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EXPERIENCE, INTENTION AND PRACTICE IN THE TEACHING OF 5-14 PRIMARY SCIENCE

by

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Dicit ei Iesus ego sum via et veritas et vita nemo.

Venit ad Patrem nisi per me.

[*Jesus saith to him, 'I am the way, and the truth, and the life,*

no one doth come unto the Father, if not through me.]

[John 14 : 6]

ABSTRACT

This research used quantitative and qualitative research methods to examine the experience, intentions and practice of pre-service primary students in order to determine the nature of student teachers' paradigms of science. The research identified a dissonance between the students' aspirational rhetoric and the actuality of the experiences they provide for learners.

This research framed the discourse of teaching and learning in terms of objectivist and constructivist paradigms. It was argued that the objectivist paradigm of science teaching has historically been dominant in science classrooms; however, it is the constructivist paradigm which is linked to an effective pedagogy in science education.

This research examined the students' school qualifications in science, stated confidence levels in teaching the 5-14 science curriculum and the students' views on how best to take forward teaching and learning in primary science. The students were found to be poorly qualified in science; however, it was shown that this does not have had any adverse upon the pre-service students' self-rated confidence levels in teaching primary science. Confidence indices were found to be consistently high, albeit slightly lower with respect to Physics. This research has also shown that there is a consistent pattern of increasing confidence with progression through the BEd course, and consistently low levels of confidence with respect to the PGCE students.

This study identified a dissonance between the pre-service students' experience of science and how they propose to teach science. It was shown that the pre-service students' experience was negatively orientated, and firmly rooted within the objectivist paradigm. However, it was found that the students' stated intentions are framed in terms of the constructivist paradigm. The research also determined that the students are confident that they possess the professional skills necessary to take forward teaching and learning in primary science.

An observational schedule was developed and used to facilitate an exploration of the classroom practice of students teaching primary science. The structural components of several lessons were examined, and it was shown that there is a generic pedagogy used across a range of different types of lesson. This research shows that pre-service students seek to control the pupils' learning environment through deploying a transmissive pedagogy. This is related to the pre-service students' lack of school qualifications in science along with a range of negative views towards school science, particularly Physics.

This research found that the experience of science, provided to pupils, consisted of a 'closed pedagogy' utilising factual and procedural talk with questioning formats focused on the 'recitation' of 'right' answers. The research also shows that the pre-service students plan lessons which fail to engage with the pupils' knowledge base. This study identified a number of problems with regard to the pre-service students' lack of knowledge of science. The research identified multiple instances of incorrect science teaching as well as 'linguistic looseness' in engaging pupils in science talk. However, there were also a number of students who displayed 'constructivist' traits in their teaching.

The research suggests that there is a need for cross-fertilisation of ideas and thinking between the Department of Curriculum Studies (Science) and the Centre for Science Education. Further observational studies, focussing on the 'folkways' of teachers' teaching, are required to consider the behaviours of pre-service student teachers in a structured and integrated way such that we can develop a strategy for progressive change. This study suggests that a possible way forward is the creation of 'communities of science education practice' (CoSEP) rooted in an interpretation of experiential learning which stresses the importance of collaborative, problem-solving activity rather than imitative practice. The CoSEP would aim to engender discourse between the science tutors, students, especially more knowledgeable others among the student body, and professionals working in primary schools. This discourse would focus on the activity of science education through the use of 'microteaching' enabling students to derive meaning from the information that is exchanged. Microteaching would be used to create a 'performative space' enabling students to triangulate the multiple perspectives of the CoSEP within authentic contexts (*i.e.* realistic, meaningful and relevant to real-life situations).

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CHAPTER 1 INTRODUCTION

1.1 A paradigm shift?

One only knows something if one can explain it.

[Giambatista Vico, 1710]

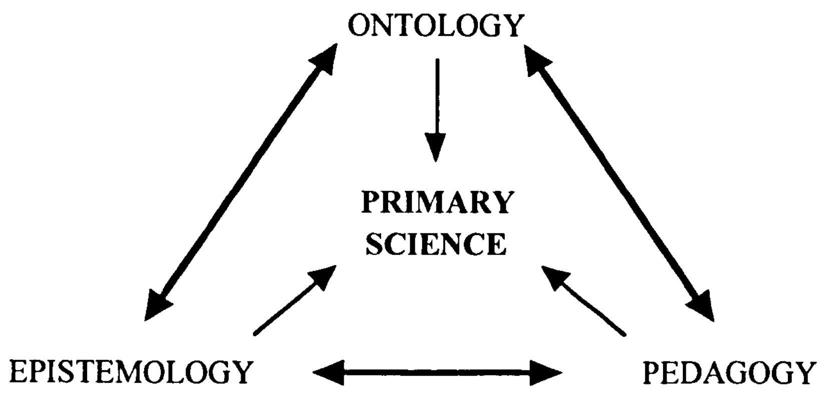
Within primary science education there has been a sea-change in thinking over the last fifty years, what Kuhn (1970) would call a *paradigm shift*, as science educators have sought to re-examine and reconceptualise their views of learning and teaching (Burbules and Linn, 1991; Tobin, 1993; Nola, 1997). Paradigms consist of three features: ontology, epistemology and pedagogy (Cohen & Manion, 1994). This distinction between ontology, epistemology and pedagogy is important in understanding the nature of the experience of science that teachers provide to learners (see Figure 1.1).

It is generally held that an individual's epistemological views are dependent upon their ontological views (Coll and Taylor, 2001). The question as to what is the form or nature of reality, what is there that can be known, is referred to as ontology. The term epistemology comes from the Greek word epistêmê which is their term for knowledge. Epistemology concerns itself with the relationship between the knower and the known with the question of 'how can we be sure we know what we know?' (Coll and Taylor, 2001). In simple terms ontology is *the what to know*, and epistemology is the philosophy of knowledge or *how we come to know*. Cohen and Manion (1994) indicate that there are basically two views of looking at reality by asking the question:

> *is reality external to individuals, imposing itself on their consciousness from without, or is it the product of individual consciousness?*
>
> [Cohen and Manion 1994, p.6]

That reality is external to the individual is the position of the long-dominant epistemological theory of *objectivism* (Hardy and Taylor, 1997), this is often referred to as the *traditional* approach in many policy documents. From an objectivist perspective scientific knowledge exists outside the reference frame of the observer (Taylor *et al.*, 1997). This reality is immutable and conforms to natural laws, many of which possess the nature of cause and effect. This leads to a realist ontology which has, in its most extreme form, developed a view of the *curriculum-as-product*, comprising a fixed body of knowledge which the learner must come to *know*. Within such an objectivist perspective the aim of science education is to transmit the knowledge experts have acquired to the students. Implicit in this is the belief that experts' knowledge is closer to reality than beginners' knowledge (Davis *et al.*, 1993). Within such a curriculum information is divided into parts which build to form a whole concept. The role of the teacher-as-expert is to serve as the conduit for the transfer of this information through teacher-talk, worksheets and textbooks. There is little opportunity for pupil-initiated questions, independent thought or interaction among pupils. The converse of this is the emerging *social constructivist* epistemology. This gives rise to a relativist ontology which asserts that there exists multiple, socially-constructed realities. Learners construct personal realities which make sense to them through negotiation with others, so developing shared meanings. This relativist ontology leads to a view of the *curriculum-as-process* whereby the teacher's role is as a facilitator of the pupils' learning, this is often referred to as the *progressive* approach in many policy documents. The pupils' experience of science education is one in which the focus is less concerned with absolute truths rather than agreed, contextual explanations which make sense of and explain observed phenomena (Davis *et al.*, 1993).

Figure 1.1: Linkage between ontology, epistemology and pedagogy with primary science



[Adapted from Littledyke, 1996]

The third element of a paradigm is that of pedagogy which is derived from the Greek paidagögiá which in turn comes from paidagögós (paid-, boy; + agögós, leader) A pedagogue was someone, usually a slave, who led a boy to school. There are many interpretations placed on the modern-day meaning of pedagogy such as '*any conscious activity by one person designed to enhance learning in another*' (Mortimore, 1999, p. 3) or more simply the *how to teach*. Pedagogy is a term which is not much used in English-speaking countries where the more commonly used term, in literature on education, is that of 'methodology' which has as its focus the study of the *methods* and activities of teaching that we can use to develop our understanding. Epistemology and methodology are intimately related with the former concerned with how we come to know the world whilst the latter concentrates on the *practice* which will best support us in coming to know the world. Once more the answer to the methodological question is dependent upon an individual's stance on the ontological and epistemological questions. For example, those subscribing to realist ontology and objectivist epistemology tend to rely on inquiry that is experimental, in which variables are controlled, questions or hypotheses are stated and are evaluated by empirical testing. In this approach careful control of experimental conditions is necessary to prevent outcomes being subject to extraneous influences (Coll and Taylor, 2001).

An appreciation that an individual's ontological assumptions affect our epistemological assumptions which in turn affect our methodological assumptions is not simply an academic exercise; as this will enable us to negotiate a passage through the minefield which has been strewn between the commonly held educational paradigms of objectivism and constructivism. In a later chapter it will be shown that these two paradigms have been dominant in much of the thinking within primary science developments. The relationship between ontology, epistemology and methodology is intimately related to the paradigm adopted. This, in itself, is not necessarily controversial. However, implicit in this is that we cannot select an alternative methodology as each methodological approach is predicated upon epistemological and ontological assumptions and, more controversially, these methodological approaches are then presented as being mutually exclusive. This has resulted in a degree of polarisation with respect to pedagogy. This is unfortunate as it is my contention that science education can accommodate a constructivist pedagogy based around ontological and epistemological assumptions which are allied to an objectivist perspective (Driver and Bell, 1986). Furthermore there are times when it may be appropriate simply to provide factual information as part of the pedagogic strategy. Consequently my position is that rather than a paradigm shift, we have come to recognise and use language to describe a duality of approach which has always been evident in the scientific endeavour. What is clear is that the choice of pedagogy is never innocent as it is a medium that carries its own message, it communicates a conception of the learning process and the learner (Bruner, 1999).

1.2 Student teachers and primary science

Among the key aims of science teaching is the development in our pupils of an understanding of the science subjects, the scientific enterprise and the nature of science. To achieve this it is necessary to be aware of and articulate the epistemological view of science, as it relates to teaching and learning, that we wish to share with our pre-service primary students. This thesis will look at what pre-service primary students think about science. This knowledge will enable us to explore strategies to challenge and develop the pre-service students' understanding of the nature of science. The contention is that such an understanding is important if the pre-service students are to develop effective teaching strategies to take forward learning in the primary school. Currently it is unrealistic to expect pre-service students to have detailed knowledge of the nature of science for the simple reason that it is not a significant component of their primary science method courses. Accordingly, this thesis will not seek to examine in depth the values and assumptions inherent in the different philosophical viewpoints of the nature of science; nor is it my intention to assert that there is a single accepted view. This said it is, nevertheless, important that we have a contextual framework within which to frame our thinking. The danger inherent in attempting to outline such a framework is that we become a hostage to fortune at the mercy of those who hold different views. This cannot be avoided, and indeed is expected when one considers that the debate on the nature of science has largely been conducted amongst those with an interest in science education within philosophy and education departments, rather than amongst active scientists. Each of these groups is likely to bring with them slightly different perspectives to the debate which may not be compatible.

Murcia and Schibeci (1999) argue that science is essentially a human activity and that this contradicts the experience that most pupils have of school science, which tends to be individual and non-social. School students also come to see science as the memorisation of facts and formulas rather than the development of investigative skills linked to resolving problems in real-life contexts (Burbules and Linn, 1991). The constructivist perspective adopts a different position with respect to school science education leading a number of researchers (Cleminson, 1990; Lederman, 1992) to articulate some of the salient features, or basic 'tenets', of current thinking on the nature of science:

- scientific knowledge has a temporary status and should not be accepted as unquestionable truth;
- scientists study a world in which they are a part and as such their work is not objective or value free;
- new scientific knowledge is produced as a result of creativity and imagination coupled with scientific method;
- science progresses through continuing research and critical questioning;
- science is dynamic and on-going, not a static accumulation of information;
- observations of the world are made through coloured lenses built up by prior knowledge, beliefs and theories;
- scientists and the scientific community generally display the professional standards of openness of mind and honesty. They are moral and ethical in their approach.

[Murcia and Schibeci, 1999, pps. 1124-1125]

It could be argued that the 'tenets' of current thinking on the nature of science, outlined above, are themselves only one view of science through 'coloured lenses'. Science teachers are rarely explicit about pedagogical theories which guide their practice. Indeed, it has been suggested that science teachers are often cynical about the worth of such theories (Newton *et al.*, 1999). However, science does consist of a socially-constructed body of knowledge. Knowledge claims are verified by the scientific community on the basis of the strength of the argument presented. These knowledge claims are tested, with experiments being repeated and checked by other scientists, who often will attempt to present alternative interpretations themselves, in order to decide whether to accept, modify or reject the claim. In this way scientific knowledge moves forward, or returns to the known, within the context of scrutiny by the scientific community.

Murcia and Schibeci's (1999) basic 'tenets' are consistent with the views expressed by those with an interest in school-based science education such as the American Association for the Advancement of Science (1993) in their statement of benchmarks for scientific literacy. Similar developments in Scottish education (SEED, 1999; SEED, 2000b) seek to introduce constructivist thinking into 5-14 science teaching as part of the strategy to enhance pupils' experience of science and as a means of raising attainment. As such I intend to make use of these 'tenets' as a contextual back-drop to frame the pre-service students' views on the nature of science, and the teaching strategies they deploy when teaching primary science.

There have been several studies which have attempted to explore the views that pre-service students have with regards to the nature of science and the significance of these views for science education (Cleminson, 1990; Lederman, 1992; Matthews, 1998). The assumption is that knowledge of why science believes what it does, and how science has come to think that way, is critical in informing science teachers' decision making (Abell and Smith, 1994). Research has also attempted to determine the nature of the linkage between a teacher's knowledge of a subject and the way that they teach their subject (Craven and Hand, 2002; Tsai, 2002). This has led to the development of a '*deficit model*' of teachers' knowledge (Askew *et al.*, 1997; Brown *et al.*, 1998) with the clear conclusion that teachers could not teach what they did not know (Bennett, 1993; Poulson, 2001). Additionally some research has speculated that teachers' beliefs may affect their teaching practice (Nespor, 1987; Koulaidis and Ogborn, 1995). These linkages are not straightforward (Lederman, 1999); however, connections have been detected between teachers' epistemological views, understanding of the subject and classroom practice (Brickhouse, 1990; Kennedy, 1998; Tsai, 2002).

It has also been argued that a deeper understanding of the nature of science is more likely to result in a greater degree of scientific literacy (Bybee, 1997) and that this leads to a greater engagement with science (Matthews, 1994b; Lederman, 1998).

Matthews (1994b), and Abell and Smith (1994) also argue that teachers with a more complex understanding of the nature of science are more likely to make appropriate teaching decisions which will develop scientific literacy in their students:

> *if students are to become scientifically literate, in part through understanding the nature of science, it stands to reason that their teachers must understand how science works so that they can model appropriate behaviours and attitudes.*
>
> [Abell and Smith, 1994, p. 475]

Research has also indicated that pre-service students generally have views of the nature of science which are out-of-step with current accepted thinking (Hewson and Hewson, 1987; Lederman, 1992; Solomon *et al.*, 1996). Clearly this is of concern in that those teachers with an inappropriate understanding of the nature of science will be unable to make effective pedagogic choices (Lederman, 1992). King's (1991) research with pre-service science teachers found that they were unable to articulate teaching methods related to the nature of science. In order for teachers to promote appropriate behaviours and attitudes amongst their students it is first necessary for them to have an understanding of the nature of science (Abell and Smith, 1994; Murcia and Schibeci, 1999). Yet worryingly questions of an epistemological nature remain hidden, despite occupying a critical role in science education (Brickhouse, 1989; Koulaidis and Ogborn, 1995). Consequently it is important to address teachers' epistemological commitments in order to bring about more advantageous classroom practices.

Much of the research which has raised concerns about teachers' views on the nature of science has been in relation to secondary school science teachers (Brickhouse, 1989; Aguirre *et al.*, 1990; King, 1991; Koulaidis and Ogborn, 1995). Koulaidis and Ogborn (1995) found that science teachers value the 'scientific method' with scientific knowledge being seen as an end product of the application of the 'scientific method'. Thus scientific knowledge is contextually situated and as such is not different from other forms of knowledge. These studies focused on teachers who did have a background in university science and as such, despite their misconceptions, may have cognitive strategies which enable them to address conceptual problems when they become aware of them. However, primary school teachers may have little or no background in science beyond their own secondary school experience (Wragg *et al.*, 1989; Bennett and Carré, 1993) and their subsequent training is generalist in nature (Poulson, 2001).

There is only a limited amount of research with respect to pre-service primary students (Bloom, 1989; Abell and Smith, 1994; Murcia and Schibeci, 1999; Craven and Hand, 2002). Much of this research has detected problems with regards to the pre-service students' views on the nature of science. Bloom (1989) detected an anthropocentric view amongst pre-service elementary teachers who saw the purpose of science in terms of the development of technology and the improvement of their quality of life. Abell and Smith's (1994) study detected naïve realist and positivist ideas about science amongst the teachers studied. Science is seen as a process of discovering what is out there and not as a human process of developing explanations; a view of science which is based on the science teaching that teachers have witnessed and the lessons they have experienced. These teachers, in their turn, adopt pedagogic strategies which are typically discovery based, didactic or activity driven (Abell and Smith, 1994). This corresponds to the transmissive approach to teaching outlined by Aguirre *et al.* (1990) in their study of pre-service science teachers. In this latter study (Aguirre *et al.*, 1990) some fifty percent of the sample held the view that science teaching was a matter of knowledge transfer from the teacher's head and textbooks to the empty minds of the children. There is an absence of such research within a Scottish context.

Research on Taiwanese science-teachers identified 'nested epistemologies' (Tsai, 2002) in terms of teaching science, learning science and the nature of science; with a marked preference for a traditional or objectivist orientation amongst the teachers in the study. Tsai (2002) states that teachers with this perspective see their role as presenting the factual content of scientific knowledge; on transferring this knowledge learning becomes a process of reproduction by the pupils. Furthermore it is suggested that the Taiwanese teachers develop a traditional perspective on teaching science, learning science and the nature of science as a result of their own experience of school science. Appleton and Kindt (1999) suggests that once teacher-centred practices become established in teachers of primary science they become difficult to reformulate. The concern would be that such dated approaches to teaching in primary science will hinder pupils in the attainment of higher level curricular outcomes. This may also be linked to a decline in children's interest in science in the later years of primary schooling (Murphy *et al.*, 2004) developing into a 'flight from science' in the secondary school years. Thus it becomes important to establish exactly what pre-service primary students think about science in the Scottish context of 5-14 Science.

Consequently this thesis will, using quantitative and qualitative research methods, explore the experience, intentions and practice of pre-service primary students. The thesis will seek to determine the nature of student teachers' paradigms of science through an exploration of the pre-service students' aspirational rhetoric and actual teaching practice with respect to primary science.

CHAPTER 2 THEORIES of LEARNING

2.1 Introduction

Theories of learning and teaching are rarely explicitly stated in official documentation. Despite this theories of learning have and do influence, support as well as determine government policy. Most of the recent reform efforts linked to raising standards within education in the United Kingdom have focussed upon teaching rather than learning (MacGilchrist *et al.*, 2004). Policy makers assume that in getting the teaching right learning will automatically follow. There appears to be no conception that teaching and learning are in fact interdependent.

There are a number of ways in which it is possible to understand the tacit beliefs about learning permeating educational thinking within the United Kingdom. Moore (2000) suggests that theories related to the processes of learning and teaching in public policy are:

- evident in the dominant discourses in learning and teaching (*e.g.* Levels in the 5-14 curriculum, learning outcomes, *etc.*);
- evident in the discourse linked to the 'teacher-led' vs 'pupil-centred' debate;
- embedded in the teachers' everyday classroom practice and teaching philosophy.

[Adapted from Moore, 2000, p.3]

The problem that arises is that this assumes that teachers' classroom practice is informed, explicitly or implicitly, by theories of learning. Some researchers have asserted that:

> *all science teachers have, and* ***must necessarily always have had*** *(my emphasis), a philosophy of science -- a set of beliefs about the nature of scientific inquiry, of scientific progress, of scientific reasoning, of scientific data, theories and so on.*

[Grandy, 1997, p.45]

This, I would suggest, is a questionable claim even for secondary school science teachers. Although science teachers will have a personal set of beliefs and values these may not necessarily be congruent with the prevailing philosophy of science. Science teachers enter the profession through a variety of routes, many of which would not necessarily expose them to an in-depth study of their specialism, with any exposure to the philosophy of science being 'absorbed' as they engage in learning the content of their specialism. This is certainly not the case for primary teachers who are expected to teach science as part of the 5-14 curriculum. Indeed recent research (Mortimore, 1999) has suggested that teachers generally have little explicit knowledge on theories of learning and teaching. At best this is likely to be implicit and acquired unreflectively along with content knowledge during initial teacher education courses. Most teachers tend to focus on the actual experience of teaching, and what it means to be in the classroom, rather that understanding and adopting a particular theoretical perspective.

Teachers may well operate within an epistemological perspective without necessarily being able to articulate why this is so with reference to theory, what Bruner (1999) calls '*folk pedagogies*'. That teachers may rely on everyday intuitive theories does not, by itself, negate the validity of their epistemological position. Bruner (1999) suggests that there are four models as to how teachers see learners and the learning process. The adoption of any given model by a teacher is dependent upon the context in which the teacher is working. These models are hierarchically arranged, although they are not mutually exclusive, with the fourth model (*i.e.* the management of objective knowledge) being seen as pedagogically superior to the others. The four models include:

➢ *Seeing children as imitative learners: The acquisition of 'know how'*
The teacher-as-expert transmits skills they have acquired to the learner who in turn absorbs the information received through imitation or practice. There is little or no distinction between what Ryle (1990) calls *procedural knowledge* (*i.e.* knowing how) and *propositional knowledge* (*i.e.* knowing that).

➢ *Seeing children as learning from didactic exposure: The acquisition of 'know that'*
Learning is something that happens to learners through the actions of their teachers. The learners' mind is seen as a tabula rasa onto which the teacher writes and this is a cumulative process. Didactic teaching, presents the facts to be learned, remembered and applied with knowledge being that which learners look up and listen to. This model views pupils from the '*outside*' rather than trying to understand what is happening *internally*. Learning follows a defined path, which is linear and sequential in nature, with knowledge being fixed. This is consistent with an objectivist perspective which views learners as being qualitatively different from teachers.

➢ *Seeing children as thinkers: The development of intersubjective interchange*
The learner is seen as constructing their own meaning from experience with the teacher seeking to understand what pupils think and how they arrive at this thinking. The teacher's role is to alter the learner's conceptions in order that they arrive at a shared understanding, This is achieved through active experience which involves discourse. In so doing naïve conceptions are brought into congruence with scientific conceptions. This model is more concerned with interpretation and understanding rather than with the acquisition of factual knowledge or skill performance. This is consistent with a constructivist perspective, promoting a relativist ontology, which argues that a constructivist learning is tautologous as all learning involves construction.

- *Seeing children as knowledgeable: The management of 'objective' knowledge*
  This model seeks to develop an awareness in children of the difference between personal knowledge and '*what is taken to be known*' by the culture. Dialogue is used to facilitate a *situated cognition* (Bliss, 1995) with learning taking place in a socio-cultural context. Such an approach does not propose a free-for-all relativist ontology as the focus of learning is an understanding of '*objective*' knowledge (*i.e.* knowledge that has withstood scrutiny having been tested and verified). The role of the teacher is to:

  > *help the child reach beyond his own impressions, to join a past world that would otherwise be remote and beyond him as a knower.*
  >
  > [Bruner, 1999, p.17]

This is consistent with a socio-cultural constructivist perspective which asserts that intellectual development occurs on the social level, within a cultural context -- all knowledge has a history. Carnell and Lodge (2002) have developed a similar, albeit much simpler, classification of approaches to learning:

➢ reception (instruction)	Thorndike, Pavlov and Skinner
➢ construction	Piaget
➢ co-construction	Vygotsky, Bruner.

I have adapted this to include some of the key thinkers behind those learning theories which have been influential in the United Kingdom.

2.2 Behaviourist learning theory

The development of learning theory has been closely associated with psychology for over a century. There are a number of schools of thought amongst psychologists with regards to the study of learning, two of which have been influential with respect to policy developments in primary science. These are commonly referred to as *behaviourist* and *cognitivist* (Sprinthall *et al.*, 1998; Child, 2004). Behaviourists argue that the task of psychology is to examine the relationship between stimulus (S) and response (R) bonds or connections[2.1], leading to other terms such as connectionists and association learning being used to describe behaviourist learning theory. The subject being studied, much of the early work involved animals (*e.g.* cats, dogs, pigeons), develop observable responses to stimuli. Using experimental methods these S-R bonds can be manipulated and the results observed. Within such an approach the S-R bonds

[2.1] Behaviourist learning theory claims that all behaviour is a response to stimuli and that learning is a matter of strengthening the linkage between stimulus and response. Responses can be conditioned by repeating the stimuli and that reinforcement of responses is important to achieve learning. This linkage between stimulus and response is referred to as a bond or connection.

Thorndike (1847-1949) demonstrated that pleasurable experiences reinforced stimulus-response while discomfort reduced the bond . He suggested that there was a need to maximise the strength of a bond, primarily through increasing the duration and frequency of the link between stimulus and response. External reward was seen as being particularly effective, while punishment was less important.

are external to the subject. Consequently, behaviourist theory is *objectivist* (*i.e.* the observer and the subject are different) and *externalist* (*i.e.* the actions of the observer, in manipulating the S-R bonds, seek to promote learning in the subject) in its approach.

Early work in the development of the behaviourist approach was carried out by Ivan Pavlov (1849-1936) along with Edward L. Thorndike (1847-1949). Although their work was of little direct relevance to teachers it was nevertheless important in that they laid the foundations for a perspective on learning which arguably still informs present-day teaching practice. Ivan Pavlov's contribution was an accidental outcome of his work on the digestive activity of dogs, for which he was awarded the Nobel Prize in 1904. Pavlov developed experimental methods for observing stimuli and responses with respect to physiological reflex actions, specifically the salivation reflex in dogs.

