

Chapter 22

Teacher Learning and Professional Development in Science Education

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The Institute of Education in London hosts one of the nine Science Learning Centres set up in England in 2004 to promote the professional development of science teachers in each region of the country. The Centres are part of a government initiative to enhance science teaching and learning and offer Continuing Professional Development (CPD) courses that are perceived to be most needed by teachers. A CPD course could focus on technical aspects of teaching science, such as practical procedures, or more fundamental pedagogical practices, such as formative assessment. Courses may be just 1 day, or 2–3 days over a period of time with teachers taking ideas and activities to try out in their schools so that they can reflect and subsequently feed back ideas to colleagues on the course. A model of professional development that entails teachers coming out of school to attend short courses may be limited in its impact on pedagogy, even though such a model is financially and organisationally the most viable. Our concern as Institute researchers is to work in partnership with the Centre, sharing our research findings on teachers' response to innovations to develop a greater understanding of what makes professional development effective. Recently, the Centre has initiated outreach activities in schools in response to science departments requesting such support whilst they attempt to initiate fundamental changes in practice, such as assessment, and these are tailored to be more relevant to teachers' contexts and needs. Our ongoing research, informed by the wider international literature on professional development, attempts to explore other models of professional development that can enrich the work of the Centre.

This chapter presents a review of the literature that has informed our perspective and research on teacher learning and professional development. We address some questions that help to clarify our perspective and discuss models that have informed

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our work. We also draw on our own research on professional development to illustrate practices that provide insights to the success and limitations of professional development design.

What Do We Mean by Professional Development?

In 1996, Beverley Bell and John Gilbert published a book called *Teacher Development: A Model from Science Education*. The model they proposed was based on a 3-year study documenting how a group of New Zealand science teachers changed as they implemented new teaching approaches that would take account of students' existing thinking. The study arose from substantial research into children's ideas and learning in science (Osborne and Freyberg 1985) and constructivist views of learning (Osborne and Wittrock 1985), which had implications for teachers' roles and activities in science classrooms. Essentially, teachers were challenged to change their teaching from a process of transmitting knowledge to a process of helping students to construct scientific knowledge through questioning and testing existing ideas, engaging in different activities and contexts for learning, and reflecting on learning. Bell and Gilbert based their model on a view of learning that takes into account human development and the development of self-identity, social constructivism, and reflective and critical enquiry. The model portrays teacher development as taking place in three intertwined domains, the personal, professional and social, and identifies how progress occurs in each of these three domains. What makes this model so relevant and enduring is that it arose from a study where teachers *reconstructed* their understanding of what it means to be a science teacher in fundamental ways. In recent years there have been other innovations in science teaching that are also underpinned by substantial theoretical research, and we shall document some of these; however, results show that unless teachers really want to change, or really value how a particular change can make their and their students' experience more worthwhile, they will not alter how they perceive themselves as science teachers or radically change their practice.

In our view, Bell and Gilbert's model for teacher development continues to be powerful and relevant as it was underpinned by fundamental questions about teacher learning that we are still concerned with today, and which are appropriate to other innovations being implemented in science classrooms. Bell and Gilbert use the term teacher development interchangeably with teacher learning, yet a distinction between the terms 'development' and 'learning' has since received some attention in the literature. Garry Hoban (2002), for example, rejects the term development as conveying a mechanistic, linear view of learning, characterised by one-off workshops that tend to reinforce existing practice. Hoban argues for a paradigm based on complexity theory where teachers generate new ways to rethink and change existing practice within a professional learning system. Our view of teacher learning and how it can be facilitated coincides with Hoban's, as we show later; however, our interpretation of 'development' as used by Bell and Gilbert, encompasses the notion

of ‘learning’, and their underpinning questions could be read as development or learning:

- What is the nature of teacher development?
 - What factors help and hinder teacher development?
 - What model of teacher development can be used to plan teacher development programmes and activities?
 - What teacher development activities promote growth?
- (Bell and Gilbert 1996, pp. 9–10)

The following account in this section addresses the first three questions in terms of teacher learning, drawing on international perspectives and experiences from our own work in science education. The fourth question is addressed in a further section and focuses on specific examples from our experience of activities and contexts for learning within science education initiatives.

What Is the Nature of Teacher Learning?

