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CONTEMPORARY TRENDS AND ISSUES IN SCIENCE EDUCATION 38

The Pedagogy of Physical Science

Springer

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The inception of this project derived from a professional concern about effective teaching to support meaningful learning in science. It is an attempt to develop insight into effective pedagogy from the perspective of the learner. The book draws on researching pre-service and practicing teachers' learning of science on teaching programmes at Manchester Metropolitan University over the last decade. We would like to thank all those students and teachers who gave freely of their time and participated enthusiastically in such a way that allowed us to gain insights that would have otherwise been impossible.

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About the Authors

Dave Heywood is Reader in Education and **Joan Parker** Senior Lecturer in Education at the Manchester Metropolitan University Institute of Education, England. Their research interests are focused on developing teacher subject and pedagogic knowledge. They work collaboratively with colleagues to research how pre-service and practicing teachers develop science subject and pedagogical knowledge in order to enhance higher education taught provision in Initial Teacher Education (ITE) and Continuing Professional Development (CPD) programmes. The research undertaken provides evidence that by engaging in a metacognitive approach to learning, in what are problematic subject areas for many science trainees and teachers, there resides the opportunity to foster not only understanding of scientific concepts but also pedagogical insight into the learning of them. Their current research interests concern the development of this approach and exploration of its application in the classroom practice of teachers. They have recently been involved in working with the Manchester Museum of Science and Industry (MOSI) education officers and school teachers in promoting out of school learning to develop pupils' enthusiasm and confidence in science, technology, engineering and mathematics (STEM). They are passionately committed to focusing research on practice to inform future programme provision for both ITE and CPD. They have published internationally and presented at conference both nationally and internationally.

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Chapter 1
Introduction

Pedagogy, the principles and practices of teaching, is a central concern in science education and has formed the focus of much educational research over the last 2 decades. This book focuses on the process of how subject and pedagogic knowledge emerge through teachers' learning in science. It draws on a substantive body of empirical research, collated over the past decade, focusing on conceptual domains that are known to be difficult for learners including forces, electricity, light and basic astronomy. The findings are derived from analysing pre-service and practicing teachers' responses to engaging with difficult ideas when learning science in higher education settings. In an effort to address the questions regarding problematic science concepts in their own learning, the teachers in the studies we report here are themselves afforded an opportunity to focus on the nature of the concepts being explored and the manner in which an understanding of them might be developed; they are, therefore, referred to as learners or students of science throughout.

Despite recent relative success in achievement as measured by knowledge acquisition, there is an increasing concern with about the problem of pupils failing to see meaning in the ideas they encounter in their science learning. The issue remains a significant one, not least in regard to the lack of interest in the subject pupils exhibit in the subject as evidenced in the declining uptake of the sciences in higher education. While the factors that impact on this are multifaceted, the importance of teachers developing sufficient confidence to teach science creatively in order to engage and enthuse pupils' learning of science is likely to be a significant contributing factor. The breadth and depth of curriculum content in science has placed a considerable demand on teachers' subject knowledge. Subsequently, this has had significant influence on both initial and in-service teacher education. The tensions in regard to supporting teachers in developing their subject knowledge so that they feel confident in teaching science in interesting, challenging and creative ways are difficult to reconcile. This is particularly the case in respect of pre-service teachers who are non-specialists in the subject.

The conceptual demand of science places the teachers' subject knowledge at the heart of developing confident and competent practitioners. Teachers require not only a sound and secure base of subject knowledge, but also the ability to implement

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a range of teaching and learning strategies to develop appropriate explanations to support learning. This entails a synthesis of both subject and pedagogy and there is a need for explicit exemplification of what such pedagogic knowledge might be within specific science domains. This book addresses some of the implications arising from this.

In response to increasing the accountability of educational institutions by government agencies, there is a danger of over-emphasis on the assessment of student knowledge of facts. In teacher education, this has been evidenced by the emergence of an auditing and testing culture. This can be construed as portraying science education as a process of information transfer and recall, as opposed to one of developing ideas and explanations. One way of countering such an unproductive view of science is to ensure that during their training, students are provided with teaching and learning experiences that are designed to challenge this view of teaching. This could encourage them to consider the nature of both their own learning and that of children through carefully reviewing direct learning experiences.

Although developing personal subject knowledge for teachers is often framed within a deficit model in which initial teacher education attempts to support students in addressing areas of weakness, we propose that the very act of identifying and addressing problematic science concepts in their own learning affords an opportunity for students to focus on the nature of the concepts being explored and how understanding of them might be enhanced. This constitutes a productive way of turning a deficit model of teachers' subject knowledge into a positive experience with considerable potential for the development of pedagogy. It is a central theme developed throughout and is based on purposefully presenting the problematising of the subject as a positive condition of professional being through which insights into pedagogy emerge that would otherwise remain latent. We contend that this approach is more likely to lead to both conceptual and pedagogic change. The former is recognised as an integral and necessary element of learning science because it is often required to make sense of what initially appear to be counterintuitive explanations of the world. The latter, whilst clearly a core professional concern and valued goal in science education is not as well-articulated. It concerns the professional issue of interpreting and constructing coherent causal explanation for phenomena that serve to provide a convincing account that both persuades and engages learners because it makes learning meaningful to them. Our work here is an attempt to inform contemporary debate on this issue. It argues that the deliberate presentation of science learning as problematic (for both teacher and pupil) is both a necessary condition and a positive conceptualisation of what it is to learn science and can be used productively in promoting not only knowledge and understanding of science, but also valuable pedagogic knowledge of teaching and learning.