These observations could be measured and controlled precisely. Pavlov noted that when dry meat powder was placed in a dog's mouth, and later when they had sight of the food, it would automatically salivate. This is a reflex action which does not have to be learned. The dry meat powder is called and *unconditioned stimulus* (UCS) and the salivation is called an *unconditioned response* (UCR). The significance of Pavlov's work was the observation that when a neutral stimulus (*i.e.* a stimulus which does not provoke a response) is repeatedly connected, within a carefully controlled period of time, with an unconditioned stimulus (*i.e.* the dry meat powder) then the neutral stimulus will lead to salivation taking place. Pavlov introduced a tuning fork as the neutral stimulus which gave off a tone prior to the dog having sight of the food. Once the dog makes the connection between the tone and the production of the food it would start to salivate at the sound of the tone *prior* to having sight of the food. The tone is called a *conditioned stimulus* (CS) and salivation at the sound of the tone is called a *conditioned response* (CR). This learned response is referred to as *classical conditioning.*

Edward Thorndike's contribution, through his work with cats, dogs and chickens, was to develop a view of learning predicated on a series of stimulus (S) - response (R) bonds and how these could be strengthened or weakened. Thorndike showed that animals confined in cages were able to gain access to food through a trial-and-error process. The solution to the problem, with which they were presented, led to a *connection* being made which could be used to focus their efforts when required to replicate the solution (*i.e.* obtain food) in further experiments. From this work Thorndike postulated the following 'laws' of learning:

➢ *Law of Effect*

A S-R connection followed by a reward (*i.e.* satisfaction) will serve to strengthen or reinforce that S-R bond. Similarly a S-R connection followed by a punishment (*i.e.* dissatisfaction) is likely to weaken that S-R bond. Thorndike was less convinced by the effectiveness of punishment in weakening a S-R bond as the subject seeks alternative S-R bonds which are positively reinforced.

➢ *Law of Exercise*

The more a S-R bond is used and receives positive reinforcement, the stronger it will become. Conversely the less a S-R bond is used the weaker it will become. Repetition by itself will not lead to improved performance unless it is accompanied by knowledge of a positive outcome.

These laws give an insight as to how pupils can be motivated to learn through positive reinforcement. In addition they suggest that although punishment is unlikely to extinguish undesirable behaviour, it may nevertheless create the conditions whereby the pupil is predisposed to seek alternative S-R bonds which are more rewarding. The role of the teacher is to facilitate this by providing alternative routes. The behaviourists' basic mechanism of learning is:

stimulus ⇨ response ⇨ reinforcement

2.3 Burrhus Frederic Skinner (1904-1990)

B.F. Skinner is considered to be the most influential proponent of behaviourism as he generated much of the experimental data, working with animals, that is the basis of modern behavioural learning theory. Along with other behavioural theorists he was concerned with observable indications of learning, and what these observations could imply for teaching -- focussing on observable ‘cause and effect’ relationships. Skinner developed a framework in which desired responses act as a source of reinforcement and this, in turn, leads to learning. For Skinner the mind was irrelevant to an understanding of why people behave as they do.

Skinner was not satisfied that all behaviour, as suggested by Pavlov, was based on reflexes. Within the Pavlovian perspective the experimenter controls the response by determining what the stimulus is and when to present it. The response is a reflex action with the subject being ‘passive’ as their response must await the stimulus: this is called *respondent behaviour*. Skinner's theory required the individual to act or operate on the environment, producing a desired response, in order to be rewarded: this is called *operant behaviour*. The Skinnerian perspective stated that people learn best by being rewarded for 'right responses', or by responses that show evidence of having the potential eventually to lead to 'right responses': this is called *operant* *conditioning*. Skinner's general principle stated that if the operant (*i.e.* response) is followed by a reinforcing stimulus the rate of responding, for that particular operant, will increase (Sprinthall *et al.*, 1998, p. 252). This is a R-S association with the reinforcement being contingent upon the occurrence of the response. Skinner argued that we behave the way we do because of the consequences generated by our past behaviour. For Skinner, it is the history of reinforcements that determines behaviour. We learn to choose or avoid behaviours based on their consequences.

Skinner elaborated what he called the 'law of positive reinforcement', which includes the notion that pupils can be trained to replicate certain behaviours if they come to associate such replication with the occasional receipt of tangible rewards (Moore, 2000). A positive reinforcement is any stimulus (*e.g.* reward) that when *added*, following a desired response, increases the likelihood that the response will occur. A negative reinforcement is any stimulus (*e.g.* punishment) that when *removed*, following a desired response, increases the likelihood that the response will occur. The converse of this is an aversive stimulus which is an unpleasant or painful stimulus (*i.e.* punishment) which seeks to extinguish an undesirable behaviour. Skinner was opposed to the use of aversive stimuli as they were, in his opinion, not very effective. The role of the teacher, within such a perspective, is to facilitate the modification of the pupils' behaviour by introducing situations which reinforce students when they exhibit desired responses.

Skinner particularly insisted on the importance of reinforcement in the learning process, learning being operationally defined as changes in the frequency of a particular response. Skinner asserted that if you control the rewards and punishments which the environment gives in response to behaviours, then you can shape behaviour: this is commonly known as ***behaviour modification***. It is possible to detect elements of this in primary classes with pupils being rewarded by ticks, praise from the teacher, smiley faces in their jotters or in being given a special task or 'responsibility' as rewards for appropriate behaviour. The Skinnerian perspective articulates four major teaching/learning strategies which include:

- *Shaping*
  Successively closer approximations to some target behaviour are rewarded. The intended target behaviour needs to be as specific as possible. If people do not know what you want them to achieve, they cannot know whether they're getting closer to achieving it or not.

- *Chaining*
  Complex behaviours are broken down into simpler ones, each of which is a modular component of the next more complex stage. Breaking behaviours down

in this way has the advantage of achievability. However, caution should be exercised that the rewards do not become too regular and frequent, otherwise, according to Skinner, they lose much of their effect.

- *Discrimination*
  The learner comes to discriminate between settings in which a particular behaviour will be reinforced. For this discrimination to occur, it is important that confusion be eliminated (*e.g.* praise correct responses and provide appropriate feedback when the answer is incorrect).

- *Extinction*
  Ultimately reinforcement may be withdrawn, following the response. This will lead to a decline in the response or it being extinguished.

Behaviourism emphasises not only the importance of positive reinforcement in the classroom, but also the use of highly structured materials through which students can work step-by-step towards externally imposed goals. This has influenced the technology of programmed learning (*i.e.* chaining). Initially the teacher would determine what the student already knows and can do, establishing a *baseline*, to determine at what point in the programme they should start, thereafter each time a learner achieves a step they are rewarded with immediate positive feedback followed by them moving onto the next step. Skinner assumed that careful and systematic teaching will guarantee correct learning (Nussbaum, 1989).

Behaviourism is predicated on a transmissive, instructional approach which is teacher-directed; consequently, it has become synonymous with an objectivist epistemology. The pupil's mind is seen as an empty vessel to be filled; pupils have a passive role within the learning process, namely that they should replicate the content and structure of the objective reality contained within the instructional format. Skinner further asserted that in order not to demoralise or demotivate the learner, interfering with their steady progress, the instructional formats should, as far as possible, be 'error free'. Lessons should have a coherent structure, determined by the teacher through the production of a lesson plan. Within a Skinnerian framework this plan would 'fix' the teachers' words, questions to be asked and pupil activities in advance. This is sometimes referred to as the 'traditional', discursive pattern which consists of the teacher initiation (*e.g.* asking a predetermined question or providing a simple instruction) followed by the student responding (Moore, 2000).

At a basic level learning involves both '*knowing that*' and '*knowing how*' (Ryle, 1990). This is not necessarily a dichotomous classification as evident in Ramsden's (1992) suggestion that learning consists of five, hierarchical categories:

- learning as a quantitative increase in knowledge: knowing a lot;
- learning as memorising: storing and reproducing information;
- learning as acquiring facts, skills, and methods that can be retained and used as necessary;
- learning as making sense or abstracting meaning: integrating knowledge;
- learning as interpreting and understanding reality in different ways: comprehending and reinterpreting knowledge.

The first two categories, which mostly involve 'knowing that' whilst the third category also involves a sense of 'knowing how' to make use of knowledge. The knowledge base is not necessarily integrated in a meaningful way and may still be said to be context-specific. These categories suggest that learning is something external to the learner which is done to them by teachers. This is consistent with the notion of a '*product-based curriculum*' which defines learning in terms of the end products to be achieved through a set of objectives or learning outcomes. The 5-14 curriculum is an example of a product-based curriculum as it defines these products as a series of specific attainment outcomes stating what the '*pupils are able to*' do. Furthermore the 5-14 curriculum specifies these attainment outcomes in terms of content making it both a product- and content-based curriculum. This suggests an objectivist paradigm which tends to be the main focus of the behaviourist approach to teaching and learning. Learning is seen as unproblematic being easily and effectively achieved through careful attention to developing sequenced instructional events.

The behaviourist approach is largely drawn from the work of Skinner whose work, as an associationist, was based on data derived from experimental methods. There was no attempt to produce a 'theory' or to engage in deductive interpretations. The key idea of conditioning continues to be influential within British education particularly with respect to current-day thinking on the 'behavioural' aspects of teaching and learning through behaviour modification techniques. Within the classroom appropriate responses are acknowledged through a variety of praise systems in our schools (*e.g.* ticks, in jotters, verbal praise, good conduct awards, *etc.*). The assumption is that all learners will strive to work towards achieving these external rewards given that the instructional events being provided are appropriate to the stage of progression of the learners. Herein lies the appeal of the Skinnerian perspective, namely that it suggests that good teaching hinges solely on arranging the proper sequence of reinforcements and the the provision of these reinforcements is contingent upon the learner providing the correct response (Sprinthall *et al.*, 1998). Good teaching is all about getting the instructional event correct with learning, measured by assessment techniques, being assured (Smith, 1999). Those who are unwilling to play the '*behaviour game*' are classed as disruptive and deviant rather than as learners who are constructing a different and impoverished meaning from the experiences with which they are provided.

Skinner does provide an insight as to how it is possible to simplify and make more efficient the learning of the informational background. However, changes observed in overt behaviour do not necessarily imply that this change will be matched by an internal process whereby learners draw upon previous knowledge to generate new knowledge. The approach advocated by behaviourists is much too simplistic to determine why and how change takes place in learners' experience, understanding and conceptualisation of the world around them. Among the problems with Skinnerian thinking are:

- ➢ it reduces questions of process to a simple matter of conditioning;
- ➢ it views learning as essentially a receptive process demanding a transmissive pedagogy;
- ➢ it fails to acknowledge that concepts can and do develop rather than remain the same;
- ➢ it reduces, closes down questioning to a right or wrong format with knowledge being crystallised and finite;
- ➢ it leads a a curriculum which is content-laden driven by achieving objectives;
- ➢ it leads to a rigid differentiation of learners on the basis of their capacity to achieve;
- ➢ it fails to acknowledge that learning can be obtained through errors and taking risks by seeking to be 'error free';
- ➢ it sees motivation as the outcome of learners obtaining externally-conferred 'rewards', rather than becoming independent learners who see learning itself as intrinsically rewarding.

[Adapted from Moore, 2000]

The last two categories of Ramsden's (1992) taxonomy are qualitatively different from the first three as they articulate an '*internal*' or personal aspect to learning. Learning is seen as something that the learner does in order to understand and derive meaning from, and of, the real world. That learning is primarily concerned with '*knowing how*' is consistent with the notion of a '*process-based curriculum*'. This aligns with the cognitivist paradigm which tends to be the main focus of the constructivist approach to teaching and learning. Within this approach it is the cognitive development of the learner which is the primary concern. This leads to a child-centred curriculum in which learning is seen as an active process based on meeting the experiential needs of the individual learner (Child, 2004).

2.4 Cognitive (constructivist) learning theory

Cognitivists would argue that an understanding of the internal processes (*e.g.* perception, personality, motivation, *etc.*) of the subject or organism (O) is critically important: codified as S-O-R. The means by which this understanding can be accomplished is through the process of introspection (Child, 2004). This involves the observer attempting to elicit from the subject a description of their conceptions in order that they may interpret how this may influence subsequent behaviour:

> *learning comes about through the learner's active involvement in knowledge construction. Within this broadly 'constructivist' perspective learners are thought of as building mental representations of the world around them that are used to interpret new situations and to guide action in them.*
>
> [Driver, 1989, p.481]

Constructivism, therefore, is a metaphor for learning which postulates that knowledge resides in individuals, and is '*constructed*' by them. This differentiates it from views of education that presume that it is possible to transfer information directly into a pupil's mind. Constructivism asserts that real learning can occur only when the learner is *actively* engaged in operating on or processing incoming stimuli. Furthermore the interpretation of these stimuli depends on *previously* constructed learning.

Although the basic epistemological position appears to be fairly straightforward there is, nevertheless, a profusion of different interpretations of the constructivist epistemology, such that one researcher identified twenty-one varieties (Matthews 1994a). Attempts to classify constructivism have led to different formulations:

- Geelan (1997): personal, radical, social, social constructionism, critical and contextual;
- Grandy (1997): cognitive, epistemic and metaphysical (individual and social);
- Matthews, M.R. (1997): educational (individual and social), pedagogical, philosophical and sociological;
- Boudourides (1998): philosophical, cybernetic, educational (personal and social) and sociological;
- Fox (2001): Piagetian, neo-Vygotskian, mediated learning, radical and social.

Matthews (1994a) suggests that constructivism is a '*broad church*' containing a continuum of positions from *hard* (or radical) constructivism through to *soft* (or pragmatic) constructivism. Within these variants there is a broad agreement with a relativist ontology and a subjectivist epistemology (Coll and Taylor, 2001). Rather than review all of the different perspectives on constructivism I will concentrate on educational and pedagogical constructivism (Matthews, 1997), as they have influenced thinking in primary education, namely Piagetian constructivism and the socio-cultural constructivism of Vygotsky and Bruner along with the work of Gagné on the design of instructional events. The premises of constructivism that emerge from this work are:

- learning is an active and interactive process;
- knowledge is constructed, not transmitted;
- prior knowledge impacts the learning process;
- learning is essentially a process of making sense of the world;
- initial understanding is local, not global;
- effective learning requires meaningful, open-ended and challenging problems for the learner to solve.

[Adapted from Fox, 2001]

From a constructivist perspective, school science is a process that assists pupils to make sense of their world. The constructivist perspective suggests that teachers should provide pupils with opportunities to experience science as an active, social process of making sense of experiences; as opposed to '*instructional science*' whereby pupils are given the facts and theories of science. This is not to say that facts are not important, but rather it is the context in which they are examined which is important within a constructivist perspective. Teachers are encouraged to actively engage students in science (*i.e.* 'hands-on, minds-on science') through the use of problem-solving as a learning strategy; with learning defined as adaptations made to fit the world they experience (Lorsbach and Tobin, 1997). Constructivists would argue that teachers who make sense of their teaching from an objectivist perspective fail to recognise that students who are not actively engaged in the learning process tend to separate school science from their own life experiences (Solomon, 1987). Consequently there is a dissonance between the learning outcomes objectivist teachers intend and what they achieve.

Previous learning is critically important within the constructivist perspective as it is significant in terms of how pupils come to understand school science. Frequently the scientific interpretation of phenomena differs from the interpretation pupils construct; pupils construct meanings that are viable in the sense that they allow them to make sense of their environment. This can lead pupils to construct meanings different from those intended by the teacher. In order that meanings are consistent social constructivists (*e.g.* Vygotsky and Bruner) suggest that a co-operative learning strategy will provide pupils with an opportunity to test the fit of their experiential world within a social context. The *teacher-as-expert* has an important role to play, particularly within school science, in communicating the successes of science (Nola, 1997). This, according to Matthews (1994a), is a *soft* constructivist position as it rejects a relativist ontology. Within school science there would be little to be served by suggesting that pupils should develop understandings which are not consistent with the agreed and verifiable understandings of the scientific community (Millar, 1989).

2.5 Jean Piaget (1896-1980)

Jean Piaget was a Swiss psychologist and pioneer in the study of cognitive development who is considered to be one of the most influential thinkers in twentieth-century developmental psychology. Piaget is best known for his research on the development of cognitive functions in children; with his theories forming the foundations of the modern constructivist movement. For Piaget cognition (*i.e.* thinking and rational thought) is an active and interactive process (Boudourides, 1998), with learners engaged in interacting with their environment, such that the learner affects and is affected by the environment. Piaget's approach was based on an evolutionary or genetic epistemology with the main concern being a study of the '*epistemic subject*' (Bliss, 1995). The focus of his work was the development of an epistemological theory of the structure of knowledge rather than a concern with the psychology of the individual. The importance of Piaget's work is that the theoretical framework that developed from this study of the 'epistemic subject' was grounded in the behaviour observed in the psychological subject (Matthews, P.S.C., 1997). The theory that he developed has three important dimensions:

- *genetic* -- the higher cognitive processes evolve from biological mechanisms rooted in the development of the central nervous system;
- *maturational* -- the process of concept formation follows an invariant pattern of identifiable stages linked to specific age ranges;
- *hierarchical* -- the stages must be experienced and passed through in order for further development to take place.

Piaget asserted that thinking patterns evolve through an invariant sequence of stages in which cognitive structures become progressively more complex. Piaget postulated four stages, each of which is qualitatively different from the preceding stage, of cognitive development:

- *The sensorimotor stage* (0 to 2 years).
  Towards the end of this period the child, by exploring the world through sensory experiences and movement, begins to represent the world in terms of mental images and symbols through the acquisition of basic language.

- *The pre-operational stage* (2 to 7 years)
  The pre-operational stage is sub-divided into pre-conceptual and intuitive stages:
  - The pre-conceptual child (2 to 4 years) is unable to abstract and discriminate the attributes of a concept: *inductive reasoning*. Neither can the child use deductive ways of thinking. Instead they use what Piaget terms *transductive reasoning* (*i.e.* going from one specific instance to another specific instance) so forming *pre-concepts*.
  - The intuitive child (4 to 7 years) considers only one variable of a situation at a time to the exclusion of all other aspects. In the Piagetian framework this is called *centring*.

- *The concrete-operational stage* (7 to 11 years)
  The child begins to think hypothetically where two or more variables can be considered at once. However, there may still be a tendency to adjust the facts to meet the hypothesis: an *assumptive reality* (Child, 2004). The development of logic structures continues to require concrete experience to which the logic can be applied.

- *The formal-operational stage* (11 years onwards)
  During this period the child starts to use abstract reasoning. Abstract hypotheses can be built along with the capability to hold some variables constant while manipulating other variables in order to determine their influence. Analytical and logical thought no longer requires reference to concrete examples.

For Piaget the development of human intellect proceeds through adaptation to the environment by the organisation of actions, or patterns of behaviour: called *schemata.* Disequilibrium (*i.e.* mental conflict which demands resolution) gives rise to the *assimilation* of a new experience which is incorporated alongside existing knowledge. New ideas may also require an adjustment to take place in the individual's thinking, giving rise to *accommodation* (*i.e.* modification of existing understanding to provide for the new experience) which leads to *internalisation* of the new learning. Once this has been accomplished the learner can be said, within a Piagetian perspective, to *know.* Assimilation and accommodation complement each other, *they do not operate in isolation,* as part of the process of *equilibration.*

The constructivist approach is largely drawn from Piaget's theory of genetic epistemology which asserts that learning is an active and interactive process with the learner being an active maker of meaning through interaction with their environment. The translation of Piaget's ideas about the 'epistemic subject' to the individual pupil has proved to be difficult. In acknowledging Piaget's contribution to our understanding of the development of knowledge it is important to realise that, *"teachers have to teach pupils, not 'epistemic subjects'"* (Bliss, 1995, p.155). Piaget also suggested that mental age is a more meaningful concept than chronological age as it is concerned with intellectual and not physical development. Furthermore thinking patterns, which defines mental age, go through a invariant sequence of increasing complexity in cognitive structures. These stages of cognitive development are seen as only having descriptive value (Marín and Benarroch, 1994). Piaget suggests that active methods are more likely to produce cognitive growth. However, this is not developed as his theoretical framework is descriptive rather than prescriptive. Indeed this theoretical framework, nor that of constructivism in general, does not offer much by way of pedagogy (Matthews, M.R., 1997; Watts and Jofili, 1998; Coll and Taylor, 2001), despite being linked to the notion of child-centred education, with the role of the teacher being merely to assess progress and facilitate new experiences. Piagetian theory found favour in policy documents linked to primary education during the 1960s and 1970s. Towards the end of the twentieth century, in stressing the independent aspect of the individual's learning allied to a 'progressive' child-centred pedagogy, Piagetian thinking came increasingly under attack from governments wishing to return to an objectivist paradigm.

The significance of Piaget's work for the classroom is that the patterns of cognitive development that emerge can be replicated and, despite different interpretations being placed on the findings, are found to be consistent with respect to race, culture, *etc.* From a Piagetian perspective upper primary school children function at the concrete-operational stage whilst those in the lower primary function at the pre-operational stage. This suggests that the experiences which teachers provide, particularly in science, should be practical and experimental in nature rather than requiring deductive reasoning. This may encourage some teachers to opt-out from teaching 'difficult ideas', until the pupils are intellectually ready, especially with regards to science (Bliss, 1995). Discourse is also important as language facilitates the assimilation and accommodation of the learner's practical experience and thus supports internalisation. However, any attempt to 'accelerate learning', *across the Piagetian stages*, is ultimately futile, or at best will only have a marginal effect, as development can only take place when the learner has the cognitive structures in place to assimilate new experience.

2.6 Lev Vygotsky (1896-1934)

Lev Vygotsky, a Russian developmental psychologist and philosopher, died of tuberculosis at the age of 37 in 1934. Vygotsky articulated a view of psychology, and more specifically learning, which was different to that favoured within Stalinist Russia, namely the Pavlovian perspective. Consequently his work was suppressed and did not become widely known outside the former Soviet Union until the reprinting of '*Thought and Language*' in 1962[2.2].

Vygotsky was interested in understanding the socio-cultural context of cognitive development and, in particular, the role of language, which is itself a social construct, in the development of higher cognitive functions (Hodson and Hodson, 1998). For Vygotsky learning involves collaborative action, to be shaped in childhood, when the

[2.2] Julia Gillen (2000) has suggested that a revision of Vygotsky's work is necessary in light of deficient translations of his work. Indeed she suggest that the title of Vygotsky's seminal work 'Thought and Language', with its abstract and philosophical overtones, is a mistranslation of 'Thinking and Speech'. There is also a much more serious contention that whole scale deletions are evident with respect to references on Marxism, Marx, Engels, *etc* which serves to distort the source of Vygotsky's ideas.

the convergence of speech and practical activity occurs (Boudourides, 1998). This marks a departure from the Piagetian perspective which was largely concerned with the structural aspects of concept growth stressing biological adaptation as the significant feature in the emergence of developmental stages. Piaget's theory is essentially defined in terms of genetics and maturation. However, Vygotsky did not see his position as being necessarily dichotomous with the Piagetian perspective, but rather as offering the opportunity for a holistic approach.

The Vygotskian perspective asserts that a child's development is affected by the social environment or culture in which they are enmeshed. In simple terms this culture is responsible for teaching the child not only *what* to think, but *how* to think. Learners appropriate understanding through social encounters. Knowledge is not merely handed-on, nor is it discovered by the individual, but rather it is part of a process of *co-construction.* Pedagogy provides the framework, through problem-solving activity, that enables the learner progressively to access the world of knowledge that is initially beyond them, but of which they are a part. Learning takes place when *internalisation* occurs; this is the process whereby the social becomes the psychological: from the *interpsychological plane* to the *intrapsychological plane* (Scott, 1998).

Vygotsky also asserts that for learning to take place *comprehension* is necessary. Activities created by the teacher which do not promote, or lead to comprehension are ultimately empty. From a Vygotskian analysis any activity which seeks to do little more than transmit knowledge should be avoided. Dialogic interaction encourages the exploration and development of meaning. Clearly language is central to this process enabling us to share and co-construct meaning. For Vygotsky the child's on-going interaction with the social world will lead to the development of an ever more complex view of objective reality; along with the development of their language skills which become the primary tool of *intellectual adaptation.*

Vygotsky did not accept the Piagetian thesis that learning must wait for development to take place. Vygotsky asserted that children are capable of operating at different levels with learning being possible in advance of development within a *zone of proximal development* (ZPD)[2.3]. The ZPD is the difference between *actual* development as determined by independent problem solving and the level of *potential* development as determined by problem solving under adult, as well as more able peer, guidance (Hodson and Hodson, 1998). Vygotsky asserts that pedagogy should be aimed '*not so much at the ripe as at the ripening functions*' (Vygotsky, 1962, p.104). Within such a framework '*teachers do make a difference*' (Bernstein, 1996).

[2.3] Gillen (2000) suggests that is not an original proposition of Vygotsky.

According to Vygotsky learning is possible only when the teacher presents the pupil with a problem to be solved. In working towards a solution it is necessary to provide substantial opportunities for discussion, stressing the importance of language in the classroom situation. Dialogue is used as a tool to enable pupils, working collectively or individually, to negotiate conceptual change. The pupil creates and tests any insights obtained rather than having them given to them by the teacher (Sprinthall *et al.*, 1998). The crucial component of this interaction is that it involves problem solving which leads, if it is to be effective, to comprehension. Thus cognitive development arises out of a dialectical process whereby a child learns through problem-solving activity, supported by their teacher. This dialectic enables us to incorporate the ideas of the past (*scientific thought*) into the thought processes in the present (Griffith and Benson, 1994). Scientific knowledge has a history (Bruner, 1999) which remains relevant to our teaching programmes in the present day.

The support provided by teachers is called *scaffolding*, a term developed by Wood *et al.* (1976). This support should only be provided when the pupil requires assistance to bridge the gap between actual and potential development. This support does not alter the nature of the task but rather impacts upon the learners participation through graduated assistance (Hodson and Hodson, 1998). Crucially this support should be gradually removed as the pupil achieves success. Consequently teacher-pupil interaction becomes a dynamic process with the teacher constantly gauging when support is needed, the nature of support required, how much support is needed as well as considering when and how to progressively remove the scaffolding. As such there remains an asymmetry in the teacher-pupil relationship with regards to knowledge (Scott, 1998) and an assumption that teacher-pupil interaction is grounded in rational behaviour based around collaborative rather than dysfunctional competitive activity.