The durability of the Bell and Gilbert model is also evidenced by its continued use in more recent attempts to theorise the nature of teacher learning and how professional practice can be changed in sustainable ways (e.g. Fraser et al. 2007). In drawing on the model, Christine Fraser and her colleagues make a distinction that we find useful between what is meant by ‘teacher learning’ and ‘professional development’:

[T]eachers’ professional learning can be taken to represent the processes that, whether intuitive or deliberate, individual or social, result in specific changes in professional knowledge, skills, attitudes, beliefs or actions of teachers. Teachers’ professional development, on the other hand, is taken to refer to the broader changes that may take place over a longer period of time resulting in qualitative shifts in aspects of teachers’ professionalism. (pp. 156–157)

This distinction made by Fraser et al. has synergy with our interpretation of the work of Susan Loucks-Horsley et al. (2003), as these authors also refer to professional development in addressing broader issues of designing programmes, and to specific strategies for professional learning of teachers.

Besides clarifying their position on teacher learning and professional development, Fraser et al. incorporate the concept of teacher change, which they see as coming about through a process of learning that can be described in terms of transactions between teachers’ knowledge, experience and beliefs on the one hand, and their professional actions on the other. David Clarke and Hilary Hollingsworth (2002) also draw on both individual and professional aspects of learning in their account of ‘professional growth’; from a cognitive perspective, teacher growth involves construction of knowledge in the personal domain of the individual teacher, a perspective adopted in Shulman’s early work on pedagogical content knowledge (Shulman 1986), and from a situated perspective teacher growth is constituted through the evolving practices of the teacher (the professional domain). The need to

conceptualise teacher learning from both perspectives is supported more widely in the literature; Hoban (2002) draws attention to the importance of both cognitive and situated perspectives in analysing teacher learning, by taking into account individual processes as well as social and contextual influences; Hilda Borko (2004), in taking what she terms a situative perspective, also emphasises the need to consider both individual teacher-learners and the social systems in which they are participants. The recognition of both cognitive and situated perspectives as important for understanding teacher learning in our view complements and builds on the work of Bell and Gilbert. We conceptualise teacher learning as a complex combination of the individual teacher's knowledge growth, the professional teacher practicing in a particular setting and the social teacher working collaboratively with others in that setting.

What Factors Help Teacher Learning?

In addition to a rationale for professional development based on perspectives of teacher learning is the need to consider how that learning takes place, for example, how the domains of Bell and Gilbert's model can progress, or how Clarke and Hollingsworth's 'growth' can be facilitated. Early studies undertaken by one of the authors enabled her to begin to identify the factors that can influence teacher learning. In the early 1990s, Shirley Simon undertook a study with Alister Jones, Paul Black and other colleagues called the Open-Ended Work in Science project, or OPENS (Jones et al. 1992). This project focused on how teachers, working alongside researchers, could make changes in their practice as they engaged in more inquiry-based activities in response to the new national curriculum in England. Working with a group of teachers we explored each existing situation to negotiate a starting point for development, planned the new approaches with the teachers who subsequently put these into practice, then reflected on and evaluated the changes and outcomes with the teachers. We found that teachers were so different in their individual needs and contexts that these features of existing practice, negotiation, reflection and evaluation were critical for change (Jones et al. 1992). Though the study was researcher dependent and did not follow through to gauge learning and sustained change, it alerted us to the need for establishing these features in a professional development context.

Some years later, Simon became involved in the professional development of teachers as part of a major innovation called Cognitive Acceleration in Science Education (CASE). CASE was founded by Michael Shayer and Philip Adey, drawing on a theoretical base derived from the work of Piaget and Vygotsky. Shayer and Adey set out to apply their analysis of students' reasoning in terms of Piaget's stages of development (Shayer and Adey 1981) and over many years established evidence for the effects of cognitive acceleration (Adey and Shayer 1994). They designed science curriculum materials to promote formal operational thinking (Adey et al. 1995), and a professional development programme to support teachers as they attempted to use the materials to promote cognitive conflict and social construction

of reasoning. The development programme involved university-based workshops, in which teachers were introduced to the theoretical base, engaged in activities to experience cognitive conflict and construction, and shared with each other reflections on practice. These workshops were combined with in-school coaching (Joyce and Showers 1988), where ‘trainers’ observed lessons and gave individual or departmental feedback. Evaluation of professional development was not focused on individual teacher learning, but on sustained implementation by science departments. Collegiality and ownership of the innovation were seen as critical factors in helping to maintain its implementation, as evidenced in a study of ‘level of use’ conducted by Adey, Simon and others (Adey 2004). Factors influencing individual teacher learning became apparent through close contact with teachers, and included motivation to want to change, an understanding of the theoretical basis of the curriculum materials and teaching approach, and an appreciation of perceived benefits for students.

