general and the significance of students' participation in scientific inquiry in particular (e.g. Leach, Millar, Ryder & Sere, 1999). Documents such as the *National Standards in Science Education* (NRC, 1996) in the United States advocate the teaching of the nature of science, science as inquiry as well as unifying concepts and processes of science. The unifying concepts and processes, such as 'evidence, models and explanations' and 'form and function' are intended to facilitate students' 'ways of thinking about and integrating a range of basic ideas that explain the natural and designed world' (p. 115).

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