Vygotsky identified four stages of concept formation determined through experimental methods. The experiment materials consisted of grouping-sorting objects, namely twenty-two blocks which had three principal attributes, *shape* (*e.g.* square, triangle, circle, semi-circle, hexagon and trapezium), *height* (*e.g.* tall or low) and *size of horizontal surface* (*e.g.* large or small) with colour used as a distracter. One of the blocks, with specific attributes (*e.g.* large and tall) was selected by the experimenter and shown to the subject. The subject was then asked to identify blocks which has similar attributes in order to identify the underlying concept. The stages identified by Vygotsky are generally in agreement with Piagetian stage theory. Vygotsky's stages do not contain a rigid maturational progress as the teacher can support progress through the stages (Boudourides, 1998; Child, 2004) which consist of:

- *Syncretic stage*
  Children arrange the objects as random groupings of blocks rather that reasoned groupings. Trial-and error is a common strategy.

- *Thinking in complexes stage*
  This involves a primitive form of grouping according to criteria which do not, necessarily, conform to the attributes of the concept. There are a number of sub-stages within this whereby children select on the basis of one attribute (*e.g.* tall) producing *associative complexes.* They may engage in a series or reordering of the groupings, called *chain complexes,* according to different attributes. When there are no links between successive groupings we have a *diffuse complex.*

- *Pseudo-concepts stage*
  The child groups the blocks according to the physical attributes, which mirror the concept, however, they are not able to explain why as they have not fully grasped the concept.

- *Potential concept stage*
  The child is able to cope with one attribute but is not able to manipulate all of the attributes simultaneously.

Vygotsky's theory postulates that development occurs on the social level, within a cultural context with learning being essentially an active and interactive process. The child internalises the mental processes initially made evident in social activities, and moves from the social to the individual plane, from interpsychological functioning to intrapsychological functioning. Learning and development is a social and collaborative activity that cannot be '*taught*' to anyone. It is up to the learner to construct their own understanding in their own mind. The teacher does, nevertheless, have a crucial role to play in designing appropriate activities / experiences which should involve discourse. Furthermore this perspective does not accept the proposition that teachers should wait until learners are deemed capable of absorbing experience. Indeed for Vygotsky and Bruner it is possible to teach any subject matter, and for this to be understood, if it is well presented. However, Vygotsky does not provide any guidance as to what would constitute an appropriate teaching strategy (Rowlands, 2000). Thus the teacher has a crucial role to play, as suggested by Bruner, in providing support or '*scaffolding*' for optimal learning. Scaffolding along with the concept of the zone of proximal development, Piaget's cognitive fragments, suggests that learners, with assistance, are capable of performing tasks that they would not be capable of without support. Vygotsky and Bruner do not see their work as being in opposition to Piagetian analysis but rather as complementing it.

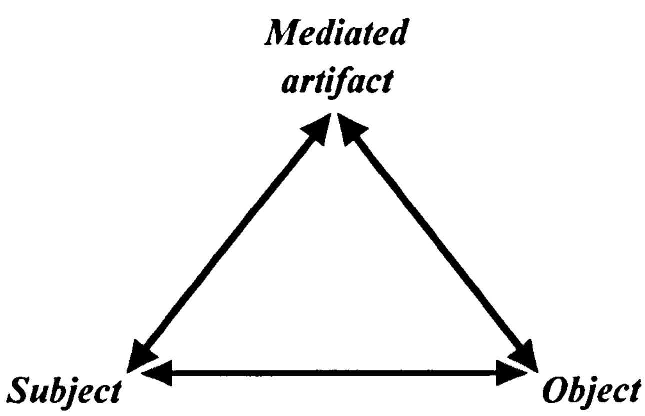
2.7 Vygotsky reframed: Activity Theory

The concept of activity theory also emerged from the work of Lev Vygotsky along with two of his collaborators, A. N. Leont'ev (1904-1979) and A. R. Luria (1902-1977). Leont'ev's work on general activity theory and Vygotsky's work on cultural-historical psychology developed into cultural-historical activity theory (CHAT) which offers a framework for analysing work-based learning as:

> *it is deeply contextual and orientated to understanding historically specific local practises, their objects, mediating artifacts, and social organisation*
>
> [Engeström, 1999, p.377]

Activity theory (AT) is a complex, holistic psychological paradigm which was used in the study of work-related behaviour in the former Soviet Union (Bedny *et al*, 2000). AT is a powerful descriptive tool that provides concepts and a vocabulary for describing human activity conceptually as 'artifact-mediated and object-orientated action' (Vygotsky, 1978, p. 40). According to AT, the human mind, or consciousness, can only be understood in the context of the interaction between the individual and the environment. This interaction is mediated by cultural means such that people do not simply absorb, or react, but actively explore and transform their environment (see Figure 2.1).

Figure 2.1: Vygotsky's model of mediated action



Activity theory establishes a linkage between individual psychology and culture through the triadic relationship of 'consciousness-culture-behaviour' (Bedny *et al*, 2000). This theory was derived, in part, from earlier sources including the philosophy of Kant and Hegel as well as the writings of Marx and Engels. According to Quek and Alderson (2002) activity theory consists of several basic principles that form a conceptual system, which can be used in conjunction with other theories:

- *Hierarchical structure of activity*

  This principle, drawn from Leont'ev's three-level model of activity (Engeström *et al*, 1999), states that there are three hierarchical levels of an activity: activity, action and operation. An activity is carried out to achieve a motive, giving it a specific direction and consists of conscious, goal-directed actions that are implemented through operations. Operations are the automatic steps necessary to undertake an action.

AT maintains that the elements of activity are not static but can change as conditions change. This means that an activity can turn into an action, while an action can acquire a motive and become an activity (Quek and Alderson, 2002). Repetition of an action or activity may result in them becoming operations. Alternatively an operation, placed within a new context, may be elevated to the status of action if the operator finds it necessary to re-evaluate and re-integrate the operations necessary to carry out an action within a new contextual situation.

- *Objective-orientedness*
  This principle states that every activity is different and activities can be distinguished from each other according to their different objectives. 'Objective-oriented' suggests that activities have a direction. The objective of an activity may change in the process of carrying out the activity.

- *Internalisation / Externalisation*
  This principle differentiates between internal activities and external activities. It emphasises that internal activities (*e.g.* planning) cannot be understood if they are analysed separately from external activities (*e.g.* writing) as they interact into each other. Internalisation involves transforming external activities into internal ones by carrying out activities externally (*i.e.* we learn by doing). Externalisation is the process of internal activities transforming into external ones (Quek and Alderson, 2002). Science lesson which require learners to make a prediction of the result that they should achieve prior to carry out an activity exemplifies externalisation.

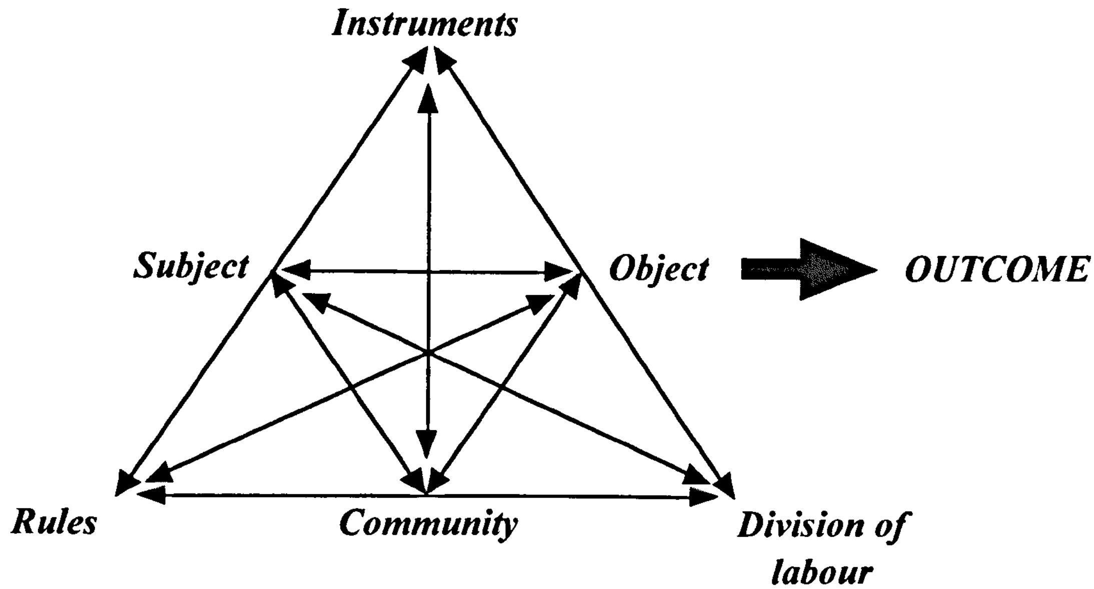
- *Tool mediation*
  This principle states that human activity is mediated by artifacts or tools in order to achieve an objective. Tools can be physical (*e.g.* instruments) or psychological (*e.g.* language). Tools enable us to manipulate and transform objects and are used to change the environment as well as human behaviour through their use.

- *Development*
  This principle states that a system can only be understood by analysing how work has developed over time in order to fully grasp how work is done today. At the same time, the concept of development tells us that change and development are certain to occur whenever humans are involved, and we need to be alert to changes in work practice (Quek and Alderson, 2002).

More recently the Finnish academic Yrjö Engeström has utilised AT to understand organisational change and development. Engeström's seminal work '*Learning by*

Expanding' (1987) elaborated the theory and modified it to include social and collective aspects of human activity producing a model of collective activity system (see Figure 2.2).

Figure 2.2: Human activity system (Engeström, 1987)



An activity is the basic unit of human behaviour that can be analysed with a meaningful context. The purpose of carrying out an activity is to turn an objective into an outcome. Within each activity that is carried out, there are six components: the subject, the tools, the objectives, the community, the rules, and the division of labour. Consequently we cannot analyse a system comprehensibly by just looking at human behaviour as people exist within a social and cultural context, and their behaviour cannot be understood separately from it.

The subject carries out an activity using tools to achieve an objective, thereby turning the objective into an outcome. The relationship between the subject and the objective of an activity is said to be mediated by the tools. The subject can be either an individual or a group of people. Tools can be physical, such as a scientific apparatus, or they can be psychological, such as language or symbols. A subject can carry out many activities, and each of the activities will have a different objective.

The community encompasses all subjects and groups of individuals who share the same general objective and who distinguish themselves as distinct from other communities. The relationship between the subject and the objective is mediated by the community. Rules govern the subject's actions and behaviour within the community. The relationship between the subject and the community is mediated by the rules. Rules refer to explicit and implicit regulations that direct actions within the activity system. Finally, we have the division of labour, which the community uses to achieve the objective. The division of labour refers to the way work is divided between the members of the community, both vertically (between management and workers) and horizontally (between colleagues of the same rank) in an organisation. The relationship between the community and the objective is mediated by the division of labour.

Expansive learning (Engeström, 1987) argues that the notion of the vertical transfer of knowledge, from the expert to the novice, with its focus on providing curricular and pedagogical experiences linked to specialist knowledge fields (Lave, 1988; Lave and Wenger, 1991), although still important, does not necessarily assist individuals in solving new problems successfully or to learn quickly in new situations. Furthermore it is not possible to predict the problems that students will encounter when on their teaching practice, as such, it is not possible to provide them with a 'learning kit' (Tuomi-Gröhn, 2003) that would provide them with solutions to problems. This sees learning as involving the acquisition of knowledge and skills and that these are portable as the learning can be abstracted from the experience. Such portable knowledge is disputed by theories of situated learning (Beach, 1999; Lave and Wenger, 1991) where the focus is on knowledge creation through participation in meaningful activities. Thus social engagement provides the context for learning to take place with knowledge acquisition being inseparable from practice. Within such a context practice (*i.e.* participating in teaching) is fundamentally more important in terms of learning and transfer.

Expansive learning (Engeström, 1987) also argues that vertical and situated concepts of learning and transfer provide us with a very narrow understanding as individuals are limited by the range of the spheres in which they operate. The learning of an individual is only understandable if we first understand the nature of learning of the collective activity system. Essentially individual learning and learning of the collective activity system are intertwined with significant learning processes achieved by collective activities with boundary-crossing events (*i.e.* teaching placements when students move from the teaching institute to schools) being seen as shared research and learning events (Lambert, 2003). Thus the unit of analysis needs to be the collective activity systems mediated by cultural artifacts (tools and signs) as well as rules, communities and division of labour (Tuomi-Gröhn, 2003).

The complexity of schools within a culture of change and the provisionality of knowledge requires all involved in education to effectively and efficiently seek knowledge from a variety of different sources entailing co-operation with different experts. Socio-cultural theories stress that the acquisition of knowledge is fundamentally a social process (Guile and Young, 2003) which is a function of interaction within/between groups and organisations as well as something which resides in the individual. Although educational institutions are knowledge producing organisations no-one person will have the answers or solutions to the problems that arise, as such, in addition to vertical expertise practitioners require to develop horizontal expertise, whereby knowledge is created collectively through engaging in dialogic interaction. Such horizontal expertise can be developed through an examination of 'boundary objects' (Star, 1989). A boundary object is something precise such as a concrete artifact (*i.e.* form) or shared mental model that can be used to facilitate and promote collaboration between partners by enabling them to share and merge their different perspectives through dialogic interaction. Such a collaborative learning process facilitates the development of horizontal expertise.

Wenger and Lave (1991) describe this in terms of engagement within a 'community of practice' (CoP). A CoP involves learning brought about by a shared practice around an area of knowledge or activity making it different from a geographical community or a community of interest as it is 'about something' rather than merely being a network of relationships. CoP's develop around activities that matter to people. Learning is seen as a process of enculturation into a CoP (Deforges, 2001). Interestingly for Wenger (1998) CoP's are self-organising systems with practice being determined by the community rather than external dictate. For Wenger (1998) a CoP is defined in terms of:

- what it is about - its joint enterprise
- how it functions - social and collaborative interaction which binds members together
- what capability it has produced - the resources (*i.e.* tools, documents, language, *etc)* developed over time.

[Wenger, 1998]

Within the school this will involve the teacher, students and pupils working together on the basis that learning occurs through collaborative activity. This activity enables the student to move from the boundary to full participation in the core activity of the school through learning from others. Wenger (1998) describes organisations (*i.e.* schools) as a constellation of interrelated CoP's with overlapping membership, with people being core members of some CoP's whilst operating on the periphery of others, which allows for the transfer of knowledge from one context to another through social and collaborative activity. Such membership is dependent upon participation rather than job specification or role within the organisation.

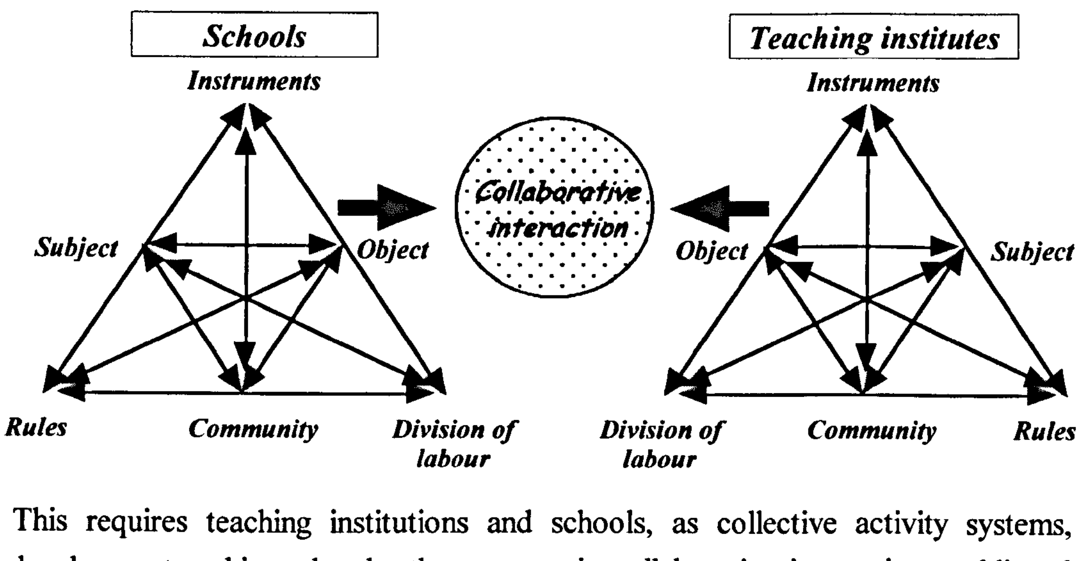
Knowledge gained and codified in one context cannot simply be transmitted in a different context without the active participation of the students in the process of recontextualisation. Consequently learning experiences encountered in science methods courses cannot simply be replicated within the school context without collaborative activity aimed at recontextualisation of the learning experience:

> *what is transferred is not packages of knowledge and skills that remain intact; instead, the very process of such transfer involves active interpreting and reconstruction of the skills and knowledge to be transferred*
>
> [Tuomi-Gröhn, 2003, p. 202]

A key focus of the work in teaching institutions should be to develop knowledge appropriate for boundary-crossing purposes (Lambert, 2003). However, Lambert (2003) is critical of the lack of interaction that takes place between teaching institutes and schools such that:

> *pedagogical interaction is restricted only to the classroom context, between the teacher and the students, and hence, the development work does not expand into school contexts, outside teacher education, but ends when the student teacher finishes the teacher education programme.*
>
> [Lambert, 2003, p. 235]

Figure 2.3: Interacting activity systems (Engeström, 1987)



This requires teaching institutions and schools, as collective activity systems, to develop partnerships whereby they engage in collaborative interaction enabling them to learn from each other through negotiation and exchange between cultures (see Figure 2.3). Though collaborative interaction the two activity systems can create mutually relevant 'boundary practices' (Wenger, 1998) from which they can both derive benefit. Problems that arise are resolved with deploying the expertise extant in both activity systems. Tuomi-Gröhn (2003) argues that such collaborative activity aimed at creating knowledge and solving problems is capable of being transferred from one situation to another. Such a dynamic process is multidirectional and multifaceted describing developmental transfer.

2.8 Piaget, Vygotsky and Cognitive Acceleration

Adey and Shayer's (1994) work on the Cognitive Acceleration through Science Education (CASE) programme in secondary schools utilised a Piagetian framework as well as drawing upon the socio-cultural psychology of Lev Vygotsky to develop the cognitive acceleration teaching strategies. Piaget's later work indicated that the transition between stages may be a little more flexible that he had previously thought due to the presence of cognitive fragments (Sprinthall *et al.*, 1998; Moore, 2000). It has also been found that pupils can also operate at different Piagetian stages depending on the context, or domain, in which they are working (Matthews, P.S.C., 1997). This occurs when learners, in nearing the end of one stage, begin to develop thinking patterns which will become more fully developed in the subsequent stage. Adey and Shayer (1994) have shown it is possible to 'accelerate' or support learning *within* a stage by providing learners with general thinking strategies. Shayer and Adey (2002) outline 'six pillars' of cognitive acceleration consisting of:

- *schema theory* - this is a general way of thinking, linked to Piaget's concrete operations, which can be utilised in a variety of contexts;

- *concrete preparation* - this is the context, including the language to be used, within which problems are set;

- *cognitive conflict* - the activities set contain challenges which are sufficiently difficult that the learner will be unable to achieve a resolution of the challenge without support (or scaffolding). In the process of assimilation aided by support new conceptual frameworks are 'constructed';

- *social construction* - cognitive acceleration approaches encourage learners to describe and explain their thinking in relation to new ideas and to engage in group discussions in order to support individuals in reaching new understandings;

- *metacognition* - following the completion of a problem-solving activity learners are encouraged to make their thinking processes explicit (McGuinness, 1990);

- *bridging* - once a new understanding has been reached within one context learners are encouraged to consider other contexts into which this new understanding can be translated.

Adey and Shayer (1994, 2002) argue that these 'six pillars' enable learners to discover ways of thinking which will bring about solutions to problems. To achieve this teachers engage learners in a three stage act of:

- *concrete preparation phase* - during this initial phase the learners are introduced to the problem-solving activity. Some construction may be necessary in terms of clarifying the nature of the activity or in making connections (*i.e.* bridging) with previous learning;

- *collaborative construction phase* - working in groups the learners attempt to outline a solution to the problems using a variety of idea generating techniques (*i.e.* brainstorming, 'piggy-backing' ideas, *etc*) supported by tactical questioning by the teacher as they move around the groups;

- *presentation and distillation of ideas phase* - as each group presents their 'solutions', many of which may be incomplete, to the whole class group they are engaged in a dialogue which seeks to achieve a distillation of the key elements of the learning experience as well as facilitating metacognition.

The critical skills developed as part of this strategy is an attempt to translate a psychological model into educational practice (Shayer and Adey, 2002) necessitating:

> *refocusing the main aim of the whole enterprise of education from being primarily concerned with content - knowledge, understanding, skills and attitudes - towards a primary concern for intellectual development per se.*
>
> [Shayer and Adey, 2002, p.16]

Vygotsky did not see his work as being in opposition to Piagetian analysis but rather as complementing it. Adey and Shayer (1994, 2002) provide an insight into a teaching strategy, synthesising the Piagetian and Vygotskian perspectives, that is social and collaborative in nature with the learner internalising the mental processes initially made evident in social activities. The Piagetian perspective provides a model of the child whilst the Vygotskian perspective provides a model of the social aspect of cognitive development (Shayer and Adey, 2002). The teacher has a crucial role to play in designing appropriate activities, involving discourse as well as providing support or '*scaffolding*' for optimal learning.

2.9 Jerome Seymour Bruner (1915-Present)

The work of Jerome Bruner is often seen as part of a progression in thinking within developmental psychology. Piaget laid the groundwork by articulating a view which outlined the *psychological context* of learning. Vygotsky built on Piaget's work by developing a *social context* for learning. Bruner, in his more recent work, has taken this a stage further by developing a theory of cognitive growth which has incorporated a *cultural context* (Geelan, 1997) with learning taking place within a socio-cultural context giving rise to the notion of *situated cognition* (Bliss, 1995). However, Bruner would be uncomfortable to have his work considered in a chapter of learning theory as he views such theory as descriptive and reactive telling us only what happens after an event (Sprinthall *et al.*, 1998). Bruner's early work concentrated on developing a prescriptive '*Theory of Instruction*' (1966) focussed on assisting teachers in improving rather than describing learning.

The *Process of Education* (1960) was a seminal text; outlining a view of children as active problem-solvers who are ready to explore 'difficult' subjects. Several important themes emerge out of this work. Firstly Bruner suggests that it is possible to identify the structural components of any body of knowledge. Furthermore it is possible to break down and organise these structural components in order that it may be passed on and understood by almost any learner. Effectively communicating this will depend upon:

- *Mode of presentation*
  The technique that a teacher selects to communicate knowledge should take into account the pupil's level of development. Bruner argues that understanding can be achieved through either *enactive* (physical actions and experience), *iconic* (pictures, diagrams, *etc.*) or *symbolic* (language) representation. The mode of representation is dependent upon the pupils age, background as well as the subject matter itself. Science is one of the subjects, particularly in the early years of schooling, which should be represented by all three modes.

- *Economy of presentation*
  This can be stated simply as the fewer the bits of information the learner must process then the greater the economy. This will be particularly important at points in the lesson when instructions necessary to complete the task are issued or when learning outcomes are summarised as part of lesson recap.

- *Power of presentation*
  The simpler the presentation the more effective it is in enabling learners to comprehend.

Bruner also asserts that schools waste a great deal of the pupil's time by postponing the teaching of important areas because they are deemed to be 'too difficult': the notion of *readiness for learning.* Bruner asserts it is possible to *sequence* the presentation of subject knowledge such that it is accessible to all learners. This notion underpins the idea of the *spiral curriculum* with pupils engaged in learning experiences which involve revisiting previous experiences, through repetition and revision, followed by gradual progression (Smith, 2002). Within such a curriculum the learner constantly revisits 'previous' learning and understandings in order to assist the development of 'new' learning and understandings. This introduces the notion of *provisionality* (Moore, 2000) in learning in which our understandings are subject to revision as we develop. Bruner suggested that intellectual ability developed in stages through step-by-step changes in how the mind is used, and that this will involve learners stepping backwards as well as forwards in order to revise understandings.

Bruner argues that developing an interest in the material to be learned is the best stimulus to learning. External motivation, through 'rewards' that emanate from 'outside' the individual learner (*e.g.* ticks, smiley faces, *etc.*), is important with respect to making sure that certain desired responses are repeated. Consequently Bruner accepts that reinforcement has a role to play in supporting learning. However, external motivation has, for Bruner, an ephemeral effect upon learning. The will and drive to learn can only be maintained through *intrinsic motivation.* This can either be already present in the individual or, more importantly for Bruner, arise out of an interest in the activity itself. Developing problem-solving activities which are challenging but for which solutions are achievable, given the pupil's knowledge base, becomes the key task for teachers. Such tasks are more likely to activate the pupil's curiosity and encourage them to explore.

Bruner does not appear to give much weight to *extrinsic motivation* where the learner projects outwards towards the achievement of some external goal (Scott Baumann *et al.*, 1997). This could involve the learner engaging in the learning in order to please others (*i.e.* social motivation), or to obtain good grades (*i.e.* achievement motivation). research indicates that effective learners tend to have a learning rather that a performance orientation (MacGilchrist *et al.*, 2004). Dweck (1999) develops the concept of self-theories as a way of understanding the different orientations to learning tasks adopted by learners. Learners with a performance orientation are prone to 'learned helplessness' whereby they tend to give up easily when they encounter difficulties. Success is linked to ability rather than effort with learners believing that they have little control over their learning. Conversely learners with a mastery orientation remain confident that they can be successful, despite unsuccessful outcomes, by revisiting and adopting different strategies as well as increasing their efforts.