Our more recent work on research into professional development has drawn on the insights of Hoban (2002), who, in arguing for the notion of a professional learning system, identifies eight conditions that are needed to bring about teacher learning. These include:

- A conception of teaching as a dynamic relationship with students and with other teachers where there is uncertainty and ambiguity in changing teaching practice
- Room for reflection in order to understand the emerging patterns of change
- A sense of purpose that fosters the desire to change
- A community to share experiences
- Opportunities for action to test what works or does not work in classrooms
- Conceptual inputs to extend knowledge and experience
- Feedback from students in response to ideas being tried
- Sufficient time to adjust to the changes made

An evaluation of whether or not these conditions for learning are present in the context of an innovation can provide the basis for planning work with teachers. As Hoban points out, on its own, each condition is unlikely to sustain teacher learning; it is the combination of conditions that is important.

What Models of Teacher Learning Can Be Used?

In this section we look at ways in which factors and conditions for helping teacher learning have provided models for planning professional development. Models take different forms and we discuss some of the features of models that have informed our work with teachers.

Bell and Gilbert’s model (1996), which we have outlined above, included a key feature of progression in each of the three domains of development, personal, professional and social. The first stage of development occurs when teachers begin to see an aspect of their teaching as problematic (personal) and practicing in isolation

as problematic (social), so they are motivated to seek out and try out new ideas in their practice (professional). As they progress in their development, teachers deal with feelings and concerns that come about as they behave differently, for example, loss of control, insecurity in subject knowledge, or uncertainty about how to intervene, and begin to change their ideas of what it means to be a science teacher (personal). They also begin to see the value of collaborative ways of working (social) and have confidence to develop their own ideas for classroom practice (professional). Progressing further in their development teachers feel empowered through increasing confidence (personal), they initiate or seek out collaboration (social) and eventually facilitate new kinds of professional development activities (professional). The notion of progression in this model can provide a basis for teachers to evaluate their learning within each domain, and how the three domains are intertwined. In an account of how particular teachers developed in the study, Bell and Gilbert identified the process of reflection as a key condition for progression. Reflection has become an integral part of many other models, either generating cycles of action, as in Jones et al.'s negotiated intervention (1992), or as a fundamental process for stimulating change, as in Clarke and Hollingsworth's Interconnected Model (2002).

Clarke and Hollingsworth built on Thomas Guskey's (1986) linear model for change and created a cyclic version with different entry points, where change is seen to occur through the mediating processes of reflection and enactment in distinct domains: the personal domain (teacher knowledge, beliefs and attitudes), the domain of practice (professional experimentation) and the domain of consequence (salient outcomes). In addition, the external domain provides sources of information, stimulus or support. The term enactment was chosen

... to distinguish the translation of a belief or a pedagogical model into action from simply 'acting', on the grounds that acting occurs in the domain of practice, and each action represents the enactment of something a teacher knows, believes or has experienced. (p. 951)

The term 'reflection' originates from Dewey's notion of active, persistent and careful consideration where, for example, a reflection and re-evaluation of outcomes can lead to an alteration in beliefs and, hence, a reflective link between the domain of consequence and the personal domain. A further consideration of the Interconnected Model is the change environment, for example, being a member of a school community where colleagues can share the consequences of their experimentation. We have found this model particularly useful in mapping out changes we perceive over time in how teachers engage in an innovation. Teachers can be seen to be stimulated by external sources of ideas which prompt changes in practice (enactment leading to changes in the professional domain), they review their practice and re-evaluate what is important in their student outcomes (reflection leading to changes in the domain of consequence), begin to reconstruct their notion of teaching (the personal domain), which in turn leads to further enactment in the professional domain, a re-evaluation of outcomes and so on. Mapping progression using this cyclical model can form the basis of a dialogue between researchers and teachers, and amongst teachers, which enables them to recognise the continuous nature of their own learning and the processes through which it is mediated.

