1.5 Learning About Science Teaching: Perspectives From an Action Research Project

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The findings of research carried out internationally over the last 20 years have led to widespread recognition that young people have informal or spontaneous ideas about natural phenomena which are commonly considered in science instruction (Carmichael, Driver, Holding, Phillips, Tippner & Watts 1990; Driver, Guesne & Tiberghien 1985; Pfundt & Duit 1994). Teaching and learning studies have shown that the evolution of students' ways of thinking about phenomena tends to be a slow and piecemeal process. In some cases, students' informal ideas have been shown to persist through extended tuition in science whilst, in others, the ideas presented in instruction are assimilated by students in ways which are in keeping with their current conceptions. Further instruction then can reinforce misunderstandings of this hybrid nature. Such findings draw attention to a significant problem and challenge for science teaching.

In response to this challenge, science educators, over the last decade, have been focusing attention on approaches to teaching science which take account of students' informal conceptions (Black & Lucas 1993; Duckworth, Easley, Hawkins & Henriques 1990; Fensham, Gunstone & White 1994; Glynn, Yeany & Britton 1991; West & Pines 1985). In the early 1980s in the UK, research findings from studies carried out by the Children's Learning in Science (CLIS) Research Group, on students' conceptions in science, were gaining attention and questions were being asked by science teachers and researchers about possible implications for teaching. It was with this focus that the CLIS Research Group initiated a research project into teaching and learning for conceptual understanding of science in classroom settings. In this chapter, we offer an overview of the research, present the main findings and review these in light of our present thinking about developments in the field.

The research reported here was grounded in the realities of teaching and learning science in high school classrooms in the UK and involved researchers from the

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CLIS Research Group working alongside groups of local science teachers. The overall strategy was to work with teachers as collaborators in exploring ways of improving students’ conceptual understanding of selected topics in science. The project had two strands: (1) the development of curriculum and pedagogy to promote conceptual understanding; and (2) teacher professional development and change. This chapter focuses principally on the first of these, namely, the design, development and evaluation of curriculum sequences for teaching specific scientific concepts and the features which need to be taken into account to ensure that these are responsive to what we know about students’ learning. The chapter also draws attention to the changes in teachers’ practice which were required by the project and how teachers responded to these.

A COLLABORATIVE PROJECT

An initial open meeting with local science teachers was held at the University of Leeds early in 1984 to outline and discuss the central aim which was to ‘devise, implement and evaluate teaching materials and strategies which attempt to promote conceptual change in selected science topic areas’ and to base teaching on a constructivist view of learning (Driver & Oldham 1986). The three topic areas of plant nutrition, particulate theory of matter and energy were selected because (1) research on children’s conceptions indicated that they presented particular conceptual problems for learners, (2) they are all concepts which are central to the sciences and (3) they represent important concepts in both the biological and physical sciences. An educational case therefore could be made for investing time and effort in them.

In the overall planning of the project, the issue of what part teachers should play had been the subject of careful thought prior to the first meeting. A number of different ways of working were considered, each reflecting a different relationship between researchers and teachers. There appeared to be two extreme positions which could be taken. The first focuses on the researchers who develop curriculum units, based on specific principles, which they themselves then teach in selected schools. In this model, the teachers do no more than provide access to their classrooms and students. The advantage of such an approach is that the people who are most intimately aware of the rationale behind new curricula and associated pedagogy (the researchers) take the lead in field testing. However, researchers do not know the students and are not aware of the work practices of particular schools. Nevertheless, such an approach has been taken in similar research projects (Adey & Shayer 1994). At the other extreme, researchers work with teachers in a non-interventionist way, observing teaching of specified concepts and identifying, documenting and developing best practices. Such an approach would use an action-research methodology to report back to teachers on what learning is happening in their classrooms and hence give them the opportunity to reflect on and modify their practice. This course of action is essentially
conservative in providing a mirror to teachers' existing good practice, and it
tends to reveal implicit craft knowledge of teaching.

Neither of these approaches matched the aims of the CLIS project which set
out to introduce a new theoretical perspective in devising teaching approaches
which explicitly took account of, and promoted change in, students' existing
ways of thinking. Although such approaches were radically different to exist-
ing practice for most teachers, the aim was to develop materials and expertise
that could be used by experienced teachers in the day-to-day context of science
teaching in high schools. Therefore, it was decided to adopt an interventionist
approach in which researchers worked alongside teachers so that the theoreti-
cal perspective might be brought to bear on the design and development of
teaching schemes which would be practicable in UK high schools (taking into
account factors such as class size, available equipment and lesson time alloca-
tion). In this approach, the research team had responsibility for setting the aims
of the project, for providing a theoretical steer, for providing guidance in
developing curriculum materials and for monitoring and evaluating classroom
trials. The teachers were centrally involved in developing the materials which
they field tested in their own classrooms.