The significance of intrinsic and extrinsic motivation should not be lost within the classroom where it is essential that teachers present pupils with tasks that will stimulate their interest as well as ensuring that this interest is sustained. This may well involve the teacher in assisting the pupils in 'seeing' the relevance of the task by projecting beyond the task itself. Watkins *et al.* (2001) developed this thinking by distinguishing between '*metacognition*' and '*meta-learning*'. The former is essentially '*thinking about thinking*' suggesting that it is important for learners to have a sense of control over their own learning (Gipps and Murphy, 1994). Meta-learning is a much broader concept involving an awareness of the goals, feelings, social relations and the context of learning (Watkins *et al.*, 2001). Dweck (1999) argues that constructive feedback should praise effort and strategic behaviours as well as providing further insights into the processes of the task. This is infinitely preferable to praise that focusses on performance (*i.e.* outcomes of the task) and intelligence.

Bruner advocates that learners should be provided with opportunities to restructure their understanding through experience with the environment. Rather than being '*given*' answers learners should '*find out for themselves*' through *discovery learning.* However, Bruner does not advance the argument that learners are involved in 'discovering' solutions to problems which run counter to scientific thinking. Such a methodology does recognise that in (primary) science courses the knowledge content is not subject to any dispute: it is known and verifiable science. What is being suggested is a methodology which enhances the learner's understanding by engaging them with the basic principles which underpin aspects of our knowledge base. This approach, according to Bruner, is more likely to lead to a deeper level of understanding than would be possible by a transmissive methodology. This approach is more demanding of the teacher as it involves conceptual learning with the focus being on ideas rather than facts.

The teacher should seek to '*stretch*' the learner by providing them with opportunities to perform at higher levels rather than merely testing what they have already achieved. This contrasts with the assessment procedures extant within the 5-14 curriculum whereby pupils are assessed against descriptors based on *what they have achieved* rather than *what they are capable of.* Professional judgements of 'learning readiness' serve to constrain learners. Bruner develops the Vygotskian perspective to suggest a prescriptive theory of instruction which attempts to describe how teaching should be accomplished. Bruner's conception of a spiral curriculum which sees the acquisition of knowledge as a process in which every new experience builds on the foundation established by previously learned experiences provides teachers with a starting point in the development of instructional events. Bruner further suggests that these instructional events should incorporate '*discovery learning*' techniques as they are more likely to promote learning, which will involve understanding and the sharing of meaning, by providing learners with opportunities to search for solutions and meaning through the exploration of alternatives (Child, 2004). Critics of the constructivist perspective would argue that pupils in constructing their own understanding are unlikely to construct a scientific understanding (Hodson and Hodson, 1998). There is also a concern that 'discovery methods' may lead to a relativist ontology (Kelly, 1997), with constructivist learning being tautologous (Matthews, 1994a), and as such it is necessary that:

> *if knowledge construction is seen solely as an individual process, then this is similar to what has traditionally been identified as discovery learning. If, however, learners are to be given access to the knowledge systems of science, the process of knowledge construction must go beyond personal empirical inquiry. Learners need to be given access not only to physical experiences but also to the concepts and models of conventional science.*
>
> [Driver *et al.*, 1994, p.7]

2.10 Robert Mills Gagné (1916-2002)

Robert Gagné's position has been described as *eclectic behaviourism* (Child, 2004). His major work '*The Conditions of Learning*', first published in 1965, was firmly rooted within the behaviourist tradition. However, subsequent revisions (Gagné, 1985) of this work included cognitive thinking, particularly information-processing theory, whilst retaining an instructional design theory which continued to be influenced by the behaviourist paradigm. The significance of Gagné's theoretical framework is that it is prescriptive rather than descriptive, representing an attempt to *plan* for cognitive change in the learner.

Gagné argued that the acquisition of knowledge is a process in which every new experience builds on a foundation established by previously learned experiences (Gagné, 1985). For an instructional event to be successful it is necessary that the teacher be knowledgeable of the developmental capabilities of learners; thus the conditions of learning which affect the process of learning has components which are internal and external to the learner (Maschke, 2004). He applied this thinking to the sequencing of instruction in the classroom. The task of the teacher becomes one of identifying learning tasks which will achieve a desired *learning outcome* (*i.e.* cognitive change). Within an instructional events it will be necessary to break down the learning task into a planned sequence of sub-tasks by a process of *learning task analysis* (Child, 2004). Nine instructional events were identified along with their corresponding behavioural and cognitive processes. The first five events are designed to facilitate the acquisition of knowledge whilst the last four are designed to determine whether this knowledge has been processed. The nine instructional events proposed (Gagné, 1985) include:

- *Gain attention **(reception)***

  Present a problem or a new situation. Try to grab the learner's attention so that they will watch and listen, while you present the learning point.

- *Inform pupils of the objective **(expectancy)***

  This allows the pupils to organise their thoughts around what they are about to see, hear, and/or do (*e.g.* describe the goal of a lesson, state what the learners will be able to accomplish and how they will be able to use the knowledge). *Tell them what you're going to tell them; tell them; then tell them what you told them.*

- *Stimulate recall of prior learning **(retrieval)***
  This allows the pupils to build on their previous knowledge or skills (*e.g.* remind the pupils of prior knowledge relevant to the current lesson).

- *Present the stimulus **(selective perception)***
  Chunk the information to avoid memory overload.

- *Provide learning guidance **(semantic encoding)***
  This is not the presentation of content, but the instructions on how to learn. The aim is to reduce time lost or confusion amongst the pupils who may base their performance on incorrect facts or poorly understood concepts.

- *Elicit performance **(responding)***
  Enable the learner to do something with the newly acquired behaviour, skill or knowledge.

- *Provide feedback **(reinforcement)***
  Provide the learner with a test, quiz, or verbal comment which will facilitate specific feedback on their performance.

- *Assess performance **(retrieval)***
  Test to determine if the lesson has been learned.

- *Enhance retention and transfer **(generalisation)***
  Review the lesson, provide additional practice or present similar problems, *etc.* Activity which permits the transfer of learning is beneficial.

[Adapted from Gagné, 1985]

Gagné also suggested that learning tasks for intellectual skills can be organised in a hierarchy, placing the learning of some skills before others, according to complexity. This hierarchy consists of stimulus recognition, stimulus-response generation, chaining, verbal association, discrimination learning, concept formation, rule application, and problem solving (Maschke, 2004). The primary significance of the hierarchy is to identify prerequisites that should be completed to facilitate learning at each level. Prerequisites are identified through learning task analysis. Learning hierarchies provide a basis for the sequencing of instruction. This hierarchy suggests a progression of skills that need to be learnt from simple stimulus-response through to more complex cognitive processes. Gagné's theory further postulates that there are several different types of learning outcomes or domains of learning (Maschke, 2004). The significance of these classifications is that each different type will require different internal and external conditions as well as different types of instruction. Gagné identified five major categories of learning outcome:

- verbal information;
- intellectual skills --
  - discrimination,
  - concrete concepts,
  - defined concepts,
  - rules,
  - higher-order rules;
- cognitive strategies;
- psychomotor skills; and
- attitudes.

Identifying the domain of learning will have implications for the hierarchy of skills as it is important to determine the level of skill development necessary to take forward learning. These in turn impact upon the process of learning task analysis necessary to design an instructional event which seeks to promote cognitive development.

Despite the apparent problems presented in operationalising constructivism science does offer an opportunity to develop a constructivist pedagogy (Driver and Bell, 1986). Gagné takes this a step further by developing a theory of instructional design which seeks to unify behaviourist and cognitivist thinking to produce a prescriptive model for the design of instructional events. This provides a practical framework which offers the possibility, through managed instructional events, of blending making personal sense of the real world with understanding the socially constructed world of scientific ideas (Bliss, 1995). A constructivist-based model of teaching is likely to consist of:

> *elicitation of prior ideas, their clarification and exchange within the class group, exposure to conflict situations and construction of new ideas, followed by review of progress in understanding.*
>
> [Millar, 1989, pps.588-589]

This is not to suggest a relativist ontology, with pupils' views being given the same status as scientific theory (Jenkins, 2000). This would be a nonsensical position to adopt in teaching '*known*' science (Millar, 1989) drawn from scientific theories, based on a considerable body of verifiable evidence, which constitute the successes of science (Nola, 1997). The strength of constructivism is that it offers an epistemological insight which is of importance, namely that the learners' previous learning informs their alternative conceptions and these are of importance as they impact upon the learning process. Millar (1989, p.588) describes concept learning rather more eloquently as the '*reconstruction of meaning rather than simply the accretion of new ideas*'. The pedagogical approach proffered by Gagné suggests a means by which teachers can develop classroom activities which elicit previous knowledge, clarify and reconstruct ideas within a structured sequence of instructional events. Whilst the learner is engaged with such activities the teacher is active in monitoring and managing the reconstructive process. Interestingly this methodology does not preclude transmissive strategies, if they are appropriate, focussing upon good teaching rather than adopting a purist position with respect to constructivist epistemology, what Matthews (1994a) refers to as *pragmatic constructivism.* Accordingly:

> *science should be taught in whatever way is most likely to engage the active involvement of learners, as this is most likely to make them feel willing to take on the serious intellectual work of reconstructing meaning.*
>
> [Millar, 1989, p.589]

Pragmatic or pedagogical constructivism (Matthews, M.R., 1997), or what Bell and Gilbert (1996) refer to as a 'constructivist mind-set', suggests that science education, given that the knowledge base is agreed and verified, should be taken forward by whatever methodological approach that is deemed to be effective. Although a constructivist approach is useful in particular contexts this is not the same as saying it is universally useful. To abandon other methodological approaches because they are inconsistent with a radical epistemological interpretation of constructivism would narrow the range of experiences which we can provide to the pupils. This is consistent with Feyeraband's (1975) notion of *epistemological anarchy.* No single approach is by itself adequate.

The next section of the literature review will look at the impact that these theories of learning have had upon policy developments in primary science.

CHAPTER 3 POLICY DEVELOPMENT

3.1 Introduction

> *That education is not an affair of 'telling' and 'being told', but an active and constructive process, is a principle almost as generally violated in practice as conceded in theory.*
>
> [Dewey, 1916, p. 38]

The term 'primary school' first appeared in the Education (Scotland) Act 1901 to replace the term elementary. The elementary school was created as part of a national system of compulsory schooling, to promote the development of basic education, the 3R's, for children aged five to thirteen by the Education (Scotland) Act 1872. This was education for the '*carriers of water and the hewers of wood*' (Harlen and Simon, 2001). Science in the elementary school had been promoted through H.E Armstrong's[3.1] 'heuristic method' or 'object lessons' approach in physical science, particularly chemistry. Armstrong sought to promote science through practical work with pupils being encouraged to understand science by discovering it for themselves (Adey, 2001; Harlen and Simon, 2001). However, Armstrong's ideas were not universally accepted at the time with many stressing the importance of transmission of factual information through instruction. Throughout the historical development of science in the primary school there has been a tension between differing views as to how learning takes place. This recurring theme in the development of policy with respect to primary science throughout the twentieth century is the focus of this chapter.

During most of the 20th Century several trends can be identified in the development of the primary school curriculum and more specifically in terms of science education:

- the expansion of subject content;
- the re-framing of science education in terms of the relative importance of scientific knowledge (content) and methodology (process skills);
- integration of the curriculum along with a move away from teachers teaching to children learning;
- the re-emergence of specialism in the upper school.

During this period the primary science curriculum has seen a refinement in its curricular focus: from the introduction of nature studies through to the idea of science, then onto the sciences, science within the context of Environmental Studies and finally developing into the present 5-14 Science attainment outcomes. Policy developments have followed a tortuous path which provides an insight into the contemporary issues and problems within primary science education. Thus in primary science, as in science itself, to understand the present one must appreciate the legacy of the past.

[3.1] Professor Henry Edward Armstrong FRS (1848-1937). Professor Emeritus, Imperial College and President of Royal College of Science Association (1914-1919).

3.2 Pre-1960s: Science as Nature Study

The consensus that emerged during the early part of the 20th Century was that science should consist of nature study: with the aim to educe a love of nature based around practical activities, more specifically observation, rather than through 'traditional' lessons. This view was officially endorsed by the Hadow Report (Board of Education, 1931) entitled *The Primary School* which described the primary school as an instructive environment in which:

> *the curriculum of the primary school is to be though of in terms of activity and experience rather than of knowledge to be acquired and facts to be stored.*
>
> [Board of Education, 1931, Recommendation 30]

Hadow argued that the starting point for learning within nature study should be the experiences, curiosity and the interests of the children themselves. Arguably the scientific aspects of nature study were subsumed under the spiritual and aesthetic considerations of nature. In reality this consisted of a syllabus planned on a seasonal basis effectively leading to a perpetual series of lessons linked to the cycle of naturally occurring phenomena. This Report represented a key statement of progressivism, making a break with the 'traditional' perspective, which saw the learner as a passive entity whose role was to absorb factual information transmitted to them by the teacher. The curriculum was that which was to be taught, having been determined with no reference to the learner. Thus at the very heart of this often overlooked report lay the seed, which was to germinate into the 'child-centred' approach, of subsequent reports including the much later, and better known, Primary Memorandum (SED, 1965).

Hadow's Reports (1931, 1939) offered a legitimation of primary school education as both an idea and a legal entity (Alexander, 1995). However, the 1930s was a period of inadequate funding in education, as a result of the poor economic situation following the slump in 1929, and this combined with the poor training of teachers, led to an innate conservatism in the face of change which came to characterise the elementary tradition in teaching. This meant that the approach advocated by Hadow was not realised in terms of the experience of the pupils.

The next significant development in the science curriculum came with the publication of the 1950 Memorandum: *The Primary School in Scotland* (SED, 1950). This Memorandum was begun in 1942 but publication was delayed for a variety of reasons which included incorporating the legislative framework of the Education (Scotland) Acts of 1945 and 1946. The first outcome of this process came when the Advisory Council on Education in Scotland published its report entitled *Primary Education* (SED, 1946). This Report advocated the bringing together of Nature Study with

Geography and History in a precursor to Environmental Studies. In the early stages of the primary school it was argued that these should be closely associated rather than sharply differentiated. The aim of curricular integration was to meet the needs of the child to 'know his world' (SED, 1946). The child was not to be 'troubled' with facts and ideas outside their natural range of interests and receptivity which could arise if the teacher sought to impose the form and content of lessons. Rather the teacher's role was that of facilitating learning by directing observation, answering questions and encouraging classification linked to the interests of the child. Any syllabus drawn up by the teacher should be thought of as a rough outline of what they hope to achieve rather than a prescriptive body of knowledge to be taught and learnt (SED, 1946). The principles outlined in this report were translated into terms of classroom practice with the publication of the Memorandum (SED, 1950).

The 1950 Memorandum highlighted the fact that children were missing out on the practical experience of science, namely nature study, which was being taught largely by didactic methods which had little relevance to the lives or environment of the children being taught. The criticism that pupils tended to play too passive a role in their own education was linked to the contention of the 1950 Memorandum that structurally the primary curriculum had remained unchanged for over 50 years (SED, 1950). Teaching methods and subject content had become fossilised; with the experience of many pupils in the 1950s, being little different from that of preceding generations. The 1950 Memorandum in endorsing the role of activity and experience in the study of science, advocated in the earlier Hadow Report (Board of Education, 1931), observed that:

> *while the principle has received wide acceptance in Scotland, it has not influenced the practice of our schools to anything like a sufficient degree.*
>
> [SED, 1950, Para. 65]

The 1950 Memorandum asserted that methods based on activity and experience were supported by psychological evidence which had emerged since the publication of the Hadow Report (Board of Education, 1931). However, it did not cite what this psychological evidence was, and state why it was important in explaining the assertion that changes in attitudes to the curriculum had taken place since the 1930s such that:

> *the school should be 'child centred' and not 'curriculum centred' - that it should be concerned with teaching children rather than with teaching subjects - and that, in consequence, the method by which the child learns is as important as, and sometimes more important than the facts learned.*
>
> [SED, 1950, Para. 10]

and later that:

> *every subject, when treated skilfully, may give pupils the thrill of exploration and discovery and the solid satisfaction that comes from a sense of increasing power.*
>
> [SED, 1950, Para. 10]

There was a degree of ambiguity about how the curriculum was to be structured as the Memorandum also argues that the division of the curriculum into subjects is merely a matter of convenience. Teachers are advised to take care not to teach subjects in isolation from one another. Additionally the 1950 Memorandum clearly advocates learning by experience which should relate both to the 'pupils' experience' and the school's environment. In terms of the science curriculum "*actual objects and living specimens should be studied at first hand*" (SED, 1950, Para. 343). The teacher should, in facilitating learning through experience, make use of the pupil's past experience, in and out of the school, in order to identify an appropriate learning path for each child. This emphasis on 'process', in which children are actively involved, came to define a 'progressive' pedagogy. However, it would be wrong to assume that such a 'progressive' pedagogy is endorsed to the exclusion of the more 'traditional' pedagogy; which was seen as little more than the transmission of facts by the teacher and absorption of these facts by the child. In the introduction to the 1950 Memorandum it argues that:

> *it would, indeed, be wrong to ignore the need for and, within its proper sphere, the value of information given by the teacher and memorised by the pupils.*
>
> [SED, 1950, Para. 5]

Thus the 1950 Memorandum argued that content and process are inextricably interlinked. Additionally, it introduced the notion of context through, in terms of 5-14 terminology, the development of informed attitudes to nature. This is evident in the stated aims of the nature study curriculum which were described as:

- to train the child in careful observation;
- to impart some knowledge of familiar natural phenomena;
- to foster an appreciation of nature;
- to indicate in a simple fashion the interdependence of men, animals, and plants, and their dependence on physical conditions;
- to encourage a humane attitude towards living things, and to counteract any inclination towards wanton destruction;
- to provide a valuable leisure-time interest.

[SED, 1950, Para. 340]

These two documents illustrate an area of epistemological and pedagogical tension within science education which persists today. The 'traditional' view sees science as a body of established knowledge and theory derived from the facts of experience, obtained through observation and experiment. Science education concerns itself with the development of skills and the learning of scientific facts and principles. It is the teacher who controls this process through instruction and the use of textbooks. Children engage in a passive learning process in which they are introduced to the 'correct' scientific view. The converse to this view is that knowledge is tentative, being subject to periodic revision, and constructed within a socio-cultural framework. This framework will influence both the nature of the knowledge and the processes by which this knowledge is derived. This gives rise to a process approach to science with the learner developing understanding through exploring and testing ideas against evidence. Essentially people create their own understanding, derived from their experiences, which may or may not be in agreement with accepted scientific understanding. Conceptual change may take place, following further directed experiences, if this is seen as appropriate by the learner. In this approach it is argued that the learner is in control of the learning experience (*i.e.* a 'child-centred' approach) with the teacher facilitating this process. This latter, constructivist view is currently the dominant paradigm within science education (Nussbaum, 1989; Jenkins, 1992; Littledyke, 1996).

3.3 1960s and 1970s: An age of discovery?

The 1960s saw the publication of two influential reports, namely *Primary Education in Scotland* (SED, 1965 - *The Primary Memorandum*) and *Children and their Primary Schools* (DES, 1967 - *The Plowden Report*). Both these reports advocated the replacement of nature study with a combination of natural and physical science, or *science as a whole*. The aim of science was to:

> *cultivate an attitude of mind as a result of which the pupils will enquire, observe, experiment and perhaps even link cause and effect.*
>
> [SED, 1965, p. 141]

Thus the emphasis was on the scientific method which was to be realised through exploration and discovery methods: the 'process' of science. The Primary Memorandum included Science along with History, Geography and Mathematics as part of its newly articulated Environmental Studies framework. These were not to be seen as discrete disciplines, especially in the lower primary (pre-Primary 5), as:

> *it is quite impossible to treat the subjects of the curriculum in isolation from one another if education is to be meaningful to the child.*
>
> [SED, 1965, p. 37]

The subject matter of primary school science was thought to be self-evident in that it consisted of those objects and phenomena in the physical world which attract and interest the child. This was, to some extent, dependent upon the context of the school's environment, the resources available as well as the interests of the teacher. These reports advocated an integrated approach, as "*knowledge does not fall into* *rigidly separate compartments*" (DES, 1967, Para. 503), through 'topics' or 'centres of interest' (SED, 1965) which link with pupils' interests both within and outside the classroom as long as that interest is maintained by the pupils. The systematic teaching of single curricular disciplines was seen as a teacher-centred pedagogy which was dull and remote from the child's interests and, as such, less valuable than the more global approach advocated through centres of interest and a variety of 'project methods' (CCC, 1983). However, beyond Primary 5 differentiation into discrete subjects was seen as appropriate in order to engage in more systematic study.

Both reports also advocated an extension of the concept of the 'child-centred' curriculum; asserting that "*at the heart of the educational process lies the child*" (DES, 1967, Para. 9). The child was seen as an "*agent of his own learning*" (DES, 1967, Para. 529). Learning was viewed as taking place through individual exploration and discovery as a result of first-hand experience. Nature Study was criticised for the lack of first-hand observation evident in the primary school curriculum. The teacher's role is seen as changing with teacher-dominated methods and subject-centred curricula giving way to methods and curricula based on the needs and interests of the child (SED, 1965). Thus the teacher's role was no longer that of a leader and initiator of the learning process, but rather as someone who provided a context for learning to take place by "*creating situations which provide opportunities for activity and discovery*" (SED, 1965, p. 128). This resulted in a pedagogical rift between the 'traditional' didactic methods, which were viewed as regressive, and the more favoured 'progressive' methodologies based on exploration and discovery. The emphasis was on 'process' skills and concrete experiences with content being entirely subordinate; learning to *do* science rather than learning *about* science. In addition it was the children who were both the initiators of their own work and the determinants of how long they would proceed with this work.

The Primary Memorandum criticised the 1950 Memorandum for providing guidance on the timetabling of subjects which, it argued, was interpreted narrowly; perpetuating a subject-based timetable with little variation. The 1950 Memorandum had suggested:

- Classes P1 to P2 -- 40 minutes per week for Nature Study in a 17.30 hour week;
- Classes P3 to P7 -- 60 minutes per week for Nature Study in a 22.30 hour week.

The 1950 Memorandum indicated that this was not to be seen as rigidly controlling the school day but rather as a means of maintaining a balance between the various curricular activities (SED, 1950). Furthermore curricular integration was suggested for P3 to P7 as the division of the curriculum into subjects was a matter of convenience. However, this was not justified on educational grounds but as a device to 'save time' in the crowded upper primary curriculum. Additionally teachers were warned to take care that the primary purpose of the lesson was not obscured.

The Primary Memorandum argued that this was undesirable in a curriculum where the emphasis passed from the subject to the needs of the child. Differences amongst children would necessitate flexible time-lines in taking the curriculum forward. However, this was, to a degree, contradicted by the requirement to ensure that over a term, or a session, the curriculum was well balanced and that there were no serious omissions. Accordingly it suggested a 'tripartite curriculum' (CCC, 1983) with one third of the time being devoted to each of the three principal components of the curriculum: namely language arts, environmental studies (incorporating science) and the remainder of the curricular activities. However:

> *the time which is spent on any activity is educationally less significant than the amount of work that is effectively covered, and that the assessments which teacher and head teacher make at regular intervals should be in terms of achievement rather than time.*
>
> [SED, 1965, p 72]

Despite this apparent liberal interpretation in the use of time the Primary Memorandum led to much greater curricular prescription and to a curriculum which was much more bureaucratic in nature. Rather than being child centred the curriculum was 'head-teacher centred' (McEnroe, 1983) with control of what is taught increasingly being in the hands of the teaching staff. This shift takes place due to the requirement to produce 'schemes of work' (SED, 1965) to indicate the broad outline of the work to be undertaken at each stage in the school. These were to be made available to all of the teaching staff in order that they would incorporate this knowledge in their detailed planning. This was to be articulated in 'programmes of work' (SED, 1965) to be set out for as much as a month in advance on a week-to-week basis detailing the topics to be covered, the activities undertaken and the skills to be learned. This leaves little scope to incorporate the interests of up to thirty children into curriculum planning.

The child-centred approach advocated was based upon the emergent discipline of development psychology in which the dominant paradigm was Piagetian. Piaget (1926, 1950) postulated that there was a series of qualitatively different stages to describe the intellectual development of children from birth to adolescence. Within this framework children 'construct' their own knowledge, through their own activity, by the processes of assimilation and accommodation. Knowledge is subjective and consequently the intuitive ideas of science that children develop, through their experiences, are no longer 'wrong', merely different. New learning must start from this position and as such it is child centred. This clearly is a break with the past in that the 'traditional' perspective dictates that teaching, through behavioural methods, would seek to 'correct' misconceptions in scientific ideas. However, for Piaget it is development which precedes learning and is necessary for learning to take place. Plowden (DES, 1967) utilised this stage theory:

> *as a tool to match the content of science curricula to children's spontaneous intellectual development.*
>
> [Bliss, 1995, p. 141]

The significance of this was that children should not be taught certain ideas until they were ready for them. This is immediately attractive to those teachers who found scientific ideas difficult themselves. Avoidance, in a sense, was legitimised. The Plowden Report asserted, without providing supporting evidence, that:

> *until the child is ready to take a particular step forward, it is a waste of time to try to teach him to take it*
>
> [DES, 1967, Para. 75]

and that:

> *finding out has 'proved' to be better than being told.*
>
> [DES, 1967, Para. 1233]

However, this ignores the role that teachers have in preparing children to be ready for difficult ideas through structuring their learning experiences. A critique of this approach would suggest that, taken to its logical extreme, it can lead to relativism in which any view offered by a child is acceptable (Matthews, 1994a). However, an effective science pedagogy requires constructs to be both meaningful to the learner as well as in accordance with scientific thinking. The child-centred philosophy was well received in Scotland; however, the teacher remained 'firmly in charge' (Darling, 1999). Evidence suggests that many teachers retained a 'traditional' framework (Clayden *et al.*, 1994).

The Primary Memorandum (SED, 1965) and the Plowden Report (DES, 1967) proved difficult to operationalise as they did not provide sufficient guidance and elucidation of their stated aims and procedures. The two reports were preceded by the Nuffield Foundation sponsored Nuffield Junior Science Project (NJSP) which ran from 1964 to 1966 developing materials for use in schools. The main aim of this project resonated with the recommendations of the reports in that the NJSP sought to encourage first-hand experience in science lessons; such that the learner should become a 'scientist for the day'. The approach to science education advocated that, through the development of process skills (*i.e.* the 'scientific method' or professional practice of scientists), the child would discover the facts and laws of science for themselves. The authors also argued, in line with the later Plowden Report findings, that although research evidence suggested that it was not possible to hasten concept formation schools can have a positive effect on this by providing suitable experiences and situations (Wastnedge, 1967). A similar development in Scotland is evident in Curriculum Paper No 7.