A useful analysis of different models is offered by Aileen Kennedy (2005), who presents a framework for looking at CPD (Continuing Professional Development) models in a comparative manner. The analysis focuses on the perceived purpose of each model, and Kennedy proposes a set of categories under which models of CPD might be grouped. These categories are organised along a spectrum that identifies the potential for transformative practice. The first set of models includes those that focus on training, such as the 1-day courses attended by teachers, usually off-site, deficit models that are underpinned by performance management, and cascade models where skills and knowledge acquired at training events are disseminated to colleagues. Kennedy identifies all of these models as being underpinned by transmissive views of teacher learning. These models can serve a purpose in terms of enabling teachers to become more informed, or broaden their knowledge and skills, but as they are essentially technician in nature, they are unlikely to result in fundamental changes in pedagogy. The next set of models includes those based on coaching/mentoring and communities of practice, which Kennedy terms 'transitional' as they can support either transmissive or more transformative conceptions of teacher learning, depending on the nature of the relationships involved. Coaching could take the form of expert/novice partnerships or more collegial forms of peer coaching, whereas community of practice models would involve more than two people. Fundamental to successful CPD within a community of practice is the issue of power and the level of control over the agenda (Wenger 1998) exercised by the community. Models that can be transformative in bringing about sustained change would include those communities of practice where individual knowledge and experience is enhanced through collective endeavour. Shulman and Shulman (2004) provide models of learning communities that work through a shared vision or ideology that is realised through shared commitments supported by organisational opportunities for learning. Other transformative models include action research, where teachers analyse their own practice in order to make changes in a cycle of reflection and action, or include opportunities that provide links between theory and practice, reflection, construction of knowledge and autonomy involving a sense of empowerment. In our view, these models are most likely to bring about sustained change.

Practices for Teacher Learning and Professional Development

In designing professional development for science and mathematics teachers, Loucks-Horsley et al. (2003) identify six clusters of strategies for professional learning:

- The importance of aligning and implementing quality curriculum materials with opportunities to reflect on their use
- Collaborative structures
- Examining teaching and learning through action research and case discussion
- Immersion experiences where teachers benefit from engaging in activities designed for student learners

- Practicing teaching including coaching, mentoring and demonstration lessons
- Vehicles and mechanisms such as courses, workshops and strategies for ‘developing professional developers’

In this section we draw on examples from our own practice of professional development to provide insights to the success of some of these and other strategies in setting up conditions for teacher learning and enhancing transformative aspects of professional development.

Curriculum Resources

The strategy of accessing good quality curriculum resources, embedding these within a scheme of work and having opportunities to reflect on their use was apparent in the CASE initiative. The materials produced by the CASE team (Adey et al. 1995) included detailed lesson plans for teachers that documented equipment needs, suggested timings and interaction strategies, and an abundance of student resources for each lesson. In the professional development programme, schools were encouraged to embed the 32 activities within the curriculum over a 2-year period, and to encourage all department members to adopt the scheme. Often this process worked well, as departmental implementation meant that all teachers could access the materials and were encouraged to teach the CASE lessons as part of an expectation to ‘deliver’ the programme for the school. However, many teachers had CASE foisted upon them without any sense of ownership, and much of the success of the innovation was determined by pioneering individuals who instigated the programme within their schools, convincing their senior management team of the CASE effects. When these individuals left the school to be promoted elsewhere, CASE often ceased to happen. However, the CASE approach of cognitive challenge and social construction became embedded within science teaching if it was valued, and it persisted either through the continued implementation of the CASE lessons themselves, or adaptations in different contexts that could be used to promote the same reasoning patterns.

Further experience of the power of good quality curriculum materials is evidenced in the argumentation projects undertaken by Simon since 1999. Simon worked with colleagues Jonathan Osborne and Sibel Erduran on a project called Enhancing the Quality of Argument in School Science (EQUASS). This project arose from concerns about extending the emphasis of school science to enhance reasoning (as with CASE), to help students develop their epistemological understanding (Driver et al. 1996), and to develop argumentation skills such as justifying claims using evidence in both scientific and socio-scientific contexts. The initial stage of this argumentation project involved a partnership with a group of teachers to design curriculum materials that would be aligned to their existing curriculum, thus addressing the requirements of the national curriculum. Individual teachers working on the project were provided with frameworks for argumentation activities (Osborne et al. 2004a) and either used them directly, adapted them, or designed new activities most suited to their school contexts and existing practice. Following the