A key issue for the teachers was that they needed to develop an understanding
of the theoretical perspective on teaching and learning which underpinned the
curriculum development work. Just as their students would be challenged to
develop an alternative way of knowing about natural phenomena, so too the teach-
ers faced the challenge of reconstructing their views of teaching and learning sci-
ence. Just as the teaching schemes took account of students' initial thinking, the
curriculum development process needed to help teachers to reflect on and develop
their own views of teaching and learning.

With these points in mind, working groups of about 15 teachers (all of the teach-
ers volunteered to become involved in the project) were set up in each of the three
concept areas. The thinking here was that groups of teachers would provide the
professional and social support which would be needed in a project of this kind.
Furthermore, teachers from particular schools were encouraged to enrol in pairs
to allow for support both within and across the schools represented in the work-
ing groups. In addition, it was anticipated that this number of teachers would bring
a breadth of ideas and skills to the task of curriculum development and also would
offer a range of different kinds of schools in which the materials might be tried
out.

THEORETICAL PERSPECTIVES INFORMING THE PROJECT

The project was based on a constructivist view of learning which was discussed
extensively by researchers and teachers in early meetings and subsequently was
outlined in a position paper (Driver & Oldham 1986). The main features of this
theoretical perspective are described below.
Scientific Knowledge

Science as a form of public knowledge is conjectural and socially constructed, but is also constrained by empirical and rational criteria. As the position paper indicates, 'Science as public knowledge is not so much a discovery as a carefully checked construction. It follows that science in secondary schools involves not just knowledge about events and phenomena in the natural world, but an appreciation of theories as imaginative human constructions' (Driver & Oldham 1986, pp. 109–110). The paper further argues that, although scientific knowledge is a human construction, it aims to represent a shared physical world and thus, contrary to assumptions implicit in some current critiques (Matthews 1992), it assumes a realist not a relativist ontology. An important consequence of this position is that teaching schemes have learning goals which are both conceptual and epistemological. The conceptual goals help students to understand and be able to use scientific frameworks in specific topic domains. The epistemological goals help students to recognise that scientific knowledge is conjectural and to gain an appreciation of the rational criteria (such as consistency, coherence, parsimony) which are drawn on by the scientific community in generating and validating knowledge claims.

Students' Learning

Individuals construct their personal knowledge through social interaction and experiences with the physical environment. Learning, therefore, is a purposive activity on the part of the learner and requires active engagement. Furthermore, individuals' existing conceptions influence the meanings which they construct in a given situation (whether a lecture, demonstration or practical activity), and what is learned results from an interaction between the learner's present conceptions and the various linguistic and sensory experiences provided. Designing teaching schemes to support science learning is therefore inherently problematic in that it requires some appreciation of the prior knowledge that students are likely to bring with them to the learning situation, whilst recognising that individual learners make sense of learning experiences in personal ways. It is not possible, therefore, to design learning sequences in such a way that learning outcomes can be fully anticipated.

Curriculum Development

Following this perspective on teaching and learning science, curriculum was interpreted as being a set of learning experiences which enable learners to develop understanding towards a scientific view (Driver & Oldham 1986, p. 112). This was quite different to prevailing (and current) views which frame curricula in terms of
what is to be taught (statements of the scientific end-points). Interpreting curriculum as a set of learning experiences also leads to a different view of the process of curriculum development. It is not possible a priori to anticipate the ways in which students (with their teachers) will engage with particular learning activities. If curriculum development is to involve development of activities to support learning, that process must include an empirical, reflexive step. In other words, the learning activities are first developed by drawing on best available knowledge about students' thinking in particular topic domains, and then those activities are tried out and refined in the light of those trials. Trialling is an essential part of the development process rather than an optional evaluation step. As we have argued elsewhere, effective curriculum development is essentially a research activity (Driver & Scott 1996), a view which is supported by others (Lijnse 1995). Such curriculum research results both in teaching schemes which are adapted to the needs of learners and documentation of the ways in which young people are likely to respond to the material (hence making it easier for future users of the schemes to anticipate how learners might interact with the materials).

DESIGN AND IMPLEMENTATION OF THE PROJECT

The project program was planned to extend over two years and was divided into two parts, the Preparatory and Intervention phases, each lasting one year.

Preparatory Phase

The preparatory phase of the program focused upon existing approaches to teaching in the three concept areas. Teachers in each working group taught the selected topic in their usual way, monitored the learning of one class of students (aged 13–14 years) using diagnostic tests, and kept a reflective journal of their lessons. In addition, the lessons of two teachers in each group were documented in detail by a researcher who observed and audiotaped all lessons and held discussions with the teacher and students in between the lessons. Case studies of those lessons were prepared as working reference documents for the groups and were published (Bell 1985; Brook & Driver 1986; Wightman 1986).

The purpose of the preparatory phase was to help both researchers and teachers to frame the curriculum problem under scrutiny by reflecting systematically on existing practice. Within group meetings, questions were raised about current approaches to teaching each topic, how students responded to those approaches, the particular problems that students encountered, and how teaching approaches might be revised to address those perceived problems. Thus, steps were taken to problematise the taken-for-granted nature of existing teaching approaches and to question well-rehearsed strategies which had become routinised through their familiarity.
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