To support teachers further in providing learning experiences in science, by providing a link between educational theory and classroom practice (*i.e.* with objectives in mind), the Science 5-13 Project was begun in September 1967 and ran until 1974 under joint sponsorship from the Nuffield Foundation, the Schools' Council (England and Wales) and the Scottish Education Department. This Project had a Piagetian framework in that it matched development stages, previously described by Piaget (*e.g.* linked to work on weight, classification, length and volume), through planned classroom activities to scientific processes (*e.g.* observation, finding patterns, *etc.*). It was argued that:

> *science involves exploration, and exploration involves the gathering of experience ..... we must help them to ask their own questions and find their own answers by first-hand experience.*
>
> [Ennever & Harlen, 1974, p. 5]

The principal aim of this project was the identification and development, at appropriate levels, of topics or areas of science related to a framework of concepts appropriate to the stage of development rather than the chronological age of the pupils. The Project agreed with Piaget that development was a continuous and cumulative process with each stage providing the foundation for further learning (see Figure 3.1). Thus pupils in any given class will not only be at different stages of development but that they will progress through the stages at different rates. As such it was important to differentiate the learning experience in order to assist progression in learning. To achieve this the booklets contained suggestions on how to diagnose the pupil's level of thinking so that appropriate material could be selected in order to stimulate further development. This, it was hoped, would assist teachers in helping children, through discovery methods, to gain experience and understanding of the environment and to develop their powers of thinking effectively about it. The outcome of this project was a complex curriculum based around 150 objectives linked to the Piagetian stages of development:

> *these stages we have chosen conform to modern ideas about children's learning and conveniently describe for us the mental development of children between the ages of five to thirteen.*
>
> [Ennever & Harlen, 1974, p. 65]

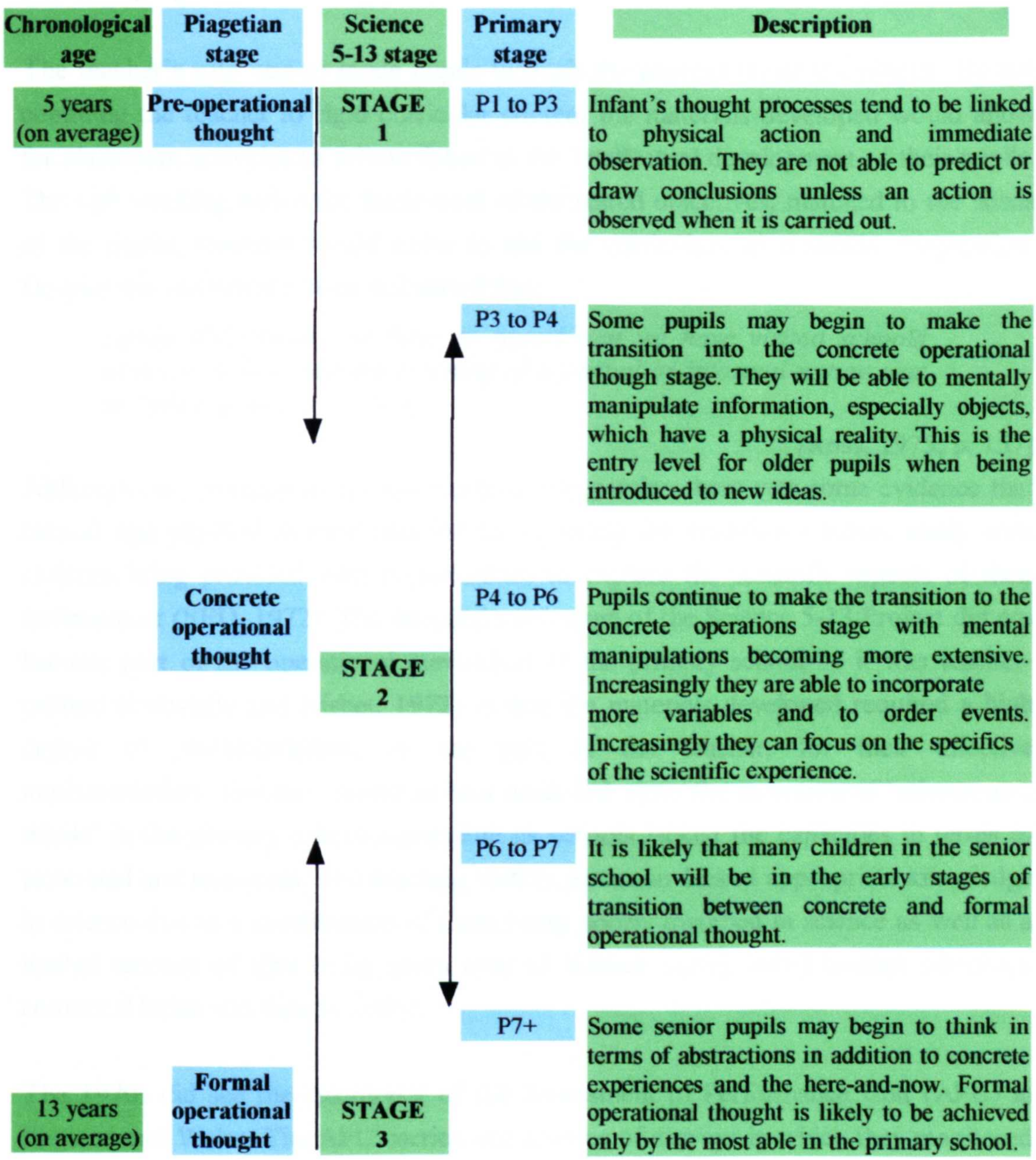
The objectives were also tied to the general aims for science education which were articulated as:

- developing interests, attitudes and aesthetic awareness;
- observing, exploring and ordering observations;
- developing basic concepts and logical thinking;

- posing questions and devising experiments or investigations to answer them;
- acquiring knowledge and learning skills;
- communicating;
- appreciating patterns and relationships;
- interpreting findings critically.

[CCC, 1981, p. 5]

Figure 3.1: Schematic linking Piagetian, Science 5-13 and Primary stages



The Science 5-13 Project was successful in moving from an intuitive base with obscure aims to a formally structured classroom approach with explicit objectives. These objectives served to define discovery in a way which enabled teachers to carefully provide opportunities for children to gain first-hand experience of living and non-living materials around them; whilst encouraging them to ask questions, detect problems and seek answers for themselves which they could communicate in ways they determined as appropriate. A major problem with the approach advocated was that discovery methods, as a teaching method, is not a general characteristic throughout the primary school. However, the real strength of the approach was that the methods developed emerged empirically throughout the lifetime of the Project. Furthermore this was not a course but rather a source of ideas which teachers could select from and incorporate into their programmes of work.

The teacher's role was to guide pupils through the process utilising dialogue. By not confining the teacher to rigid curricular content the materials developed would allow for classroom activities to follow linked to the intellectual development of their pupils. Through working within the framework of the stated objectives, matched to the needs of the pupils, teachers would come to see the curriculum as a steady progression. Despite this the Schools' Council stated that:

> *rather disturbingly we have to report that we have visited schools where very little science teaching of a formal or informal nature was included in the curriculum.*
>
> [Ross, 1975, p. 157]

Although the coverage of science teaching was patchy; there was some evidence that natural and physical science was indeed replacing the traditional nature study with children being provided with opportunities to explore the scientific aspects of their environment (SED, 1972). The intended curriculum of the Science 5-13 Project did not become part of the operational curriculum of the primary school as it was teacher-centred (Entwistle and Nisbet, 1972) in that the materials developed required a high degree of professionalism, on the part of the teacher, for their effective implementation. This has proved to be a weak link since the inception of 'science as a whole' in the primary school curriculum as schools lacked the capacities in terms of personnel and resources. The teaching staff in particular lacked appropriate knowledge in science due to a combination of them being poorly qualified in science as well as a limited amount of time being given over to science during initial teacher education courses (Harlen and Simon, 2001).

The 1970s did see the emergence of the Assessment of Performance Unit (APU) in England and Wales. The APU carried out a series of surveys in which they monitored progress amongst 11, 13 and 15-year-olds in Science, Mathematics and English. Similar surveys commenced in Scotland in 1984. These surveys have had a powerful influence upon curricular thinking within primary science in that they linked process and content indicating that a 'process is only a science process in relation to some science content' (Harlen and Simon, 2001). This debate about the nature of this linkage between process and content was to rumble on throughout the next two decades.

3.4 1980s: Primary Science and curricular definition

The 1980s commenced with emerging concerns that conceptual change was not taking place:

> *the essential nature of primary science as a process of enquiry has not been carried forward to any degree in the work of the pupils.*
>
> [Osborne & Simon, 1996, p. 105]

The HMI Report *Learning and Teaching in Primary 4 and Primary 7* (SED, 1980) detected a narrowing of the curriculum with very little science being taught at either stage. Some "*60% of all teachers giving it (science) little, if any, place in their curriculum*" (SED, 1980, p. 22). This was understandable in light of HMI's findings that many teachers lacked an adequate knowledge of science (SED, 1980). This lack of balance was compounded by findings that teachers, in the absence of a whole school policy, were able to decide for themselves the experience of Environmental Studies received by their pupils. To some 'localism' (Golby, 1988) was to be expected in the absence of a centrally prescribed curriculum. However, the concerns of the Inspectorate related to a lack of planning and continuity within a curriculum which was failing to meet the expectations of the Primary Memorandum. In addition an undue emphasis was placed on the memorisation of facts at the expense of first-hand experience (CCC, 1983) with some "*90% of P4 and 75% of P7 class teachers giving priority to the transmission of knowledge and facts*" (SED, 1980, p. 22). This led the HMI to conclude that "*the whole area of Environmental Studies requires to be reviewed*" (SED, 1980, p. 25) with a 'firm lead' being provided along with a greater degree of coordination from stage to stage.

In response to the inadequacies identified in primary science practice, outlined in the HMI report (SED, 1980), professional bodies continued to promote a 'tidy up' approach based on the philosophy of the Primary Memorandum. The Committee on Primary Education (CCC, 1981) acknowledged that science was about both content and process but, within primary education, it was the 'scientific method' which provided the best fit with children's natural way of learning. Yet science as a body of knowledge is shaped by its concepts and purposes rather than its methods (Osborne and Simon, 1996). However, it was asserted that:

> *knowledge is useful but the particular information which certainly will be gained is of less significance, educationally, than is their adoption of a problem solving approach with all that this way of finding-out implies.*
>
> [CCC, 1981, p. 4]

Thus it was how children go about their work in science that was important rather than the knowledge they gained. Additionally teachers need not be concerned with any perceived lack of knowledge that they may have with regards to teaching science as:

> *the teacher's contribution is her knowledge and understanding of individual pupils and her awareness of how they think and learn. In other words, it is her expertise as a teacher which is required, as indeed it is in all areas of the curriculum.*
>
> [CCC, 1981, p. 4]

Osborne and Simon (1996) argue that this approach was fundamentally mistaken as a pedagogy reliant solely on process fails to recognise that this is only one component of science education and as such confuses pedagogic ends with means. Other research indicates that subject knowledge is an important prerequisite to an effective pedagogy (Shulman, 1987; Summers and Mant, 1995b).

The Committee, whilst retaining the essential methodological ingredients of the Primary Memorandum did nevertheless concede that there was a need for a strategy of coordination. The Committee argued for the formulation of a policy which, in order to avoid duplication, would identify the process skills which pupils are expected to develop as they progress through the school as well as the topics covered. The Science 5-13 Project units were recommended for guidance in the development of such a policy; notwithstanding the fact that these materials had been deployed in a very limited number of schools. However, the policy being advised was merely a broad strategy that was not intended to infringe on the autonomy of the teacher to decide, at classroom level, the nature and extent of science teaching. This failed to address the growing disquiet amongst political pressure groups with professional judgement; in providing primary-school children with progressively challenging learning experiences in Environmental Studies (science).

The HMI response to Learning and Teaching in P4 and P7 (SED, 1980) was outlined in *Learning and Teaching: The Environment and the Primary School Curriculum* (SED, 1984). This paper represented a significant shift in emphasis away from the child-centred approach, and total teacher autonomy advocated in the Primary Memorandum, towards more 'disciplined learning'. The HMI were not arguing that education should not be child centred; indeed all education is child centred in that all educational processes should start from the present state of the learner; however, that may be defined (*e.g.* readiness, needs, current skills and knowledge) (CCC, 1983). However, a re-framing of our understanding was necessary as the notion of a child-centred approach had become linked with a process which did not adequately articulate its aims and objectives in terms of the concepts and skills to be acquired by children. Clarity of specification was thought necessary in order to ensure progression in children's learning. Thus HMI argued for coherent planned programmes in each curricular experience for each stage of the primary school to facilitate the:

> *need to plan the progressive development of the child's thinking about the environment, knowledge and understanding, attainment of practical skills and formation of responsive attitudes.*
>
> [SED, 1984, p. 11]

The DES discussion paper, *Science in Primary Schools* (DES, 1984) also indicated that there was a lack of planning with teachers being unaware of what science their pupils had covered in previous years, and what they were likely to cover in succeeding years. The paper recommended the development of schemes of work which outlined progression in both content and concepts; as well as providing advice on teaching methodologies, suitable practical work and on the resources available to take forward the science curriculum. This advice was supported with detailed curricular specification for the primary school years. Additionally this paper argued for caution in relation to curricular integration as the sole means of developing the pupil's experience of science. The DES discussion paper was followed by the policy paper, *Science 5-16: A statement of policy* (DES, 1985); which took these themes forward in an attempt to achieve a greater degree of definition through more detailed objectives in science education. The purpose of this paper was to "*define a framework within which change can take place*" (DES, 1985, p. 2). Central to this framework the paper identified among the key principles:

- breadth - pupils should be introduced to the main concepts from the whole range of science;
- balance - pupils should be given appropriate time to engage in a variety of learning experiences and to be able to continue their study of each of the main areas of science throughout the compulsory age range;
- coherence - pupils should be given opportunities to establish links between learning experiences in science and other areas of the curriculum;
- continuity - pupils' previous learning should taken into account as the basis for future learning;
- progression - pupils should experience differentiated learning experiences which progressively develop their understanding and skills.

These principles were to be evident in the science curriculum defined to include study of:

- living things and their interaction with the environment;
- materials and their characteristics;
- energy and materials;
- forces and their effects.

These topics were suggested, without supporting evidence, in the discussion paper

Science in Primary Schools (DES, 1984), produced by the HMI committee on Science. Subsequent curricular developments have been accretive in nature without any justification as to "why this science?".

Although this paper acknowledges that progress had taken place it was argued that "*it is still the case that too few pupils in primary schools are systematically introduced to science*" (DES, 1985, p. 6). The paper confirmed that the interests of the pupils are important and that at the heart of science education is an understanding of *process* which is best taken forward by practical, investigative and problem solving activity. However, it was also asserted that it was necessary for pupils to gain a progressively deeper understanding of some of the *content* of science which requires them to grasp certain fundamental facts, ideas and concepts in order for them to make progress. This can only be achieved through "*a carefully organised sequence of teaching if concepts are to be thoroughly grasped and progression from year to year ensured*" (DES, 1985, p. 9).

A similar development was evident in the earlier SED paper which argued that the environment was "*something to learn from, learn about and be responsive to*" (SED, 1984, p. 10). This represented a shift from the Primary Memorandum's emphasis upon 'process' to incorporate both 'content' and 'context'. Furthermore the paper argued strongly that one of the fundamental aims of education is to have an 'understanding of something' and not just to have a 'know-how or knack'. Thus:

> *skills, however, do not exist independently of the specific knowledge required to carry out particular tasks, and cannot be pursued as ends in themselves.*
>
> [SED, 1984, p. 12]

The understanding of 'what' was, for the first time, identified within the document in terms of four topics: living things and their environment, materials, energy matters and ourselves. Within each of these topics there was, unlike any of the other areas within Environmental Studies, extensive specification.

To support science education in the primary school during this period the Scottish Education Department funded the Primary Science Development Project (PSDP) which ran from 1981 to 1985. The key aim of this project was to produce materials which would facilitate the formulation and implementation of school policies in Environmental Studies (science). Eight booklets were produced which covered a range of issues such as:

- an introduction to science in the primary school;
- a rationale for a school policy in science;
- a strategy for formulating a school policy;

- science activities for the early years;
- links with other areas of the curriculum;
- class organisation;
- assessment, evaluation and record keeping;
- resources.

The project attempted to incorporate the notion of science as a body of knowledge (*content*) along with science as a method of enquiry (*process*) into policy statements. In addition the project incorporated the notion of the pupils' interests and attitudes being developed as a result of their experiences in science lessons. This would increase the pupils' awareness of the *application* of science as a factor influencing, and being influenced by, our culture. However, the work produced was not taken up in any systematic way by primary schools (Harlen, 1995). In part this was due to the failure of the project team to produce materials which were of direct use in the classroom. Teachers were expected, within the structure of the school policy formulated, to make use of either their own materials or those available commercially.

To support classroom teaching more directly the Scottish Education Department funded a national Primary Education Development Project (PEDP) which ran from 1984 to 1987. The key aim of this group was to produce programmes of work which would support the recommendations outlined by the PSDP and the HMI paper, *The Environment and the Primary School Curriculum* (SED, 1984). The science curriculum would consist of:

- ourselves,
- living things and their environment,
- materials,
- energy matters.

This initiative led to the production of a number of topic packs based around practical, problem-solving activities (Stark, 1999) This initiative in Environmental Studies was to be overtaken by a whole-school approach, namely the 5-14 development. Despite the apparent failure of the Primary Science Development Project its recommendations represented a significant sea-change in thinking, relative to the Primary Memorandum, which penetrated deep into the psyche of the educational establishment. The PSDP outlined the structural framework of the current 5-14 Environmental Studies in articulating the key principles as breadth, balance, continuity and progression in relation to a science curriculum; which was specified in terms of a body of knowledge taken forward by practical activities to illustrate science as a method of enquiry which together would enable pupils to apply their knowledge. Furthermore the curricular principles and the content were represented in a grid format which was adopted in the Environmental Studies Guidelines document (SOED, 1993). The PSDP also argued that the *thematic approach*, a multi-disciplinary approach, advocated by the Primary

Memorandum was flawed in that it contributed to a lack of curricular balance, continuity and, more importantly, progression. Accordingly the notion of the *core approach*, a single-discipline approach was outlined whereby the science programme, specified for P1 through to P7, would be studied in an ordered, sequenced and structured way.

During this period the dominant Piagetian paradigm was being subjected to re-framing due to shifts in understanding within the constructivist framework. The work of Vygotsky (1962) postulated that psychological development was dependent upon instruction rather than preceding it. Instructional activities are critical, through a 'language trail' (Scott, 1998), in promoting conceptual change from the child's cognitive starting point towards the desired learning goal of the scientific view. The teacher plays a key role, through socio-linguistic interaction, in passing on knowledge through sharing meaning. To achieve this the teacher controls the discourse of the classroom in order to transmit knowledge and to encourage guided and purposeful exploration towards a desired outcome. Thus:

> *there is no way, none, in which a human being could master the world without the aid and assistance of others for, in fact, that world is the others' world, is a symbolic world in the sense that it consists of conceptually organised, rule-bound belief systems about what exists, about how to get goals, about what is to be valued.*
>
> [Bruner, 1985, p. 32]

The teacher is able to assess progress in shared meaning and, through sensitive supportive intervention, can identify those children who require additional challenge, consolidation or support. Within classroom practice this led to attempts to assist performance through the development of the core-extension-reinforcement model. The teacher's role is to assist and raise performance within the zone of proximal development (ZPD) which the child would be incapable of achieving independently. In Vygotskian terms:

> *scaffolding is often associated with the concept of assisted performance which is central to Vygotsky's socio-cultural perspective on development and learning*
>
> [Scott, 1998, p. 68]

However, practice often lags behind theoretical developments and this did not figure to any great extent in policy literature. It is doubtful as to whether constructivist thinking has been integrated into the pedagogical schemata of most primary teachers (Littledyke, 1996). Furthermore there is currently no evidence as to the most effective approach to facilitate conceptual change (Harlen, 1999).

The final development of significance during this period was the *Education 10-14 in*

Scotland Report (CCC, 1986) which was the last major attempt by a professionally led group to not only endorse progressive ideals but to extend them into the secondary sector. This was borne out of an examination of the discontinuity between the generalist approach of the primary compared against the subject specialisms of the secondary. This discontinuity, which took place over the summer vacation between P7 and S1, could not, be justified in terms of any change in the psychology of the children. Thus the Report recommended the extension of a 'progressive' pedagogy, within an integrated rather than discrete-subject framework, into the lower years of the secondary. Additionally the 10-14 Report asserted that there should be no national prescription in terms of the content of every pupil's educational experience. This experience would aim to:

- sustain the pupils' active involvement in their own learning processes and their continuing enjoyment of learning;
- by its primary focus on the learners' world, their physical, social and moral environment, make possible a coherent learning experience;
- by its emphasis on an enlarging range of skills and understanding enable progression to take place;
- provide a range of capabilities in which skills, knowledge and understanding are combined, which build on the curriculum up to age 10 and which can be further developed through the curriculum at 14-16.

[CCC, 1986, p. 19]

Within the 10-14 stage the emphasis should continue to be on the process of scientific enquiry. However, it was recognised that:

> *enquiry had to be about something, process skills have to be exercised on some content.*

[CCC, 1986, p. 52]

The content identified as being important during the 10-14 stage was drawn from the HMI paper *The Environment and the Primary School Curriculum* (SED, 1984) with the recommendation that primary-secondary linkages should examine the nature of pupil experiences as well as the process skills which can be developed during the 10-14 stage. In articulating the ontological component of science the 10-14 Report was proposing a realignment in the progressive pedagogy. The 10-14 Report received widespread support from within the teaching profession (Pickard, 1999), although there was some dissent. However, it failed to recognise the significance of the new political reality within the UK. The ideology of the New Right was less concerned with the learning process and more focussed on learning outcomes which, in their view, progressive methods failed to deliver. The suggestion that the curriculum should be determined at the local level by teachers was an anathema to politicians who had been engaged in a lengthy dispute with the teaching unions. To avoid 'producer capture' the

New Right were increasingly moving towards a greater degree of national prescription defined in terms of content rather than process. At this time developments in Scotland closely followed those in England and Wales leading to claims of the 'anglicisation' (Roger and Hartley, 1990) of Scottish education.

Furthermore a Report which recommended an increase in staffing levels leading to increased costs was unlikely to find favour with a government committed to reducing spending on public services. Consequently the Report was out-of-step with the 'climate of opinion' (Crawford, 1998) at the time and was shelved by the then Minister of Education, Allan Stewart. This effectively ended the ability of professional groups to determine exclusively the direction of Scottish education through consensus on the merits of the educational arguments. This was torpedoed by a 'discourse of derision' (Goodson, 1983; Alexander, 1995) which sought to advance the political arguments of the New Right. The emergence of an instrumentalist or revisionist ideology is evident in policy documentation with increasing control being exerted from the centre. The stated intention was to improve the efficiency of primary schools in the teaching of science. The HMI were influential in promoting a discourse of coordinated planning in whole school teaching programmes as well as setting the agenda for 'disciplined learning' which incorporated specified content. The move to reintroduce a traditional subject-based curriculum conveniently ignored the fact that the curricular developments of the 1960s were the result of a rejection of an academic curriculum which had failed many of the school population (Crawford, 1998).

3.5 1990s: A curriculum by objectives?

The 1987 consultation paper *Curriculum and assessment in Scotland: A Policy for the 90s* (SED, 1987) encapsulated the growing concerns of the 1980s in stating:

> *weaknesses in curricular and assessment practices which need to be remedied; and the basis on which curriculum and assessment policies in Scotland are determined needs to be clarified and developed.*
>
> [SED, 1987, p. 1]

This consultative paper marked a shift in policy-making style in Scotland. Traditionally debate within the educational community was followed by a consensual position being reached which was then packaged for implementation. The emerging ideology saw the implementation of curricular reform through consultation followed by imposition by central government (Roger and Hartley, 1990). What was being advocated was a clearer definition of the curriculum with nationally agreed guidelines setting out the aims of study, the content to be covered in terms of both the knowledge and skills to be taught, the objectives to be achieved and the nature of progression specified in terms of the standards to be achieved by pupils at each stage including national testing for P4 and P7 pupils in English and Mathematics (SED, 1987).

This consultative paper initiated an inter-related programme of work for both curriculum and assessment which became known as the 5-14 Development Programme. This programme was managed by the newly restructured Scottish Consultative Council on the Curriculum (SCCC) and taken forward by five curricular Review and Development Groups (RDGs). Environmental Studies was the responsibility of RDG (3) which reported in December 1991 with the consultative document Working Paper No 13 (SOED, 1991). Initially this was criticised for its lack of science and consequently was redrafted. Working Paper No 13 created some controversy due to apparent ideological interference by the then Secretary of State Mr Michael Forsyth who argued, in the Foreword to the document, for a:

> *rejection of integration and topic work, particularly in the later stages of the primary school, an emphasis on a subject-centred approach and the suggestion that 'some form of specialism' in teaching should be introduced at the upper primary stages.*

[Stark, 1999, p. 366]

This notion of a specialist teaching in the upper primary within key, if not all, areas of the curriculum was not new. The DES statement of policy paper, *Science 5-16: A statement of policy* (DES, 1985) had argued that a major obstacle to the effective implementation of a science curriculum was existing teachers' lack of knowledge in science. Thus, whilst primary science appeared to have progressed quantitatively it seemed to be stuck on a qualitative plateau (Day, 1988). To overcome this the notion of the 'consultant teacher' (DES, 1985) was recommended. This was a teacher with a background in science who would be supported by the Local Authority and the head teacher to assist their colleagues in the primary school. The nature of this assistance would be determined by the context of their situation. The consultant teacher could be involved in developing programmes of work for use across the schools, providing teaching materials, identifying resources and possibly assisting with science lessons, particularly amongst upper primary classes. At the time the notion of specialism was a radical departure from existing practice in Scotland, and consequently encountered resistance from teachers.