research phase that focused on teachers' changing practice (Simon et al. 2006), the team developed a set of resources comprising 15 lessons that included lessons aims, teaching procedures and student materials. This publication (Osborne et al. 2004b) formed part of a set of professional development activities called the IDEAS pack. The resources in the pack have proved invaluable in helping teachers new to argumentation to 'get started', in that the materials can be used as they are, or be adapted for use to match curriculum topics and classroom contexts. The resources have been the stimulus for the development of further activities by pre-service teachers (Simon and Maloney 2006) and practicing teachers engaged in a project of evidence-based professional development using portfolios (Simon and Johnson 2008). The IDEAS resources continue to provide a stimulus for ongoing work with teachers who are developing argumentation within whole departments in London schools; initial use of the actual materials has evolved to incorporate individual designs appropriate to curriculum needs and classroom contexts.

Recently, observations and conversations with teachers using IDEAS lessons have demonstrated the need to analyse more closely the design of the lessons and their implications for effective planning and teaching (Simon and Richardson 2009). The frameworks themselves, such as concept cartoons, competing theories or predict/observe/explain activities (Osborne et al. 2004b), do not provide a sufficient indication of how they will work in practice. The science contexts in which the lessons are set and the plan of how to put them into practice are critical factors, as are the teachers' interpretations, introductions within lessons and interactions with students. Presenting teachers with readily usable resources rests on an assumption that development comes from practicing specific processes. Our concern is with the question of *how* teachers construct activities from such resources that will enable students to develop their argumentation.

Immersion Activities

Immersion activities have become a feature of both CASE and argumentation professional development programmes. For example, in centre-based workshops of the CASE programme, teachers were provided with experiences to promote cognitive conflict, including student activities from the course materials. One example observed in CASE workshops included an activity where students had to blow into or tap tubes to make musical notes (Adey et al. 1995). The tubes varied in a number of ways; they were made of different materials and had different dimensions of width and length. Students were required to articulate their reasoning about which variables would make a difference to the pitch of the note, through designing combinations of tubes that would eliminate variables systematically. As teachers engaged in this activity they were encouraged to question each other about their reasoning, and enact the kinds of intervention that would stimulate conflict and social construction of reasoning with students. These immersion activities were a common feature of CASE workshops and helped teachers to discuss the essential features of the CASE teaching approach.

The IDEAS pack of argumentation lessons is accompanied by sessions designed to promote teachers' own rationale for argumentation, and pedagogic strategies for use in the classroom such as constructing arguments, group work, evaluating arguments, counter-argument and modelling argument. One immersion activity aims to help teachers consider that the evidential basis for scientific ideas is not easily articulated and, therefore, may not be explored in science teaching. Teachers are asked to decide what evidence there might be for some common ideas, for example, Day and Night are caused by a spinning Earth, plants take in carbon dioxide and give out oxygen during photosynthesis, living matter is made of cells, and we live at the bottom of a 'sea of air'. This activity helps teachers to think about the value of using argumentation activities to extend their teaching goals beyond a focus on content to include epistemic questioning about the evidential basis for scientific claims. Other immersion activities involve the use of group-work strategies, such as listening triads, to enable teachers to experience how such strategies might work with students. Triads are often used to explore the ideas within a concept cartoon (Naylor and Keogh 2000), where students express alternative ideas about a phenomenon, such as the rate of melting of a snowman with or without a coat. In the triad one participant takes on the role of explaining the ideas portrayed by the students in the cartoon, one takes on a questioning role and one a recording role. Immersion activities such as these, using the pedagogical strategies and IDEAS lesson plans together, not only enable teachers to think about their approach, but also provide a basis for them to analyse and become familiar with resources they can use with students.