The research reported here is based on findings from empirical studies undertaken at Manchester Metropolitan University in England. In order to achieve Qualified Teacher Status (QTS), students on pre-service higher education programmes must demonstrate that they have the required subject and pedagogic knowledge in science to teach effectively. The stipulated requirements for pre-service teacher standards are outlined by the Training and Development Agency (TDA 2007)

for schools which reflect the demands of the school science curriculum. The school curriculum referred to is the English National Curriculum for schools (DfEE/QCA 1999) which has four Key Stages (KS 1–4). These are divided into year groups from year 1 to year 11 (Y1–Y11). The first two Key Stages (KS1 and KS2) are undertaken in primary schools (Y1–Y6) with Key Stages 3 and 4 (Y7–Y11) being completed in secondary school.

In order for the methodology to be coherent with the pedagogical approach adopted, it was felt necessary to explicitly acknowledge and share with students that teaching sessions were research-focused. The principal objective of the empirical studies throughout was the synthesis of research and teaching for the purposes of developing insight into the learning process. This was intended to explore a range of issues including the identification of sequences in cognition and to address the extent and limitations to which this could be paralleled with a sequence in pedagogy. A key principle in the methodology concerned securing the student perspective during the tutor and peer group discourses within taught sessions at university. The epistemological basis for this approach is different from that adopted in pre- and post-teaching evaluations of student understanding. The process attempts to capture a 'dynamic'; it places considerable (metacognitive) demand on the learner and requires them to identify and articulate significance in their own learning. To this end, student written accounts, annotated drawings, session notes and recorded discussions were collated and analysed to identify patterns that could provide insight into those elements that they found useful in developing meaningful interpretations of abstract ideas. A key element of tracking learning involved students in keeping a reflective journal to document their engagement with initial thinking about, and subsequent engagement with, ideas encountered in the teaching sessions to consider how the experience impacted on their perceptions of pedagogy. The process generated significant insights into factors influencing the emergence of pedagogy. The qualitative data that comprised the basis of the analysis was drawn from interviews, discourses, reflective journals and summative assignment writings. Written journal entries were a primary data source and in some cases, where meaning was ambiguous, students' ideas were discussed further at interview. This data was subsequently scrutinised through reviewing summative assignment tasks to determine the extent of coherence in reasoning.

It is important to recognise that the notion of problematising science subject knowledge requires analysis that is necessarily interpretative. Attempting to document the process of change in students' perceptions through a qualitative approach within an interpretivist paradigm derived from accounts of their own learning is applicable to both the researcher and the learner. Tutors initially determined what (through anticipation in planning) would constitute 'critical incidents' in learning, such as typical cases where cognitive conflict was likely to ensue as students explored the various phenomena through practical investigation. The subsequent data analysis process had a significant impact on programme development and provision. The presenting of data as narrative from students' responses is a feature of all the studies cited. Whilst earlier studies, when working with large groups of students focused on finding patterns to categorise key ideas, the emphasis in subsequent

research moved increasingly towards the presentation of data as narrative, although categories of key ideas has remained a feature. Through the act of analysing their own learning in this way, students were able to identify problematic aspects for learners in developing specific scientific ideas as well as developing insights into a range of general pedagogic implications. The physical science studies show that pre-service teachers are able to generate important insights into the nature of scientific ideas and the learning of them through such a process.

Critical features of developing a metacognitive approach include the need to create a learning environment of trust and security between tutors and students such that learners are confident in sharing perspectives. It requires time and opportunity to nurture the socio-cultural environment of learning in which knowledge is problematised. In some ways such an approach can be said to militate against the current teacher training trend towards diminishing course contact time, development of distance learning materials and ICT dependency. Factors such as personal involvement in learning and ownership of learning were important in creating a positive environment in which students were not afraid to discuss their thinking. Discussion was identified as a central feature of the learning process. There were important pedagogical insights into the teaching and learning of specific subject matter as explicitly identified by the students across the studies. This is exemplified and detailed in Chapter 7.

Through introspection and collective discussion of perspectives, students are, in effect, 'auditing' specific science subject domains such that they become aware of typical misconceptions and inherent difficulties in developing understanding of them. These features, although specific to particular subject matter, can be used to alert the teacher to likely problems in other areas. Having, for instance, recognized that there is a need to differentiate spin and orbit in translating written information about day and night and seasons, teachers can be alerted to audit other subject areas for similar potential language problems such as current flow and energy transfer in understanding the lighting of a bulb in a simple circuit.

In teacher education, research into teacher learning during university teaching sessions offers significant potential for further developing insight into pedagogy because it provides opportunity for a unique synthesis in which the students are reconciling experience as both teacher and learner. The process of problematising subject knowledge through direct experience of learning in areas of science that are known to be difficult constitutes the most productive way of realising this potential, turning a deficit model of teacher subject knowledge into a positive learning experience. The book addresses these issues in the following way:

Chapter 2 presents a review of conceptual change literature. This has had a pervasive influence on science education research over the last 2 decades, informing the direction of focus for studies that have generated significant insight into the problem of how to promote conceptual change in learners across a range of domains in science learning. We discuss various attempts to develop models of conceptual change and the theoretical rationale that underpins these and provide accounts from student learning about forces to contextualise these debates in relation to subject and pedagogic knowledge.