The *Guidelines* borne out of the ensuing process of consultation led to the publication of *Environmental Studies 5-14* (SOED, 1993) which bore little relationship to Working Paper No 13. It was asserted that:

> *through the use of the Guidelines, schools should be able to design, plan and implement policies and programmes which will give all pupils a balanced, secure and continuous experience.*

[SOED, 1993, p. iii]

It was recommended that this balanced and continuous experience in 5-14 Environmental Studies was to be achieved through allocating 25% of the pupil's time over the seven primary years. With the expansion of the curricular coverage contained within the Guidelines document this represented a significant reduction, in relation to the tripartite curriculum of the Primary Memorandum, in the time available for science. Structurally the Environmental Studies Guidelines are particularly complex being articulated in terms of five components namely Science, Social Subjects, Technology, Health Education and Information Technology. Each component such as Science is then broken down according to:

- three planning cycles / (st)age (P1 to P3; P4 to P6 and P7 to S2);
- attainment outcomes (AO) ranging over the planning cycles;
- a number of knowledge strands (KS) for each attainment outcome;
- specification of content and environmental context for each knowledge strand and each planning cycle / (st)age;
- assessable and non-assessable strands including:
  - knowledge and understanding (CONTENT)
  - planning (PROCESS)
  - collecting evidence (PROCESS)
  - recording and presenting (PROCESS)
  - interpreting and evaluating (PROCESS)
  - developing informed attitudes (CONTEXT);
- attainment targets for each strand defined as behavioural objectives (*i.e.* Pupils should be able to ...) in terms of five levels of progression A to E which linked to the planning cycles (st)ages:
  - Level A which should be attainable in the course of P1 to P3 by almost all pupils,
  - Level B which should be attainable by some pupils in P3 or even earlier, but certainly by most in P4,
  - Level C which should be attainable in the course of P4 to P6 by most pupils,
  - Level D which should be attainable by some pupils in P5 to P6 or even earlier, but certainly by most in P7,
  - Level E which should be attainable by some pupils in P7 to S1 but certainly by most in S2,
  - Level F which should be attainable, in part, by some pupils, and completed by a few pupils in the course of P7 to S2.

The science component is defined in terms of three attainment outcomes (AO) which are further sub-divided in terms of knowledge strands (KS):

AO - *Understanding living things and the processes of life (Biology component):*

KS
- the variety and characteristics of living things;
- the processes of life;
- the interaction of living things with their environment.

AO - *Understanding Energy and Forces (Physics component):*

KS
- forms and sources of energy;
- properties and uses of different forms of energy;
- conversion of energy from one form to another, transfer of energy;
- forces and their effects.

AO - *Understanding Earth and Space (Chemistry component):*
KS • the Earth in space;
• the physical nature of the Earth;
• the material resources of the Earth.

These link very closely to the secondary science subjects of biology, physics and chemistry and are a refinement of the content outline provided in the HMI Paper (SED, 1984) on *The Environment and the Primary School Curriculum*. Thus Harlen argues that:

> *in both structure and content there was considerable continuity between the 5-14 Programme and previous practice. The new curriculum was introduced not as a sweeping and a mandatory reform but as a programme of clarification and definition. The programme gives 'guidance' on the curriculum, assessment and reporting.*
>
> [Harlen, 1995, p. 116]

The point that this was not a mandatory curriculum was emphasised by the teaching unions who advised their members that:

> *the 5-14 Programme is not a national curriculum, it is a set of Guidelines which carry authority but which will be considered and implemented by schools and teachers within their own context. This view is widely accepted in principle though not always in practice by those in positions of power in the Scottish Education System.*
>
> [EIS, 1996, p. 1]

However, in the process of '*clarification and definition*' it is possible to detect significant shifts within Scottish education. Firstly there would appear to have been a shift in policy-making style from "*debate followed by consensus to consultation followed by imposition*" (Adams, 1999, p. 349). There was also a greater degree of curricular definition, particularly in science, with a shift in emphasis from the epistemological (*i.e.* the how to know) to the ontological (*i.e.* the what to know) component of science, taken without widespread professional consent. This was seen as an attempt to exercise central control over the curriculum with the justification of the curriculum on educational grounds being deemed to be incidental to ideological concerns. Additionally the Guidelines in producing a structure also caused concerns that:

> *the terminology has become more, rather than less, confusing as efforts have been made to peg objectives to (st)ages. The reader of the 5-14 document has now to contend with attainment outcomes, key features, strands and targets amidst all the usual reference to knowledge, skills, attitudes, contexts and content.*
>
> [Bryce, 1993, p. 87]

The 5-14 Programme is based around an 'objectives' model of curriculum with a greater degree of specification in terms of knowledge and attainment targets with specified levels of attainment. This emphasis on content may well create pressures on time which will hinder the development of a process-based pedagogy (Silcock, 1992). The paucity of time spent on science had been identified as a problem with some 40% of primaries having been found to allocate insufficient time to science education (SOEID, 1998). It has been suggested that less teaching takes place in science because teachers are generally less confident in teaching science than other areas of the curriculum (Harlen and Holroyd, 1995). Despite these problems Scotland's performance is generally good, when compared with other countries although less time is spent in teaching science (SOEID, 1997). Additionally performance against expected 5-14 levels is generally satisfactory although some weaknesses emerge in the upper primary (Stark *et al.*, 1997). However, an objectives-based and time-constrained curriculum creates the conditions for an instrumentalist teaching approach. Yet the dominant paradigm linked to an effective pedagogy in science education is constructivist in nature (Nussbaum, 1989; Jenkins, 1992; Littledyke, 1996; Harlen, 1999). The constructivist paradigm was introduced into curricular thinking in the UK through the findings of the Science Processes and Concepts Exploration (SPACE) project which published a series of reports[3.2] during the 1990s. This highlighted children's naïve scientific thinking which they develop by themselves as a result of their experience. Once formed this conceptual framework acts as a filter, which is resistant to change, for the subsequent development of scientific ideas. The recent *Improving Science Education 5-14* (SEED, 1999) is based around such thinking. My research will attempt to ascertain the extent to which student teachers' science education in Scottish primary schools is configured in terms of a constructivist, process-based pedagogy and how this, if present, relates to a curriculum which is framed in terms of objectivist conceptions of knowledge.

3.6 The present: A Scottish National Curriculum?

The complexity of the Environmental Studies Guidelines and lack of confidence amongst teachers partly explains the differential implementation with primary schools taking a lead over the secondaries (Adams, 1999). The fourth AAP science report (SOEID, 1998) identified only some 18% of primaries and 17% of secondaries as having fully implemented the Environmental Studies Guidelines by 1997. Accordingly the then Education Minister, Brian Wilson, instructed the SCCC, now called Learning and Teaching Scotland, to engage in a consultative exercise on the review of Environmental Studies in 1998. The main challenges identified included:

[3.2] SPACE (Science Processes and Concepts Exploration) Research Reports: Evaporation and Condensation (1990); Growth (1990); Light (1990); Sound (1990); Electricity (1991); Materials (1991); Processes of life (1992); Rocks, soil and weather (1993); Forces (1998) -- Liverpool University Press.

- to maintain all the major concepts and to seek accordance with the provision contained within the National Curriculum;
- to provide greater clarity so that the Guidelines are more easily understood;
- to adopt a model of simplification, reducing both the component coverage and the volume of content within each component, in such a manner that it will require minimal change;
- to provide exemplification concerning the level at which content is to be delivered in such a way that teachers can select coherent topics for study;
- to simplify the skill strands and create a common framework across the Environmental Studies components which is capable of being internalised by teachers;
- to better define progression across the six levels, A to F, such that planning and assessment should become more straightforward.

Subsequently the SCCC published the consultative draft document *Environmental Studies 5-14: Society, Science and Technology* (SCCC, 1999). As a result of the omission of information and communications technology and health education it was proposed to alter the time available for Environmental Studies from 25% to 15% of the pupils' time over the seven years of the primary. The science attainment outcomes were structurally similar whilst the former key features were also retained but reworked as the knowledge and understanding strand, defined in terms of behavioural objectives (or attainment targets), across six levels of progression. Although there has been some reduction in content the attainment outcomes still appeared to be content heavy. Similarly the process, or skill strands, were retained although reworked through focussing on how they are *applied*. This was accomplished by a "*unified approach to skills across Environmental Studies*" (SCCC, 1999, p. 9) comprising of:

- *Preparing for the Task* - considering and understanding the nature of the task and planning what will be done including fair testing;
- *Carrying out the Task* - making and using appropriate observations, measurements then recording findings in a variety of ways appropriate to the task; and
- *Reviewing and Reporting on the Task* - describing and presenting the findings in appropriate forms and thinking critically about the significance of the findings.

[SEED, 2000b, p. 46]

The 'unified' investigative approach recommended links scientific knowledge and process. Thus the pupils should engage in activities which will, at the same time, develop their knowledge of scientific content and give them an insight into how scientific investigations work (Laws, 1997). Furthermore this will involve pupils in carrying out investigative work which is likely to shift the emphasis of assessment from formative assessment of the individual strands to more 'holistic' or summative assessment taking place at the end of the process linked to outcomes.

The investigative approach recommended can be linked to the 'discourse of derision' in relation to 'discovery' and 'process' approaches to learning which had increasingly come under attack. The notion of discovery was seen as inappropriate in school science as pupils are engaged in learning experiences where the knowledge is known. More critically the discovery approach was seen as adopting a "*naïvely empiricist and inductivist philosophy of science*" (Laws, 1997, p. 52). Additionally an approach to science, which emphasised the acquisition of the scientific method, defined in terms of processes with knowledge and understanding incidental to the learning experience was challenged on the grounds that it was difficult in identifying processes along with a reassertion of the importance of the content and context of scientific theories (Millar and Driver, 1987; Laws, 1997; Jenkins, 1999). A critique of this attempt to realign scientific pedagogy argues that it reinforces a scientific pedagogy based on an instrumentalist ideology with a curriculum defined by objectives, knowledge as facts and with a passive learning process through instruction (Littledyke, 1996).

The consultative document formed the basis for the *Environmental Studies 5-14 National Guidelines* document (SEED, 2000a), the *what* of the curriculum (see Appendix 3.1) which, for the first time, clearly specifies objectives in terms of the knowledge and understanding strand and investigative skills across the six levels of progression. Previously these objectives had been set out in three broad planning stages leading to some confusion, particularly amongst teachers with little background knowledge in science, as to how to plan for progression in pupils' learning across the levels of attainment. This guidance is developed further in the separate *Environmental Studies: Science guide for teachers* (SEED, 2000b) offering advice on the *how* of the curriculum. The epistemological framework of this document is made quite specific:

> *it is essential to consider the pupils' ideas as the starting point for science activities. To modify and change these alternative ideas and misconceptions it is necessary for pupils to become consciously aware of their own ideas and to have these ideas challenged and debated. Meaningful learning occurs when pupils construct their understanding by modifying their existing ideas in the light of new insights gained from scientific investigations. Thus, science may be seen as an active process involving personal construction of meaning and understanding.*
>
> [SEED, 2000b, p. 17]

To ensure progression in pupils' learning advice is offered on both long-term and short-term planning. This planning within the primary school should focus on the day-to-day classroom activities as well as the developing a framework to ensure a sense of coherence to each pupil's experience across the seven years of primary. Much of this advice builds upon existing good practice within primary schools. However, more problematic is the advice given that a collaborative approach should be adopted in designing a curriculum which would span the P1 to S2 years. This approach should be implemented across primary clusters as well as the associated secondary schools. In itself this is a monumental task and current evidence suggests that only some 33% of primaries are currently engaged in joint planning with their secondary colleagues (SEED, 2000c). This may continue to be an obstacle to full implementation of the Revised Guidelines. However, the how of the curriculum is, in practical terms, likely to ensure a greater degree of implementation than has been previously the case in that every specified attainment target (*e.g.* identify the Sun, the Moon and the stars at level A) is further developed through the provision of several examples of learning activities along with background notes for teachers. Although this retains the status of advice it is arguably a National Curriculum.

The fifth AAP science report (SEED, 2000c) indicating the need for these changes in terms of 5-14 Science. According to the AAP's findings the pupils' experience of science remained limited with only some 16% of the primary schools surveyed indicating that they had fully implemented the Guidelines, a full six years after their publication. "*Teachers' concerns about their lack of confidence and experience in teaching science remained worryingly high*" (SEED, 2000c, p. 66) with some 53% of the respondents indicating that problems existed in relation to science teaching. This lack of confidence may, in part, explain the finding that some 65% of the primaries surveyed relied upon commercial resources to take forward their science curriculum with another 15% using resources produced by the Local Authority. The detailed advice contained in the Revised Guidelines is likely to enable teachers to be more focussed in their teaching of science and thus enhance their confidence.

The AAP Report also indicated that 45% of the time spent on science in P4 classes utilised science as the main focus of topic work. This decreased for P7 classes (32%) where an increased amount of time (28%) was spent in teaching science as a separate subject when compared with P4 classes (15%). Concerns were raised in the Report in relation to the nature of progression with most work in science being taken forward through mixed-ability groups (99% in P4 and 98% in P7) rather than attainment (ability) groups. It was unclear as to how teachers differentiate the work to meet the needs of individual pupils. Furthermore, practical work in science tends to be dominated by teacher-centred methodologies in the lower school. Senior pupils are provided with more opportunities for open-ended learning experiences (see Table 3.1). This later observation links to the view expressed in the 5-14 Revised Guidelines that knowledge in itself, frequently identified as the focus of teacher-centred methodologies, is insufficient for understanding. Opportunities must be provided for pupils to develop their understanding through a "*personal reconstruction of knowledge*" (SEED, 2000a, p. 6).

Table 3.1: Selected findings from fifth AAP science report

Methodology:	**Stage**	**Frequently**	**Hardly ever**
Demonstration by teacher	P4 (%)	76	4
	P7 (5)	58	6
Structured experiments where	P4 (%)	68	5
pupils follow detailed instructions	P7 (5)	62	7
Short, open-ended investigations	P4 (%)	15	21
where pupils are expected to work out method for themselves	P7 (5)	40	23

Source: Seed, 2000c, p. 68

3.7 Concluding remarks

As we enter the 21st Century the ontology (*i.e.* the what to know) of primary science has, for the moment, been specified. However, there remains an epistemological (*i.e.* the how to know) and pedagogical (*i.e.* the how to teach) tension as to how best to take forward pupils' learning in primary science. This present day situation is largely the legacy of a confused past with respect to policy development.

The 'heuristic method' advocated by H.E. Armstrong, a professional scientist with a deep interest in science education, at the onset of the 20th Century was an attempt to find an approach to science teaching which was linked to the nature of science itself. Heurism promoted the notion of 'discovery learning' but this was not a case of anything goes and anything can be discovered. The method of teaching developed by Armstrong was based on the teacher having clear aims, linked to extant scientific knowledge, as well as using a defined methodology. This method required teacher and children to play clearly defined roles and to understand the boundaries of their roles. Pupils would be engaged in activities determined by the teacher whose responsibility it was to persuade the pupils that what they were finding out was worthwhile both for its own intrinsic interest and for the way that it had been found out. Heurism was a balance of support and challenge but what was to be learned, how it was to be learned and the validation of what was actually learned was determined by the teacher.

The central role that the teacher played in the heuristic method in the construction of learning experiences was largely rejected by the worst excesses of the child-centred approach which reached full bloom in the 1960s and 1970s. During this period the debate within education was one in which the language of polarisation is clearly evident with reference to 'traditional' and 'progressive' pedagogy -- this is a legacy that has remained with the teaching profession. At this time the role of the teacher was marginalised to one in which they provided opportunities for activity and discovery rather than being the leader and initiator of the learning process. Within the realm of science education content, or factual knowledge, was derided and process was all important. However, in the earlier part of the 20th Century reformers such as Hadow, who had opened the debate for an approach to education which placed the child at the heart of the educational process, had promoted a view of science education which combined both content and process. It is my contention that the early proponents of a 'progressive' pedagogy recognised, as the 1950 Memorandum clearly states, that content and process are linked within science education. Indeed it could be argued that science as a body of knowledge is shaped more by its concepts and purposes than it is by its methods. Furthermore science is a body of knowledge which is constructed on facts and as such factual knowledge should not have a pejorative undertone, ignoring the question of who determines the what constitutes factual knowledge and its relation to learning. Science pedagogy needs to be in accordance with scientific thinking. To deny this is folly! -- in saying this I am conscious of using polarised language.

The latter part of the 20th Century was one in which there have been a number of important developments in primary science education. Detailed specification in terms of content, process as well as context was, in part, a reaction to the lack of coverage in primary science teaching identified as late as the 1980s. The primary-secondary interface (*i.e.* P5 to S2) has been another area where there has been a debate, albeit unresolved, with regards to the role of subject specialists in the teaching of science. Perhaps more significant has been the emergence of social constructivism based on the thinking of Vygotsky and Bruner. Constructivists argue that the learner's development is dependent upon instruction rather than preceding it as advanced from a Piagetian perspective. Within a Vygotskian framework the teacher leads the learner in purposeful exploration, which is intimately linked to socio-linguistic interaction which involves passing on knowledge through shared meaning, towards a desired outcome. Although the methods may be different, and the thinking not framed in terms of developmental psychology, this was essentially what H.E. Armstrong was proposing -- a chemist worthy of merit? My hope is to touch upon these themes within this research through an exploration of pre-service student teachers' involvement in the teaching of primary science.

The next section of the research will, using quantitative methods, outline the demographic characteristics of the students who participated in the study.

CHAPTER 4 DEMOGRAPHIC CHARACTERISTICS

4.1 Quantitative and qualitative research

Cohen and Manion (1994) argue that there are two conceptions of social reality upon which most research in the social sciences is based. These are differentiated by their use of either quantitative or qualitative techniques. The methodological perspective adopted in this research combined both quantitative (survey questionnaire and observation) and qualitative (observation and semi-structured interview) techniques. These methods of data collection were not seen as being separated by an epistemological chasm (Hammersley and Atkinson, 1983) but rather as capable of informing each other as part of a congruent measurement network (Bakeman and Gottman, 1986).

Quantitative research "*implies a particular stance concerning the social scientist as an observer of social reality*" (Cohen and Manion, 1994, p. 12); a reality which is both external to individuals and objective in nature. Central to quantitative research is the scientific method modelled on the natural sciences (Hammersley and Atkinson, 1983). Quantitative research aims to uncover universal laws by identifying relationships between directly observable and measurable phenomena. Educational research, within this perspective, would contend that the phenomena being investigated generates 'factual data' which, along with the techniques deployed to collect it, are deemed to be 'theory-neutral' (Hammersley and Atkinson, 1983) despite the fact that this is rarely the case. However, the contention is that quantitative methodology, within educational research, seeks to remove the impact of the observer by developing experimental procedures which are both explicit and standardised. Thus the laws developed are deemed to be true in all circumstances. This facilitates a search for causal explanation which is often accompanied by statistical measures introducing the notion of replication and generalisation (Verma and Mallick, 1999).

The method utilised in this research consisted of gathering data using a standardised procedure in order to facilitate replication by other observers who can conduct an assessment of validity and reliability. However, a degree of caution is required in rigid application of the statistical methods to studies of human enterprise. In examining the '*what*', '*how much*' and '*how many*' of education using statistical measures it is possible to lose sight of the '*how*' and '*why*' which are no less, indeed possibly more, important. It is possible to fall into the trap of adopting a mechanistic model of human behaviour which seeks to define complex interactions as clearly defined dependent and independent variables. This leads to a form of reductionism (Powney and Watts, 1987) which is arguably inappropriate in educational research as at its heart such research is about people. The concern being articulated by Powney and Watts (1987), although they do not necessarily share it, is that reductionism leads to a simplistic analysis of complex and dynamic human interactions. However, analysis by its very nature inevitably leads to a reduction in data in order for it to be both manageable and understandable; analysis is a reconstructive and not a reproductive process (Powney and Watts, 1987). As such the perspective adopted in this research is to use the data to determine the causal network through correlational analysis (Cohen and Manion, 1994) to inform the qualitative phase of the research.

Qualitative or interpretivist research is concerned with the interpretation of multiple-realities as they involve the gathering of evidence reflecting the differing experiences and judgements of individual participants. Essentially such techniques reject the notion that human behaviour can be governed by general laws. Thus qualitative research does not attempt to identify generalisations but rather to understand how a particular subject constructs their reality. This reality is no longer the product of a network of causal forces but rather the result of negotiated meaning. Understanding a subject capable of meaning is only possible through sharing others' interpretations of the world around them from an internal rather than external perspective (Cohen and Manion, 1994). Researchers who follow this research paradigm doubt whether it is possible to apply a '*scientific*' methodology to the study of complex human relationships (Bell, 1987).

Generally speaking such an approach presents problems in terms of the validity of findings as they are open to various interpretations. However, there is no claim to objective truth. The analysis of data within this perspective is an act of constructive interpretation (Powney and Watts, 1987). The crucial point in such an approach is that data is not something that is just 'there' waiting for the correct methodology to abstract. Additionally analysis is not simply the process of the recognition of facts and phenomena presented by the methodology deployed. Analysis is creative and constructive and not a reproductive process whereby our intentions inform our attention. Immersion in the data collected leads the analyst to generate theory which provides an insight as to what data to collect next. This process of data collection is controlled by the emerging theory. Such a process tends to lead to the focus of interest becoming progressively smaller as the fieldwork and analysis progresses. This tends to lend itself more to descriptive rather than statistical analysis, although the latter is sometimes possible. However:

> *the existence of numbers in an analysis does not of itself generate - or even indicate rigour. Nor is the converse true - the absence of numbers does not denote lack of rigour or quality.*
>
> [Powney and Watts, 1987, p. 159]

The validity of findings, from such a research methodology, is determined by the utility to the reader in as much as they enable the reader to make sense, in the context they find themselves, of their own reality.

4.2 Development of research instruments

During the initial phase of the research I developed and refined the research instruments as well as negotiating access to the students. The sample was drawn from the BEd undergraduate and Postgraduate Certificate of Education (Primary) students in the Faculty of Education, University of Glasgow. This sample was selected for the following reasons:

- these students were made accessible by the Department of Curriculum Studies who expressed an interest in the focus of the research following informal discussions between myself and the Science Tutors;
- these students have been and will continue to be involved in the development of knowledge and understanding as well as investigative skills in primary science;
- the Department of Environmental Education provides structured support in science at all 5-14 levels in an attempt to enhance student teacher effectiveness and improve attainment in all pupils. However, this is currently non-prescriptive.

Authorisation was sought and granted from the Dean of Faculty (see Appendix 4.1) and the Head of Environmental Education which forms part of the Department of Curriculum Studies. Environmental Education is a composite department which incorporates Science education, delivered to BEd, PGCE (Postgraduate Certificate of Education) primary as well as PGCE secondary. This authorisation related not only to gathering the survey data but also to involving the Science staff in delivering the questionnaire during class time. Although aware of the potential problems that this strategy may entail (*e.g.* students seeing this as an assessment event) it was decided that '*sponsorship*' from the Environmental Education Department, in which the Head of Department accepted the responsibility for coordinating returns of the questionnaire, was likely to increase the response rate.

4.3 The Questionnaire

There were a number of steps involved in the construction of the questionnaire which included:

- during construction of the questions the Curriculum Studies[4.1] science tutors looked at the questions to determine if there were gaps in my understanding on effective teaching and learning strategies in science;

4.1 University of Glasgow, Faculty of Education, Curriculum Studies - staff involved in BEd primary, PGCE primary and PGCE secondary courses.

- the draft questionnaire was compiled and administered to a small group of PGCE (Primary) students who were asked to read through the draft and to indicate if they found any of the questions difficult to understand in terms of meaning and language;
- following completion of the questions the Head of the Environmental Education was asked to look at the questionnaire to determine if it was suitable for distribution to the students.

4.4 Quantitative Data

The survey questionnaire was used to generate quantitative data for all BEd and PGCE (Primary) students within the Faculty of Education. "*The questionnaire has a job to do: its function is measurement*" (Oppenheim, 1992, p. 100). The questionnaire consisted largely of closed questions to facilitate ease of coding and subsequent analysis (see Appendix 4.2). However, there were a number of questions, which made up the final section of the questionnaire, which had open-ended extensions. Structurally this survey questionnaire consisted of four sections:

- background in science;
- attitudes to teaching attainment outcomes, knowledge strands and skill strands;
- attitudes to teaching and learning in science;
- the nature, purpose and experience of science.

4.5 The sample

A total of 479 questionnaires were returned and this formed the basis of the first phase of data collection. The sample was drawn from the BEd and PGCE (Primary) students in the Faculty of Education. The overall return was 79% (see Table 4.1) of the student population (N=608). This relatively high return may well be the result of the '*sponsorship*' by the Science group within the Department of Curriculum Studies who distributed the questionnaires during class time. The highest percentage returns were obtained for BEd 1 (88%), PGCE (80%) and BEd 2 (78%). These groups were given time to complete the questionnaire during class time. The BEd 3 (70%) and BEd 4 (74%) groups were given the questionnaire during class time but had to complete them in their own time, and return the questionnaire at a later date. This may well explain why there was a slight drop-off in the percentage return.

The data extracted from the questionnaires was converted into numeric form and processed using the Statistical Package for the Social Sciences (SPSS v .11). Much of the data gathered in the first section of the questionnaire was nominal or categorical in nature (*e.g.* gender, qualifications, *etc.*) with participants' responses being allocated to mutually exclusive categories. The data gathered in sections 2 to 4 of the questionnaire was largely of the ordinal type with participants providing a response within one of five categories, facilitating a degree of ranking in terms of the concepts being explored. However, it is not possible to make a qualitative judgement in terms of the degree of difference between the categories. In other words, scale intervals between ranks are not equal; the difference between Rank 1 and Rank 2 is not necessarily the same as that between Rank 2 and Rank 3. Variation in scale intervals limits the statistical methods used to analyse ordinal data.