Reflection and Sharing

We have seen that most models and perspectives of teacher learning include the notion of reflection. The idea of reflective practice became well established by Donald Schön (1983), who views the reflective practitioner as an expert performer capable of skilful action. Experienced practitioners acting in their everyday practice demonstrate the kind of knowledge, called 'knowing-in-action', that is tacit and which they depend on to work spontaneously. Schön sees knowing-in-action as the simplest component of reflective practice. In addition, 'reflection-in-action' is perceived as occurring during activity whilst the practitioner responds to the moment, resulting in constant adjustment to what is happening. A further component of reflective practice, 'reflection-on-action' involves thinking about an event after it has occurred. It is this component of reflective practice that is used in a general sense in the context of teacher learning. Many authors concerned with the nature of reflection have focused on different kinds of reflection on action, for example, Neville Hatton and David Smith (1995) and Lily Orland-Barak (2005) question what it means to be 'critically reflective'. Critical reflection can be contrasted to lay reflection (Furlong et al. 2000) or technical, descriptive and dialogic reflection (Hatton and Smith 1995). These levels of reflection are characterised by recounts of personal experience, whereas critical reflection reviews experience in the light of

other forms of professional knowledge. Nona Lyons (1998) uses the metaphor of weaving and threading to illustrate how critical reflection can connect different experiences to bring into consciousness teachers' beliefs and values.

The role of reflection in the adoption of CASE, though clearly a feature of Adey's model (Adey 2004) and the CASE programme's intentions, was not structured into the work in schools outside of coaching by the developers, unless pioneered by the teachers themselves. In later cognitive acceleration programmes for younger children teachers were asked to write a log of their reflections, but few teachers found this useful (Adey 2004). Group reflections that took place between teachers who attended workshop days based at the teachers' centre were found to be more valuable. This model of building in reflective activity when teachers from different schools come together was adopted in all the argumentation projects undertaken since 1999. In the initial project, where individual teachers were implementing argumentation in isolation, reflection became an important component of centre-based days when they all met each other. Subsequent projects additionally involved teachers constructing written reflections in portfolios (Simon and Johnson 2008). The act of reflection was powerful, but the time for teachers to produce written reflections tended to be lost to other essential activities. The role of reflection has become more prominent as a mediating factor for teacher learning in ongoing research to develop argumentation practice in whole school science departments. Within each department teachers have embedded argumentation activities within the curriculum and meet once a month to reflect on their experience of teaching the activities. Over time the nature of shared reflection has changed from descriptive personal accounts of what went well or not, to more analytical observations of personal learning, effective practice and evaluation of student outcomes. Likewise in their analysis of teacher learning in communities of practice, Shulman and Shulman (2004) note the crucial role of shared meta-cognitive reflection, where teachers critically discuss their work with each other, and reflection is the central component of their model of teacher learning and development.

The act of reflection has great significance in the learning of pre-service teachers. For them the act of reflection is a prescribed process they have to demonstrate in their qualifying standards, and reflection on action is an important process for looking forwards when planning for the future. However pre-service teachers are limited in their ability to reflect meaningfully when they have little experience of theory and practice. The following account from Sandra Campbell's research on the process of reflection in pre-service teachers shows how the use of video can be a powerful strategy for enhancing reflective practice (Campbell 2008).

Video-Stimulated Discussions with Pre-Service Teachers

Pre-service teachers in England have to show evidence of reaching Qualified Teacher Status (QTS) by being assessed against standards produced by the Training and Development Agency for schools (TDA). A recent addition to these standards

(TDA 2007) requires pre-service teachers to 'reflect on and improve their practice and take responsibility for identifying and meeting their developing professional needs'. The standard presupposes that a teacher who is able to reflect on practice can learn from the knowledge and understanding gained from this reflective process, and can become a better teacher. But what is the nature of reflection for the inexperienced teacher?

The work of Chris Argyris and Donald Schön (1978) can be used to interpret and illustrate a pre-service teacher's reflections on practice. For Argyris and Schön learning involves the detection and correction of error. They suggested that when things go wrong, a starting point for many people is to look for another strategy that will address the problem while still working within their governing variables – these governing variables being their values that they are trying to keep within acceptable limits. In doing this they are not questioning goals and values, they are trying to find a way of working within the existing framework – what Argyris and Schön would term single-loop learning. An alternative response is to critically question the governing variables themselves, this they describe as double-loop learning. Such learning may then lead to an alteration in the governing variables and thus a shift in the way in which strategies and consequences are framed. The following scenario of a pre-service teacher learning how to teach practical science can be interpreted in this way. The teacher considered her first practical lesson as unsatisfactory because she had rushed the plenary session. On reflection she realised she had not given sufficient time earlier in the lesson for the students to carry out the practical work. In her subsequent lesson she laid out the practical equipment in a tray system to save time, which allowed more time at the end to consolidate learning. This new strategy became part of her repertoire, an example of single-loop learning. In a subsequent lesson, the teacher observed the students as they collected their equipment from trays and questioned whether this practice was limiting their autonomy and collective decision-making in practical work. She was now beginning to question the governing variables of her lessons and subsequently altered her strategies again, providing an example of double-loop learning where feedback from previous experience stimulates a questioning of assumptions previously taken at face value.

