Modelling Learners and Learning in Science Education

Keith S. Taber

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Developing Representations of Concepts,
Conceptual Structure and Conceptual
Change to Inform Teaching and Research

Springer

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*Essentially, all models are wrong, but some
are useful.*

(Box & Draper, 1987, p. 424)

Preamble

Modelling is widely recognised to be important in both the doing of science and – increasingly – in the teaching of science. Modelling is equally important in research in science education as it allows us to develop ways of thinking about the nature and structure of complex phenomena and, in particular, to devise simplifications suitable for formal testing. This is especially important in an area like learning. Learning is an absolutely fundamental concern in education (science education or otherwise), and the term refers to a complex set of processes that are not fully understood. Our research in science education often relies on assumptions about the nature of learning and learners, and research to better understand learning in science is a core area of activity. Research in these areas uses and develops constructs, representations and models that are either assumed or proposed to in some sense reflect the ‘real’ nature of learning. Yet the central role of modelling in research into learning in science has not always been as clearly acknowledged as – for example – the role of modelling in the teaching and learning of the subject. In this book it is suggested that this is problematic as often researchers write (and so perhaps think) as though learning and associated notions such as understanding, thinking and knowing are not problematic. Research papers (as will be illustrated in Chap. 1) commonly report research findings in terms of student knowledge, or understanding, as though the terms are well understood and unambiguous and the notions behind them are unproblematic. Yet, as will be demonstrated here, this is hardly the case.

There is a problem, then, that because notions such as learning and knowing are so familiar from everyday use, researchers often fail to treat them as technical constructs when reporting the outcome of science education research. In some cases, this lack of sophistication undermines the value of the research to the community, as results are presented in terms that treat complex phenomena as though we all understand and agree about their nature. Yet, as this book shows, this is not a warranted assumption.

This book then explores the role of modelling in research exploring learning in science. The fundamental assumption of the book is that research into learning in science necessarily involves making knowledge claims based upon building and

representing models. Reports in research papers giving accounts of student knowledge, and/or conceptual change, rely upon the models researchers adopt or develop when interpreting their data. It follows that the modelling processes and the nature of the models produced need to be understood by those who read the research reports if the knowledge claims made in research are to be correctly understood and appropriately judged.

In this volume I offer an account of the modelling processes involved in research into student understanding and learning in science. I argue the case for the importance of acknowledging the modelling processes necessarily underpinning any account of student thinking, knowledge or learning. The book reviews the current state of knowledge in science education in relation to the modelling of scientific thinking, understanding and learning in science.

A Note on Teachers as Knowers and Learners

Much work in science education focuses on the ideas of learners in formal education – school pupils or other students. In general I have written the book referring to learners and largely have such students in mind. However, the book is equally relevant for research into informal learning (e.g. adult museum visitors who would not consider themselves learners) and into teachers – who of course continue to learn about both the subjects they teach and about professional matters such as pedagogy. In recent years there has been a significant literature looking at such matters as science teachers' beliefs about, for example, the nature of science or constructivist pedagogy. Researchers exploring these areas are subject to the same methodological problems and questions regarding the assumptions behind their research as those exploring 8-year-old children's ideas about the shape of the earth or postgraduate students' notions of types of chemical bond. The type of modelling processes inherent in research is the same in all these cases.

Moreover, although the book is largely framed in terms of formal research as reported in journals and other scholarly works, the core argument here is equally important to teachers going about their work in school or college classrooms. Teachers are not usually developing formal models of their students' learning to present in research papers. However, the process of teaching science involves designing instruction that takes into account a learner's current knowledge and understanding. Teaching is a highly interactive process where the teacher seeks to facilitate learners' sense making to shift current knowledge and understanding towards what the curriculum sets out as target scientific knowledge and understanding. That requires a good appreciation of what students already know, where they may have alternative conceptions and how well they understand key concepts.

The effective science teacher is therefore constantly seeking to update their own understanding of the current states of their students' learning. That is, science teaching depends upon an ongoing, informal process of modelling the mental states of learners. Teachers do this by constantly collecting data (by asking questions, by

reviewing students' work) and analysing it to inform the next steps of the teaching process. In effect all science teachers are involved in a process of continuous action research to inform and improve their teaching, based upon developing models of the mental states of their learners. Action research is primarily context-directed research to inform practice locally rather than the theory-directed research of academic researchers that is intended to have relevance beyond specific research sites and which is formally reported in publications. The models generated by teachers in their day-to-day work will therefore not be subjected to the scrutiny of others in the same way as the academic research discussed in this volume. Yet teachers, often even more so than researchers, tend to take for granted notions of knowledge, understanding, learning, etc., and, just as researchers, they can benefit from problematising these issues and reflecting on just how they understand – and so implicitly model – these concepts that are so central to their day-to-day work.

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This book is located in science education but draws strongly on cognitive science and psychological research and scholarship. Whilst reasonable attempts to offer appropriate citations to previous work have been made in accordance with academic conventions, I am very aware that the message of Chap. 5 is that human memory is not primarily a faculty for providing accurate records of past experience, but rather has evolved to support future action in the world. Memories are often hybrids of our past interpretations of events, patched up with what seems so feasible (based on our general knowledge of the world) that we can no longer see the seams between what we actually experienced and what it now just seems most likely we experienced.

Introspection suggests that my own memory certainly is quite good at recalling 'gist', but often poor at reporting specifics of past experience. My suspicion (or perhaps my hope) is that such a memory supports a strongly synthetic way of thinking that is able to make connections and recognise general patterns rather than focusing on the minutiae of specific details. That does not excuse bad scholarship, but I am aware that I inevitably own an enormous debt to the authors of many things I have read over the years that are not cited here as well as to colleagues and students for things I have heard in presentations and in conversations in both formal and informal contexts. I have sought to acknowledge those key sources I am aware have informed my thinking, and I would here like to acknowledge that I am aware that I am surely drawing on many other sources that I either no longer specifically recall or have simply not recognised as influences in writing this book.

I suspect there may even be some good ideas in here that I present as if original, but which have worked their way into my consciousness so slowly that I was unaware that their original inspiration was something I had long ago read or heard. I take some comfort in knowing that if this is indeed so, my failure is probably not so unusual, as is indicated by occasional high-profile examples such as when George Harrison was sued for a great deal of money for not acknowledging a highly popular song was very similar to an earlier hit written by someone else. At least working in the academic world, rather than 'the material world', such unconscious plagiarism is unlikely to lead to claims for vast amounts of unpaid royalties.

My only defence is that the model of cognition offered in this book suggests that my failings here are due to the effective way in which the human brain interprets and integrates experience to provide a viable knowledge base for ongoing effective action in the world. Human memories, like the models mooted in this book, need to be understood not as being true replicas of aspects of the world, but rather as useful thinking tools that are fit for purpose. Both should be judged by how they help us move forward, and I very much hope this book will provide useful ways of thinking for those working in science education and looking to develop pedagogy or advance research programmes.

Finally, I would like to dedicate this volume, with love, to my wife Philippa, who has suffered significant health issues during the preparation of the book. At times my academic work has had to be given a low priority in our lives, and the writing has been disrupted. Despite considerable challenges, however, Philippa has understood my drive to push forward in my work and has offered her love and support to help me balance family and work responsibilities. Completing this manuscript despite major distractions is an achievement of 'team Taber'.

Any errors, or other failings, are of course the author's own.

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