Table 4.1: Sample by year group

Year	N	PopN	%
BEd1	121	138	88
BEd2	91	116	78
BEd3	68	97	70
BEd4	83	112	74
PGCE	116	145	80
All	479	608	79

Data which is of the interval or ratio type (*e.g.* test scores) does have measurable scale intervals. Such data can be both ranked and arithmetic computations of difference are possible. There is, however, an important distinction between interval and ratio scales with respect to zero. Interval data does not possess a 'true zero'. Thus in a science test it is possible to say that the difference between 80% and 90% is the same as that between 40% and 50%. However, we cannot argue that someone scoring 80% knows twice as much as someone scoring 40%. In addition we cannot assert, although it may be true, that someone scoring 0% has no science knowledge. We must keep our frustration at such scores firmly in check. Ratio data does have a 'true zero' and as such it is the highest level of measurement. Ratio data is mostly confined to physical measures and tends not to be used in educational research. The properties of ratio data enable us to state, for example with respect to distance, that the difference between 1 metre and 2 metres is the same as that between 3 metres and 4 metres and that 4 metres is twice as long as 2 metres. Perhaps more critically 'zero metres' is a meaningful concept.

4.6 Profile of the respondents

The first section examined the students' background in science in order to explore, in part, the students' experience of science? A profile of all BEd students within each of the year groups was drawn up, with data generated on:

- aspects of their educational background in science;
- attitudes to their own school experience of science education.

A series of graphs were generated in order to outline the characteristics of the participants. For the purposes of comparative analysis data for each of the BEd year groups and the PGCE (Primary) group were treated separately. The participants' characteristics are outlined below:

- *Time spent studying science in the secondary school*

The participants were asked to indicate when they ceased studying science in the secondary school. Science has formed part of Scotland's core curriculum within the secondary school since 1988. Consequently most students, with the exception of mature entrants and foreign nationals, should have had some experience of science, at least until S4. This would suggest that the majority of the sample should have some form of school-based science qualification. This is significant in-as-much that on qualifying as teachers, the students will be expected to teach science which has formed part of the core curriculum in the primary school since 1993.

Figure 4.1: Terminal point in participants' school science education (n = 479)

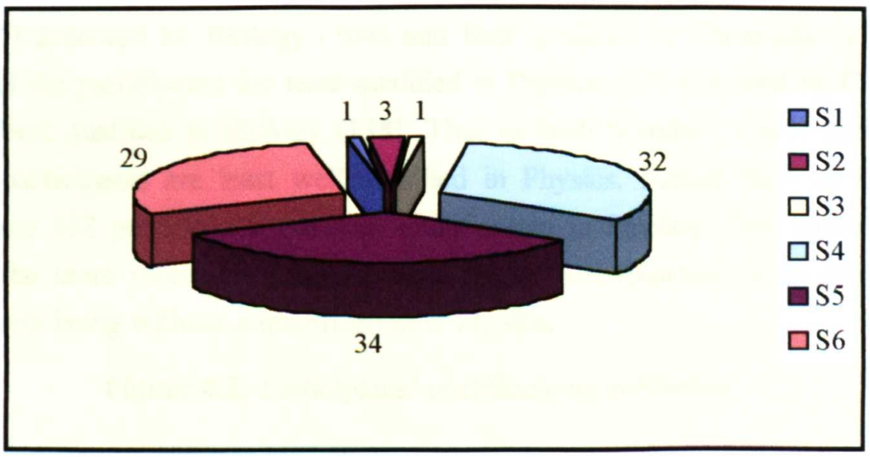


Figure 4.1 shows that only 5% of the total sample ceased school science prior to S4 and as such are unlikely to have a school-based science qualification. Some 8% of the graduates in the PGCE cohort ceased their science education prior to S4. The undergraduate BEd cohort, which tends to consist mostly of students straight out-of-school, accounts for only 4% amongst its number whose science education ceased prior to S4. This group consists mostly of mature students, many of whom have no formal qualifications, who gain entry through the Scottish Wider Access Programme (SWAP) pathway to Higher Education (see Appendix 4.3). The years during which school science qualifications can be obtained, namely S4, S5 and S6, account for approximately one third of each cohort. Within the Scottish education system this should translate into qualifications at the following stages:

- Standard Grade at S4;
- Higher level at S5 and S6;
- Advanced Higher level at S6.

The Higher level pass presents a slight problem with regards to interpretation in that there are a number of routes to obtaining such a pass. These include:

- one-year course completed at end of S5;
- two-year course started in S5 and completed at end of S6;
- one-year 'crash' course started and completed in S6.

- *Participants' qualifications in science*

The qualifications obtained by the participants were summarised according to the discrete sciences and combinations between the discrete sciences, with the highest level of qualification in each subject being recorded against each participant. For simplicity those qualifications gained from the rest of the UK have been subsumed under equivalent levels within the Scottish system (*e.g.* A levels under Advanced Higher levels). It is worthwhile to note that there is no entrance requirement for a science qualification to gain entry to the BEd and PGCE courses. The data (see Figure 4.2, Figure 4.3 and Figure 4.4) indicates that participants, in terms of the number of passes in the discrete disciplines, are generally least qualified at Standard Grade level in Physics (81) followed by Biology (104) and best qualified in Chemistry (161) . At Higher level the participants are least qualified in Physics (67) followed by Chemistry (103) and best qualified in Biology (138). Thus at both Standard Grade and Higher levels the participants are least well qualified in Physics. Indeed 66% of the total sample, some 318 participants, have no qualification in Physics. This figure is even higher for the more recent BEd intakes with nearly three-quarters of the BEd 1 and BEd 2 cohorts being without a qualification in Physics.

Figure 4.2: Participants' qualifications in Physics

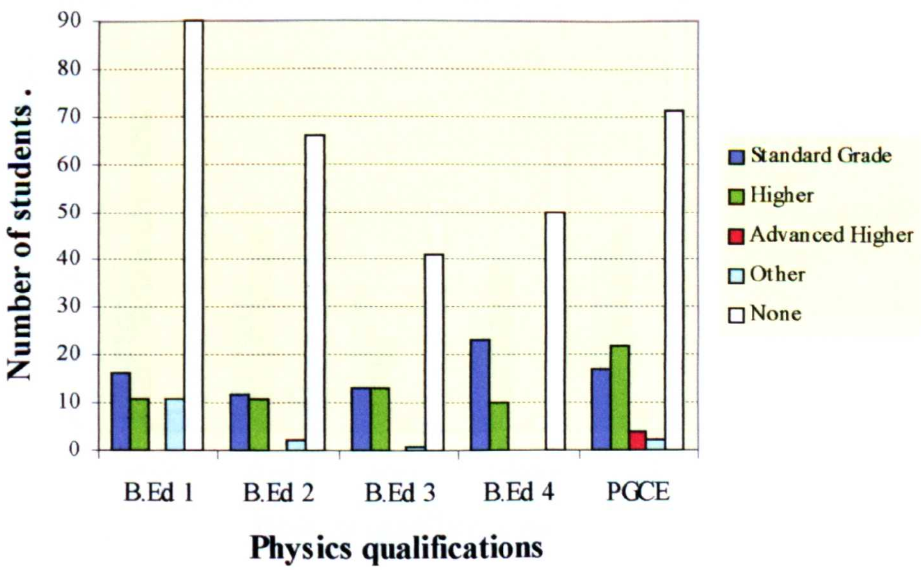
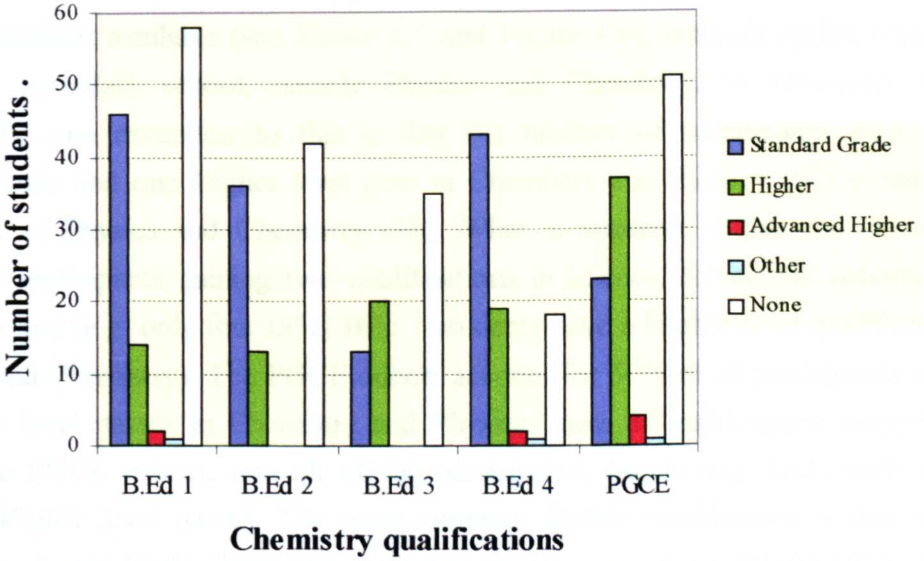
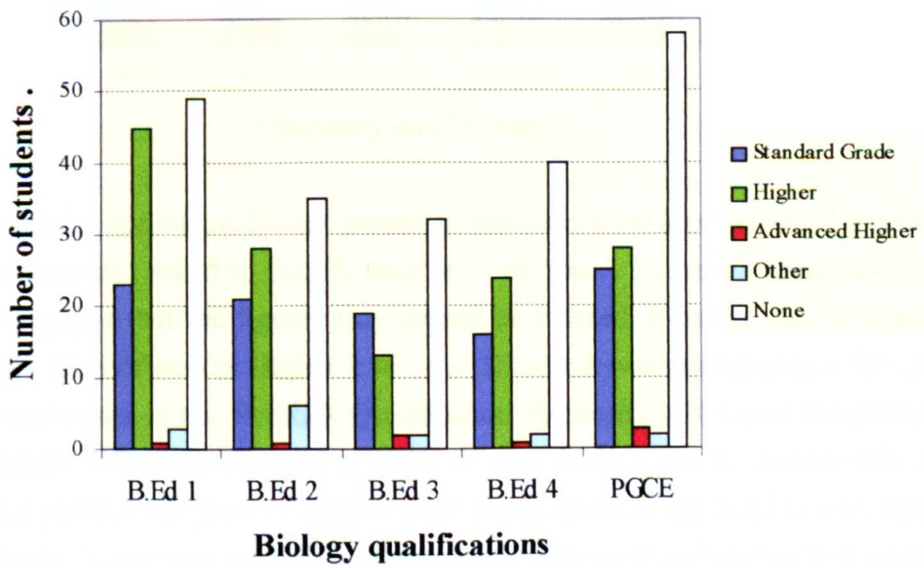


Figure 4.3: Participants' qualifications in Chemistry



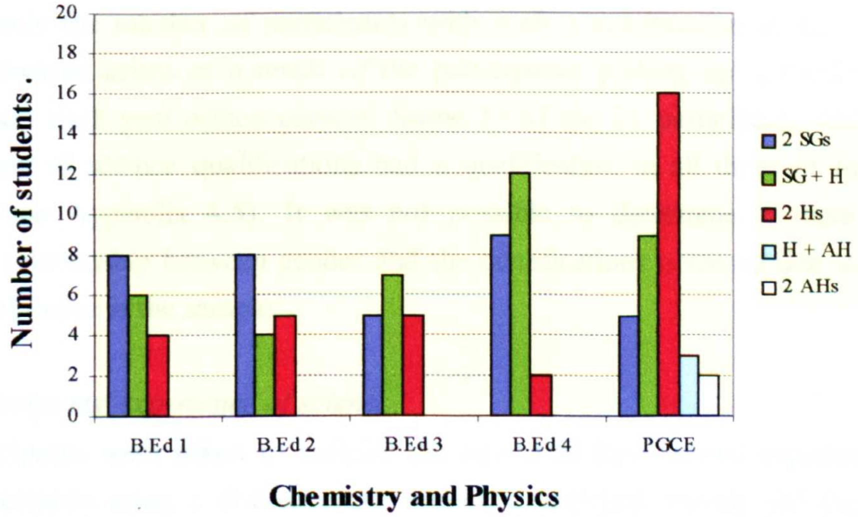
There appears to be little overall difference, in terms of the percentage of participants without a qualification, in Biology (45%) and Chemistry (43%). This data would suggest that there is a limited background, in terms of science qualifications, amongst the various student cohorts. When the highest level of pass for each year group is examined it is evident that the BEd students generally have more passes at Standard Grade when compared to Higher level passes in both Physics and Chemistry. In Biology the BEd students have more passes at Higher level. The PGCE cohort have more passes at Higher level, when compared with Standard Grade, for all three of the sciences. The PGCE cohort also have the largest number of passes at Advanced Higher level for all three of the sciences.

Figure 4.4: Participants' qualifications in Biology



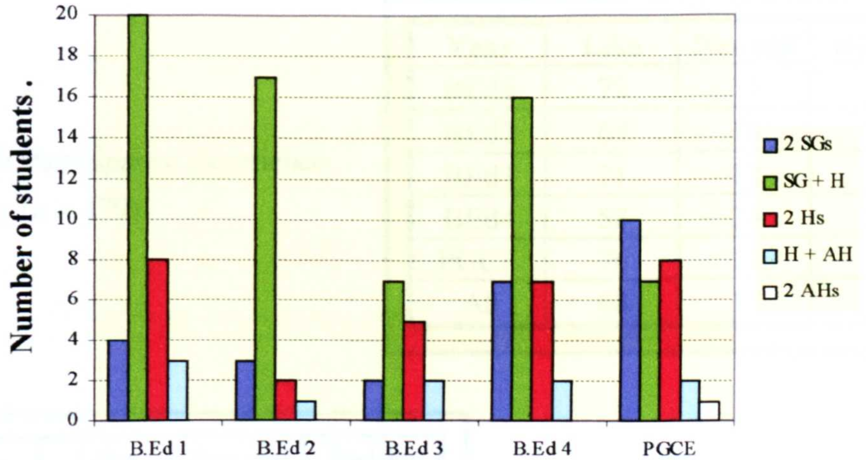
Whilst at school the students would have been provided with the opportunity to study two science subjects. There appears to be little overall difference between the main combinations available (see Figure 4.5 and Figure 4.6), through option choices within the secondary school, namely Physics and Chemistry, or Chemistry and Biology. The one exception to this is that the number of participants with one Standard Grade and one Higher level pass in Chemistry and Biology (67) is almost double that of Physics and Chemistry (38). What is apparent is that the absolute numbers of participants gaining two qualifications in science, for all the cohorts, is consistently low (*e.g.* only four (3%) BEd 1 students have a Higher level qualification in Physics and Chemistry). The PGCE cohort account for 50% of all participants with two Higher level passes in Chemistry and Physics, these 16 participants represents 14% of the PGCE cohort, and all of the participants, numbering three, with two Advanced Higher level passes. The most common double combination is that of a Standard Grade and Higher level pass in two of the three science subjects: 105 (22%) participants. Some 62 (13%) participants have two science subject passes at Higher level (see Appendix 4.4).

Figure 4.5: Participants with qualifications in Chemistry and Physics



The data gathering technique did not permit an analysis of the level of 'pass' gained as the students were not asked to specify their level of 'pass'. However, there was some evidence to suggest that the figures may indeed be inflated. Some of the participants indicated their level of pass at Higher level as a 'D' which was classified as a fail grade prior to amendments in the Scottish Qualification Authority's National Qualification guidelines which were implemented in 2004. It was decided not to include this as a pass with the participants level of qualification being taken as the level below, namely Standard Grade. There may well be a hidden methodological problem in that some of the data recorded, for which the level of pass were not supplied, may be inaccurate. It was not possible to determine whether this pattern of passes was significant due to the small numbers of males in the sample.

Figure 4.6: Participants with qualifications in Chemistry and Biology



Physics and Biology is not a common combination in the secondary school. Consequently the number of participants with such a combination is low. Generally this combination arises as a result of the participants 'picking-up' a third science as part of their sixth year option choices. Some 15 of the 21 participants who had this combination of science qualifications had a qualification in all three of the discrete sciences (see Appendix 4.5). It was not possible to determine if there was any statistical relationship between gender and the qualifications obtained due to the small numbers of males in the sample.

➤ *Participants' experience of science.*

The participants were asked to indicate the nature of their school experience of the discrete sciences using a five-category scale (*i.e.* enjoyed, mostly enjoyed, neither, mostly disliked, disliked). The mean values of the recoded categories (see Appendix 4.6 for more detailed data) were calculated and reassigned as follows:

➤ response categories 1 and 2 as '*like*';
➤ response category 3 as '*neutral*';
➤ response categories 4 and 5 as '*dislike*'.

The participants' experience of Biology (Table 4.2) is consistently positively framed, for all of the student cohorts, with 68% of the sample expressing their liking for the subject. Some 50% of the sample expressed positive views towards Chemistry (Table 4.3). The BEd 3 cohort was the only group to register a negative response. The experience of Physics (Table 4.4) is slightly weighted towards an overall negative orientation. With 45% of the sample expressing a dislike for Physics in comparison with 38% stating that they had a positive experience. Indeed the BEd 1, BEd 2 and PGCE responses were weighted towards a negative experience. The BEd 4 cohort (51%) was the only group to register a positive experience of Physics.

Table 4.2: Participants' experience of Biology (n = 479)

Year	Like	Neutral	Dislike
BEd1	72	15	14
BEd2	65	18	16
BEd3	71	12	17
BEd4	58	24	18
PGCE	76	14	10
All	68	17	15

Table 4.3: Participants' experience of Chemistry (n = 479)

Year	Like	Neutral	Dislike
BEd1	49	19	33
BEd2	46	25	29
BEd3	39	21	40
BEd4	51	22	27
PGCE	58	10	32
All	50	19	31

Table 4.4: Participants' experience of Physics (n = 479)

Year	Like	Neutral	Dislike
BEd1	37	24	39
BEd2	31	21	49
BEd3	43	14	43
BEd4	51	7	42
PGCE	36	13	51
All	38	16	45

The data was then examined in order to determine if there was any significant relationships between participants in terms of their science qualifications and their experiences of science. The Kendall tau-b ($K\tau_b$) correlation coefficient statistic (see Appendix 4.7) was calculated at the $p \leq 0.01$[4.2] and this will be denoted by a double asterisk in the tables shown below after the significance value (*e.g.* $Kt_b = 0.28^{**}$).

[4.2] This is the same as the 99% level.

Any association detected at the $p \leq 0.05$[4.3] level will be denoted by a single asterisk after the significance value (*e.g.* $K\tau_b = 0.28^{*}$). Each statistic is given to two decimal places. The key associations identified in terms of the participants' qualifications (see Table 4.5) are that there is a positive correlation between Physics and Chemistry ($K\tau_b = 0.22^{**}$). This is to be expected as this combination is a important option choice in the secondary school.

Table 4.5: Associations between participants' qualifications

Qualifications	Physics	Chemistry	Biology
Physics	1	0.22**	-0.34**
Chemistry	0.22**	1	NS
Biology	-0.34**	NS	1

This association between Physics and Chemistry is evident for the BEd 2, BEd 3 and PGCE cohorts. Surprisingly the other option pathway of Chemistry and Biology does not appear as a significant relationship, other than for the BEd 1 cohort ($K\tau_b = -0.2^{*}$), despite there being more dual qualified participants in these sciences. Physics and Biology are significantly negatively correlated ($K\tau_b = -0.34^{**}$). This association is evident for the BEd 1, BEd 2 and BEd 4 cohorts. This is to be expected as this combination, although possible in some schools, is not generally available in secondary schools (see Appendix 4.8 for more detailed data).

Table 4.6: Associations between participants' qualifications and experience

School-based qualifications	**Experience**			
	Physics	Chemistry	Biology	Science
Physics	0.32**	0.12*	-0.19**	0.15*
Chemistry	NS	0.09*	NS	0.17**
Biology	-0.28**	-0.10*	NS	NS

When participants' qualifications were correlated against their experience of science a number of key associations are discernible (see Table 4.6). Participants with qualifications in Physics generally have positive experiences of both Physics ($K\tau_b = 0.32^{**}$) and Chemistry ($K\tau_b = 0.12^{*}$). The positive experience of physics for those students with a qualification in physics is evident for the BEd 1, BEd 2 and PGCE cohorts (see Appendix 4.9). There is a strong negative correlation amongst this group in relation to their experience of Biology ($K\tau_b = -0.19^{**}$). This is evident amongst the

4.3 This is the same as the 95% level.

BEd 1 and BEd 2 cohorts. This group also has a positive orientation towards Science ($K\tau_b = 0.15^{*}$) in general. Participants with a qualification in Chemistry have a positive experience of this discipline ($K\tau_b = 0.09^{*}$) and Science ($K\tau_b = 0.17^{**}$) in general. The BEd 4 cohort is the only one to register a negative relationship ($K\tau_b = -0.26^{*}$) between those with a qualification in a subject (Chemistry) and the participants' experience of that subject. Thus the data would suggest that those participants with a qualification in Physics and Chemistry are positively orientated towards their own discipline, as well as each other, and to Science in general.

Table 4.7: Associations between participants' experience of school science

Experience	Physics	Chemistry	Biology	Science
Physics	1	0.27**	NS	0.27**
Chemistry	0.27**	1	0.16**	0.43**
Biology	NS	0.16**	1	0.36**
Science	0.27**	0.27**	0.27**	1

There appears to be no significant correlation between having a Biology qualification and the participants' experience of that discipline or Science in general. Care should be taken in this regard as there is a significant correlation between those with a Biology qualification and their experience of that discipline for the BEd 1 ($K\tau_b = 0.23^{**}$) and the PGCE ($K\tau_b = 0.21^{*}$) cohorts. There is a significant negative correlation between those with a Biology qualification and their experience of Physics ($K\tau_b = -0.28^{**}$), the only group for which this was not significant was the BEd 4 cohort, and Chemistry ($K\tau_b = -0.10^{*}$). This is evident in both the BEd 2 and BEd 4 cohorts. Thus those with a Biology qualification tend to be negatively orientated towards the other science disciplines (see Appendix 4.10 for more detailed data).

An analysis of the participants' experience of each discipline in relation to the other disciplines was conducted (see Table 4.7). The pattern which emerges is one in which those who express a liking for a particular discipline tend to be positively orientated towards the other disciplines and science in general. Thus those that expressed positive attitudes towards Physics expressed a liking for both Chemistry ($K\tau_b = 0.27^{**}$), the BEd 4 cohort is the only group for which this was not a significant association, and Science ($K\tau_b = 0.27^{**}$) but not Biology. Those who liked Biology expressed a positive orientation towards Chemistry ($K\tau_b = 0.16^{**}$) and Science ($K\tau_b = 0.36^{**}$), the BEd 4 cohort is the only group for which this was not a significant association, but not Physics. Those who expressed a liking for Chemistry are positively orientated towards the other discrete disciplines as well as Science ($K\tau_b =$

0.43**), this association is consistent across all of the student cohorts. The lack of a significant association between Physics and Biology is another 'relationship' to hold for all of the year groups (see Appendix 4.11 for more detailed data).

4.7 Concluding remarks

There is no requirement for the students to have an academic qualification in science in order to undertake the BEd and PGCE (Primary) courses. Although there is no suggestion of cause and effect it is evident from the data that there is a paucity of academic qualifications in the sciences amongst the students in the sample. This is particularly severe in Physics with 66% of the students have no formal qualification of any kind. They are slightly better qualified in Chemistry at Standard Grade level (*i.e.* S4 in the Scottish educational system) and at Higher level in Biology. However, the number of passes, particularly in relation to two science passes, remains small. That many primary teachers are poorly prepared by either educational background or experience is well documented (Carré and Carter, 1993; Harlen *et al.*, 1995; Littledyke, 1996; Mulholland and Wallace, 2003). Harlen (1997) reported on a national survey of some 514 primary school teachers, carried out in 1993, which found that some 63% had no science qualification with 15% having a Standard Grade equivalent as their highest level qualification, and a further 16% having a Higher Grade pass. A follow up survey carried out in 1996 found a slight improvement with the respective percentages being 56%, 17% and 22%. Research has also indicated that there is a gap between students' school experience of science and pre-service courses (Shallcross *et al.*, 2002) suggesting that subject knowledge may have 'faded'.

Research has identified persistent problems in the teaching of science and the poor understanding amongst teachers in key areas such as 'Earth's place in the Universe' (Mant and Summers, 1993; Summers and Mant, 1995a), 'forces and their effects' (Kruger *et al.*, 1990a; Kruger *et al.*, 1992; Summers, 1992), 'energy' (Kruger, 1990; Summers and Kruger, 1992), 'change and materials' (Kruger and Summers, 1989) and 'biological concepts in the National Curriculum' (Lenton and MacNeill, 1993). Summers (1994) detected a lack of subject-content knowledge of a range of key science concepts amongst 700 primary school teachers. Not only is there a lack of subject-content knowledge; scientific concepts are taught in a way that is contrary to current scientific thinking (Carré and Carter, 1990; Lenton and Turner, 1999). Many primary teachers rely on beliefs about subject content which are based on imagination and common-sense knowledge (Carré and Carter, 1990; Summers, 1994). The consensus reached in this research is that primary-school teachers' scientific ideas are closer to those of children than scientists (Shallcross *et al.*, 2002). This research relates to the National Curriculum; however, the key areas examined are also of relevance, in broad terms, to the 5-14 primary science curriculum. It is interesting to note that there has been little research which relates specifically to the Scottish curriculum.

The students generally have positive experiences of Biology and Chemistry in relation to their own school education. However, Physics is negatively framed in terms of the students' experience. Primary science forms part of the core curriculum; as such primary teachers are expected to include science in their programmes of work. This is significant as the combination of a limited academic background in science allied to an experience of science education which was not wholly positive for many of the students may have an impact upon their confidence to teach science. Research has detected limited confidence in teaching the physical sciences when compared to the biological sciences (Wragg *et al.*, 1989; Harlen *et al.*, 1995; Shallcross *et al.*, 2002). Topics drawn from the physics component are generally reported as being difficult by primary teachers (Kruger *et al.*, 1990b). These findings have caused concern leading some to assert:

> *it is widely acknowledged that primary teachers lack of knowledge and understanding of science is a major impediment to good science teaching in primary schools.*
>
> [Summers, 1994, p. 179]

The concern for some is that a lack of subject-content knowledge leads to instructional formats with limited intellectual inputs and more hands-on management of the pupils' experience (Bennett and Turner-Bissett, 1993) existing within a transmissive framework arising out of a lack of confidence (Pardham and Wheeler, 2000). This will be examined as part of the observation of the students' teaching.