Pre-service teachers being asked to reflect on practice can thus be operating at different levels of criticality depending on their emergent professional knowledge. They are pressed to live up to the expectation that good teachers are reflective teachers (van Manen 1995), and yet they do not necessarily have adequate guidance as to how and when to reflect. Michael Eraut (1995) suggests that pre-service teachers may have neither the time nor the disposition to reflect because they need to develop habitual routines and become familiar with a wide range of situations; the imposition to reflect may be perceived as a threat. Reflection is difficult for novice teachers as their lack of experience limits their ability to meaningfully reflect during a lesson. Work undertaken with pre-service teachers suggests that if reflection on practice takes place in discussion with others, these teachers can find meaning where it was not initially obvious. In a study to explore ways in which pre-service teachers can be encouraged to reflect, Campbell (2008) conducted research into the use of video-stimulated recall of lessons, as video has been shown to provide a powerful means

of stepping back and analysing practice when novice teachers engage in a dialogue about what is observed (Brophy 2004).

Working with three pre-service teachers studying for a Postgraduate Certification of Education (PGCE) at the Institute of Education, Campbell, who was their tutor, conducted video-stimulated recall (VSR) of in-depth interviews which took place in the week following her observation and filming of their lessons. A further interview was conducted a month later to ascertain whether the research had stimulated learning such that it impacted on practice. Campbell found that many initial comments were of a descriptive nature, for example, the pre-service teachers focused on how they were gesticulating with their hands whilst talking to the class, or how the students were behaving. Using Hatton and Smith's (1995) categories of reflective practice, she found that the most common kind of reflection was also descriptive. In some instances, the pre-service teachers reflected more deeply, stepping back from an immediate response to consider why they acted the way they had. Campbell calls this 'mulling reflection'. With some prompting and in discussion with their tutor two of the three pre-service teachers showed some instances of deeper, critical, reflection. As novices lacking experience this was not surprising. There was little unprompted discussion of subject pedagogy, with surface features such as the behaviour of the students tending to dominate the pre-service teachers' reflections. With prompting, more discussion of subject pedagogy took place, and guidance was needed to ensure that their reflection encompassed aspects of teaching and learning. The teachers in this small sample were aware of the drawbacks of having their lessons filmed, but did not believe that these drawbacks outweighed the benefits of the video. Through video-stimulated discussion they perceived advantages gained through talking about their lessons with a critical friend, and developed ideas for using the videos in a wider context.

Conclusion

In this chapter, we have drawn on international literature sources and our own experience in London to show how teacher learning can be conceptualised and professional development planned effectively. Teacher learning is a complex process, beginning with the pre-service teacher's experience and continuing throughout a teaching career. The motivation to learn comes from within a teacher as she or he reflects on the outcomes of practice, and perceives a need to change. Choices open to teachers who want to learn are often external courses they can attend, and though these can be beneficial and assist some aspects of learning, they are unlikely to initiate fundamental changes in how teachers view teaching and change practice. Increasingly, schools identify their own needs and initiate their in-house programmes of professional development, though change from within may be dictated from senior management rather than be part of a community of practice with a shared vision and commitment to change. Underpinning any approach to professional development is a perspective on teacher learning, and this perspective needs to be

recognised and taken into account in the way in which the professional development is conceptualised. In a climate where teachers have to meet teaching standards and professional developers are subject to external demands that require particular models and content of professional development programmes, it can be a challenge to pay due consideration to the conditions, factors and mediating processes that promote learning. The analysis of teacher learning and professional development we have offered in this chapter shows the complexity of the task of those who, like the staff of Science Learning Centre London, have a role to play in making provision for professional development. Sharing our analysis of models of teacher learning and professional development that are based on clearly articulated views of learning helps to foreground the agenda of personal motivation, reflective analysis of practice and evaluation of salient outcomes that is at the heart of teacher learning.

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