The next section of the research explores, in more detail, the students' experience of science using qualitative methods.

CHAPTER 5 NATURE of SCIENCE

5.1 Qualitative data

It was suggested in Chapter 1 that some knowledge and understanding of the nature of science is important if students are to develop effective teaching in their primary science lessons. In this chapter I seek to examine the students' epistemological views of science education through a small number of open-ended questions (see Appendix 5.1). The questions were derived from the work of Bloom's (1989) study of pre-service elementary teachers' conceptions of science, and Aguirre's *et al.* (1990) study of student teachers' conceptions of science, teaching and learning. These questions provide the students with the opportunity to outline their personal views on the following:

- the nature of science;
- the purpose of science;
- the impact that school science has had upon them as individuals.

The data was analysed by the technique of analytic induction (Abell and Smith, 1994; Murcia and Schibeci, 1999). This is a method based on the constant comparative method developed by Glaser and Strauss (1967) as part of the 'grounded theory' approach. The basic aim of such an approach is to generate theoretical constructs from the data rather than to impose a theoretical construct on the data. The technique involves the researcher reading and re-reading the respondents' answers in order to identify patterns (see Appendix 5.2 for illustration of technique). A coding or category system is developed on the basis of the emerging patterns. This is an iterative process as the researcher must constantly check and recheck the emerging interpretations to facilitate progressive focussing (Smith and Biley, 1997). As part of this technique the researcher incorporated a 'double run' in developing the categorisation system. This involved developing an initial set of categories followed by a subsequent attempt at developing a categorisation system for the same data. Both of the coding exercises were separated in time. Initially this was not a conscious decision but rather one borne out of the circumstances experienced by the researcher as it was not always possible to write up the findings, on completion, of data analysis. Furthermore, due to this time delay, the thinking behind the data analysis was not always immediately transparent necessitating retrospective analysis, or more prosaically, retracing the steps in the process of analysis. Although time consuming it was, nevertheless, found that this process of double analysis separated in time was useful as a means of verifying the thinking behind the categorisation process. The outcome of this was to develop a data analysis concept map (see Appendix 5.3).

This process should enable the researcher to identify similarities and differences in the respondents' answers. By comparing similar responses it becomes possible to define each concept through identification of synonyms. The differences in responses enable the research to identify coding boundaries. The next step in the process involves category integration or generalisation. These generalisations are validated by an examination of the data searching for confirming and discrepant cases (Abell and Smith, 1994). A preliminary examination of the data indicated that there was a notable drop off in response rates with respect to this section of the questionnaire survey (see Table 5.1). A large group of respondents (n = 174) failed to complete this section (see Table 5.1 -- Column X). The time frame allotted, over which the researcher had no control, was identified by two students as being insufficient:

sorry 5 minutes at end of lecture no time to do this

[PGCE student]

and

apologies for messy, unorganised attempt at answering this : pushed for time.

[PGCE student]

However, this does not explain the poor response rates from the BEd 3 and BEd 4 cohorts who were asked to complete the questionnaire in their own time. Clearly it is fruitless to speculate as to why this should be so; however, it would be interesting to examine whether there is indeed a differential response rate between closed and open-ended survey formats.

Table 5.1: Response rates to Section 5 of Questionnaire: Personal Views

Year	N	%	SampN	X
BEd1	103	85	121	18
BEd2	67	74	91	24
BEd3	28	41	68	40
BEd4	36	43	83	47
PGCE	71	61	116	45
All	305	64	479	174

5.2 The nature of science

The students were asked to outline their personal view as to the definition of science. The students' responses were grouped into five categories identified as:

- inability to define science;
- attitudinal response to science;
- perception of science as difficult;
- study of the world / environment: *the products of science*;
- science as method: *the process of science*.

Most students (n = 253) provide a single-category response. Approximately 17% of the students (n = 52) provided a multiple-category responses across the category boundaries some of whom (n = 6) provided responses covering three or more categories. (see Appendix 5.4).

The first significant category of responses (see Figure 5.1) which emerges is the inability of some students (n = 19) to articulate a definition of science through indicating that they were either 'unsure' or that they had 'no idea'[5.1]. Another group of students (n = 34) responded to this question by indicating their attitude towards science as either 'fun, interesting or boring':

Science is interesting and informative

[BEd 2 student]

and

Scary at first but 5-14 document is a big help!

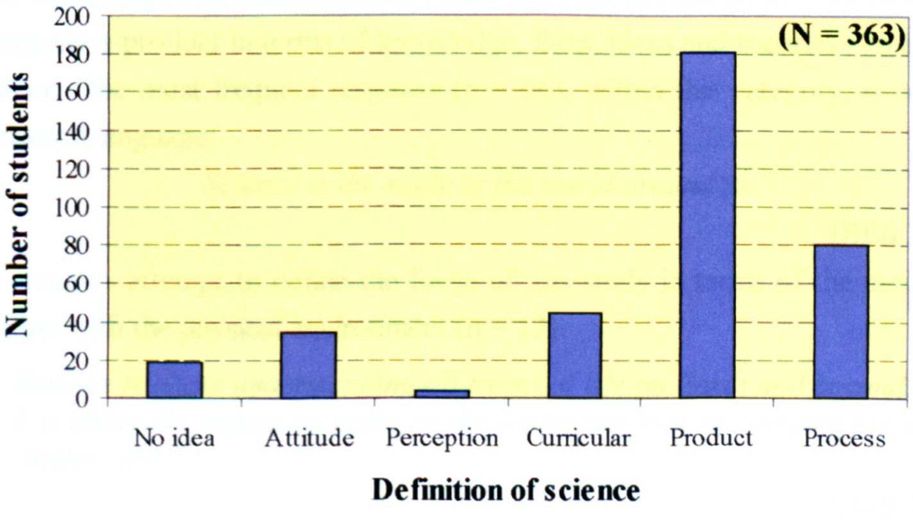
[BEd 1 student]

A small group of students (n = 4) appear to be overwhelmed by science and cannot begin to make sense of its nature responded in terms of their perception of science as being 'hard and complicated':

> *Difficult! Not a subject I warmed to at school. 'Wrong part of the brain' I believe.*

[PGCE student]

Figure 5.1: Students' definition of science



Some fifty-seven of the students were either unable to define science, or chose to respond to the question in a manner which does not give an insight into the nature of

[5.1] Citations from the students have been used to illustrate all the arguments identified in the comments made by the students. I have made no attempt to correct the spelling, punctuation or grammar of these quotes. Nor have I made any attempt to indicate that they are linguistically incorrect.

science. Murcia and Schibeci (1999), in their study of 73 pre-service primary teachers also detected the inability of some students, in their case thirteen, to provide a definition of science.

The next category of responses also provides little insight into the nature of science with students (n = 37) adopting a simplistic curricular definition:

> *I would define science as making up the subjects of Physics, Chemistry and Biology*
>
> [BEd 2 student]

or in terms of the language of 5-14 (n = 8):

> *Science is about learning about the processes of life, earth in space, and energy and forces.*
>
> [BEd 4 student]

In the responses to this question it is evident that many students (n = 102) are unable to articulate a definition of science. However, when one considers the multiple-category responses there were a number of students who outlined their attitudes to science (n = 5) and those who defined science in curricular terms (n = 20) who went on to elaborate their view of science. However, the pattern that emerges is that there is a significant number of students whose views are not so much out-of-step with current accepted thinking as their engagement with science is minimal (Hewson and Hewson, 1987; Lederman, 1992; Solomon *et al.*, 1996).

The largest category of responses (n = 181) identified science as the development of a body of knowledge and understanding of the world or environment. This views science as producing a product in terms of knowledge, facts, ideas and theories -- *the products of science*. The most frequent response (n = 96), within this category, is couched in fairly neutral language:

> *Science is the study of the world around us.*
>
> [BEd 3 student]

Some students attempt to define the focus of this study in terms of the nature of our interaction with the physical environment (n = 13):

> *Science is about understanding all forms of life on Earth and beyond. It is about the impact we make on the environment in our striving for a 'better' life*
>
> [BEd 4 student]

whilst other students focus on the purpose behind developing our knowledge and understanding (n = 33) in terms of:

> *how things are, why things are and how things work.*
>
> [BEd 3 student]

Finally a number of students (n = 38) argue that science is a vehicle for developing our factual knowledge of the world around us:

> *science points out the facts and takes away the mystery*
>
> [BEd 1 student]

and more prosaically:

> *I would define science as developing the knowledge and skills required to fully understand the world around us.*
>
> [BEd 2 student]

For these students it would appear that science is the *only* way we make sense of the world. Science provides the definitive facts about the world and these are immutable. There is no sense that science is a unique discipline which provides a specific kind of knowledge about the world. Furthermore creativity and imagination do not appear to have any role to play in the development of scientific knowledge. Additionally knowledge appears to exist in the world and once discovered this knowledge can then be received. It is not clear from the responses whether scientists, as they are not mentioned, have any impact upon the development of this knowledge or whether they are merely conduits for passing on 'discovered' knowledge.

The last category of responses to emerge from the data relates to the methods used in developing knowledge and understanding within science -- *science as a process*. Commonly words such as investigation and exploration (n = 42) are used to describe a method of enquiry:

> *Science is an investigative subject where pupils should be encouraged to ask questions and not simply believe facts.*
>
> [BEd 2 student]

For many students (n = 26) this investigative approach involves practical activity and experimentation:

> *Science is a very practical subject involving a number of skills. It allows us to research why things happen, how things occur which allows us, in turn, to develop new technology and theories which can be applied in the world around us*
>
> [PGCE student]

and

> *science consists of experiments and then drawing conclusions from results.*
>
> [BEd 1 student]

For a small group of students (n = 8) this investigative approach is linked to problem solving:

> *a problem to be solved which involves thinking about their knowledge and how to solve the problem.*
>
> [BEd 2 student]

Finally some students (n = 4) responded to the question by indicating the contribution that science makes, in general terms, to 'thinking skills':

> *process which enhance thinking and development of human understanding in almost everything we do.*
>
> [BEd 1 student]

For these students science is a method of enquiry facilitating the development of transferable skills which can be utilised in other areas of the curriculum. They do not see science as a unique discipline. However, there responses are slightly more sophisticated as facts are not to be accepted as necessarily true. There is some stress on a 'scientific method' or approach to activity within science teaching which suggest that they have a grasp of science as a dynamic discipline progressing through research and critical questioning. They do not appear to accept the proposition that science can develop through the accumulation of facts. There is also a sense that science can lead to societal improvement. There is, however, a degree of naïvety in that this 'scientific method' will inevitably lead to scientific knowledge. The suggestion remains that scientific knowledge is there to be discovered / rediscovered.

There were a number of multiple-category responses (n = 52) across category boundaries. Several students that had indicated their attitudes, positive and negative, to science combined this with their perception of the degree of difficulty of science (n = 3), the curriculum (n = 1), the product -- knowledge and understanding -- of science (n = 1) and the process of practical investigation undertaken in science classrooms (n = 4). More students grouped curriculum with product (n = 10) and process (n = 5). However, the largest combination was that of the product with the process of science (n = 28):

> *the exploration of a number of concepts to acquire knowledge and understanding of your everyday life and unknown experiences.*
>
> [BEd 4 student]

This evidence suggest that there is a substantial number of pre-service students who have a limited understanding of the nature of science. Abell and Smith's (1994) study of pre-service primary teachers also found that there was no clear conception of the nature of science. This is a cause for concern in that King's (1991) study of pre-service science teachers found that those students with a poor understanding of the nature of science were unable to articulate appropriate teaching methods.

5.3 The purpose of science

The students were asked to outline their personal view as to the purpose of science. The students' personal views on the purpose of science within the curriculum results in a response pattern consisting of five categories which include:

- ➢ to introduce theories and give knowledge and facts: *a teacher-centred orientation*;
- ➢ to provide an opportunity for developing knowledge and understanding of the pupils' everyday life and the world/environment: *the products of science*;
- ➢ to provide an opportunity to engage in investigative activity aimed at questioning aspects of the pupils' experience: *the process of science*;
- ➢ to provide an opportunity to develop intellectual and emotional competencies and skills: *a pupil-centred orientation*;
- ➢ to understand and develop new technologies: *a technological orientation.*

Most students (n = 242) providing a single-category response including a small number of students (n = 15) who articulated two dimensions within a category. Approximately 21% of the students (n = 63) provided multiple-category responses across the category boundaries (see Appendix 5.5) some of whom (n = 6) provided responses covering three or more categories. The first category discernible in the data shows a teacher-centred orientation (see Figure 5.2) with respect to the teaching of science. In this category students often indicate that the purpose of science is to either introduce theories and facts or to 'give' knowledge (n = 61):

> *to give pupils a wider range of knowledge and understanding*
>
> [BEd 2 student]

and

> *to pass knowledge onto pupils*
>
> [BEd 3 student]

and

> *the purpose of science in the classroom is to give children a basic understanding of chemistry, physics and biology and to demonstrate how science in as important aspect of everyday life.*
>
> [BEd 1 student]

For this group of students science is something which 'happens to pupils' through directed activity by the teacher. This would suggest a transmissive approach to teaching with the pupils being 'informed', 'made aware' and 'given' knowledge about science. There is no indication as to what learning takes place other than that the pupils absorb the knowledge provided. Indeed for some of the students science has to be endured:

> *to provide them with the knowledge and understanding they need to get through the subject.*
>
> [BEd 1 student]

The second category evident in the responses relates to the development of knowledge and understanding of the world, environment or everyday life. At a basic level many students (n = 101) see the purpose of science as:

> *to further our knowledge and understanding of the world around us*
>
> [BEd 2 student]

and

> *to widen children's knowledge and to allow them to have greater understanding of themselves and everything around them.*
>
> [BEd 1 student]

It is significant that this group of students focus on the learner which is both the pupil and the teacher:

> *to expand the child's or our own knowledge of ourselves and the world around us.*
>
> [BEd 1 student]

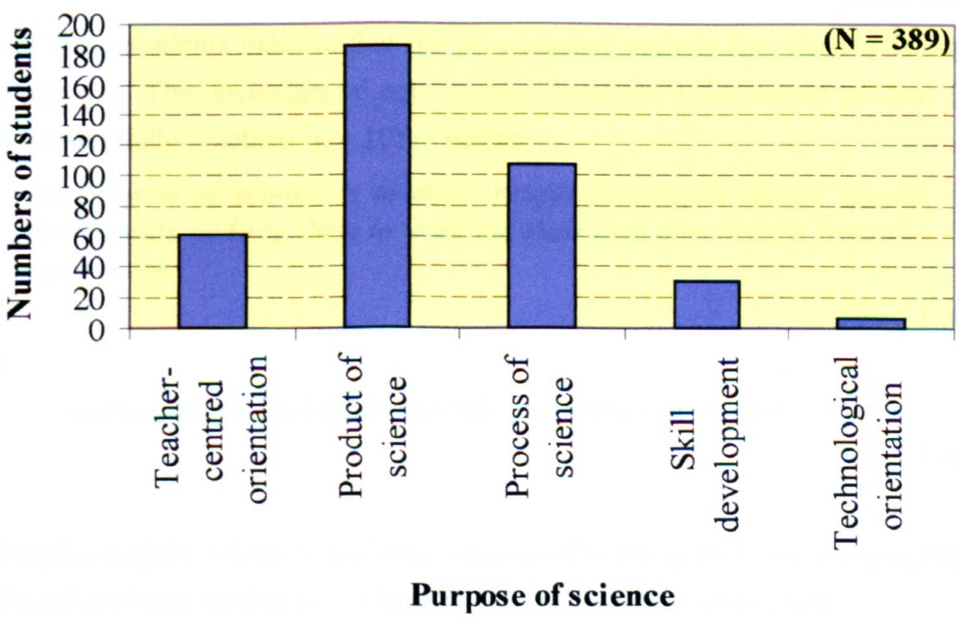
Furthermore this knowledge of the world or environment has a purpose (n = 4) in that it enables:

> *children to take responsibility for their environment*
>
> [BEd 3 student]

as well as (n = 5):

> *to understand our environment and to bring awareness as how we can improve it.*
>
> [BEd 1 student]

Figure 5.2: Students' personal views on the purpose of science



Another important sub-theme that is evident with respect to our knowledge and understanding of the world is our ability to explain 'how things work' (n = 74):

> *to allow us an understanding of how our world works, evolves and the reasons why*
>
> [PGCE student]

and

> *to provide answers about process that take place in all aspects of life. To answer unanswered questions about life changing processes.*
>
> [BEd 4 student]

Thus learning is not simply the passive receipt of knowledge but rather a dynamic process which involves interaction between the teacher and the learner. Furthermore the knowledge gained is meaningful to the learner with the teacher also being open to new learning.

The third category to emerge from the data relates to the activities undertaken by the learner in order to enhance their knowledge base. Many students (n = 81) refer to the learner investigating or exploring the environment, which may involve questioning aspects of their experience (n = 7), as a significant feature:

> *science allows children to actively investigate how things work and the ways in which they operate*
>
> [BEd 2 student]

and

> *to explore the natural world around us asking questions about why things are the way they appear.*
>
> [BEd 3 student]

Both of these students indicate that the investigative activity that the pupils engage in has a purpose. This investigative activity also involves a distinctive process (n = 9) which is essentially practical (n = 10) in nature:

> *the purpose of science is to make people investigate things, record their results and use them to work out their own conclusions from the experiment.*
>
> [BEd 1 student]

Thus:

> *science allows the children to take an active role in their learning.*
>
> [BEd 2 student]

The fourth category relates to the development of learning skills such as thinking skills (n = 7) and problem solving (n = 10) as an important aspect of science:

> *to develop an awareness of the world around us and to foster critical thinking and problem solving skills*
>
> [BEd 1 student]

and

> *to develop children's thinking skills in terms of problem solving to relate it to real life.*

[BEd 2 student]

Additionally some students (n = 10) see working within a group or class as an important outcome of learning in science in order to:

> *develop collaborative working.*

[PGCE student]

Finally a few students (n = 6) stress the significance of science in terms of its link to technology:

> *the purpose of investigating is so that we can improve life styles and nature in the future*

[BEd 4 student]

and

> *to develop our understanding of the world and develop new technologies.*

[BEd 1 student]

This final category is similar to the category 'search for new technology' detected in Bloom's (1989) study of 80 pre-service primary teachers.

5.4 The early years: Ignorance and idyll

The students were asked to outline their personal experience of science. The students' responded to this question in one of three ways:

- ➢ experience of science as a learner (n = 218);
- ➢ experience of science as a learner and a teacher (n = 28);
- ➢ experience of science as a teacher (n = 59).

This first part of the analysis examines the students' views of science as a learner (see Appendix 5.6a and Appendix 5.6b).

There appears to have been a limited experience of primary science (see Figure 5.3) amongst the students. A number of students (n = 40) cannot recall any involvement in science:

> *science is not a big part of the primary school curriculum -- I cannot remember doing any*

[BEd 1 student]

and

> *I have no memories of science in the primary -- was there any?*

[BEd 4 student]

However, only one student firmly stated that she received no science teaching in the primary school:

> *I was never exposed to science as it was a strict Catholic school. At secondary I was made to feel inferior and stupid, as a result I have an inbred hatred of science*[5.2].
>
> [BEd 2 student]

Apart from this extreme case it could be argued that distance from this experience may account for their failure to 'remember' or having a 'limited memory' of primary science (n = 8). What is evident is that primary science has had little impact upon them. Even those students who can 'recall' experience of science, it appears to be limited:

> *in primary, science was fun. I really enjoyed it. It involved pulling tadpoles out of rivers*
>
> [Shared memory of two BEd 1 students]

and

> *don't remember getting science at all before P7. In P7 there was plenty of practical work related to magnets.*
>
> [BEd 4 student]

These students have memories of salient practical events which are positively framed; presumably these are remembered as they engaged the pupils in practical activity. However, practical activity can also lead to negative experiences:

> *don't remember being taught any science except one lesson which was not enjoyable in the slightest. The teacher did a demonstration with chemicals which we couldn't touch or even go near.*
>
> [BEd 1 student]

Why should this one event be remembered? What was it about this lesson that was 'not enjoyable'? Another student provides an insight:

> *I learned science at primary school and I enjoyed taking part in experiments. However, I lost concentration when I was not doing the experiment, when the teacher carried it out.*
>
> [BEd 4 student]

Only one student had positive memories of a programme of science teaching:

> *I remember having a science lesson once every fortnight in Primary 5. Even today I could tell you the specific content of most of these lessons. This provided the foundations of the more specialised science topics in High School.*
>
> [BEd 4 student]

[5.2] This citation was included as the student made a connection between a lack of science in the primary and a subsequent negative experience of science in the secondary school. It is not meant to be indicative of a particular approach to science teaching in the Catholic school. Whereas there are areas of sensitivity (*e.g.* sex and reproduction) in Biology, borne out of my own experience as both a pupil and a teacher in the denominational sector of education, these do not form part of the primary school curriculum nor would they explain such an apparently negative view.

This is the most positive comment to be gleaned from the sample of respondents' (n = 246) responses. However, contained within this response there is a cause for concern in that the memory relates to only one year of the primary experience; several years prior to this student entering the High School. Was this the only science undertaken by this student in the primary school? Overall whatever science is being done in the primary school it does not appear to capture the imagination of the students. The problem with this is that it may well influence their future experience of science in the High School:

> *no science at primary school level. Science at secondary school = confusion. The way I thought things worked wasn't true.*
>
> [BEd 1 student]

Despite this concern the transition to the High School appears to be a positive one with respect to science (see Figure 5.3). A number of students (n = 33) indicated that S1 and S2 integrated science was:

> *fun. We explored all avenues of science and had a balanced mixture of practical and written work*
>
> [PGCE student]

and

> *I enjoyed science in S1 and S2 because I hadn't really experienced it before*
>
> [BEd 3 student]

and

> *I had experience of Science in 1st and 2nd year. This was a general introduction to Biology, Chemistry and Physics which I thoroughly enjoyed and found interesting as it gave pupils a taste of the three main areas.*
>
> [BEd 1 student]

Science is an aspect of the curriculum with which young people are eager to actively engage describing S1 and S2 science as interesting, fun and enjoyable. However, there are a small number of students (n = 6) for whom the wider context, in relation to S1 and S2 science, was problematic:

> *in first and second year I quite enjoyed science, although in second year physics and chemistry I had a lot of supply teachers and so quite a lot of coursework was not covered*
>
> [BEd 3 student who choose Biology Standard Grade]

and a student who experienced a similar disruption such that:

> *science education was minimal, if at all. This led to difficulties in S3 and S4.*
>
> [PGCE student]

This disruption in the students' experience of science education, over which schools have little control, is articulated for S1 and S2 science; however, it is not a feature of the later years of science in the secondary school. Although the numbers are small, and as such it would be dangerous to generalise, there is nevertheless a concern that teachers may view S1 and S2 science differently from the pupils. This may lead to differential staffing and resourcing. Despite these concerns the students indicate that they were positively predisposed towards science on entering the High School; this positive attitude needs to be nurtured in order to encourage future engagement with science education. Enjoyment can be translated into students choosing to continue their studies in science (n = 28):

> *I really enjoyed my 1st and 2nd year science course which is why I choose to carry it on into my Standard Grades*
>
> [BEd 1 student]

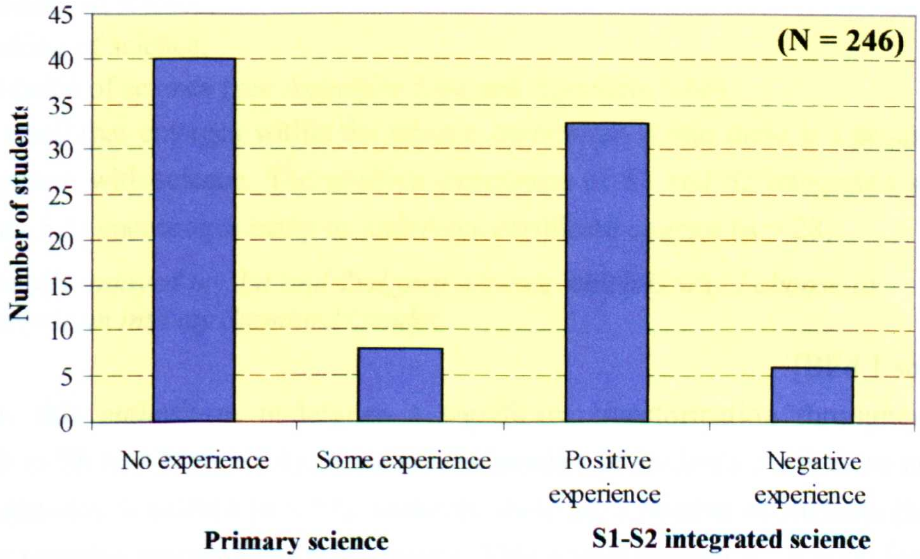
and

> *from experiencing Chemistry, Physics and Biology in 1st and 2nd year I decided to continue into Standard Grade with Chemistry and Physics.*
>
> [BEd 4 student]

This is not an universal experience:

> *I was never sure what each science involved and I picked the wrong one.*
>
> [BEd 1 student]

Figure 5.3: Students' experience of primary science and S1-S2 integrated science



Thus it does not appear that the students are innately hostile to science in the curriculum. They indicated that science was interesting and that it was not 'too difficult' (BEd 3 student) furthermore the 'hands-on experience' (BEd 4 student) was enjoyable. Some were concerned that:

> *science in early secondary was boring and at a slow pace. It was a mixed ability class so there were many distractions.*
>
> [BEd 1 student]

Generally the fact that science is seen as 'easy' by a number of students is not the key problem. The advice given by teachers and the choices made at the end of the second year appears to be more contentious:

> *I was forced to choose Biology at Standard Grade and have never really enjoyed it*
>
> [BEd 1 student]

and

> *I was made to take two sciences at Standard Grade when I only wanted to take one.*
>
> [BEd 1 student]

This is a theme which resurfaces at each option stage with the students complaining that they were ill-advised and coerced, in their opinion, into taking inappropriate curricular choices. Despite these reservations the pattern that emerges from the data is that the students had little experience of science in their own primary education. However, this did not adversely affect their experience of science in S1 and S2, which is generally positive. This undergoes a quite dramatic change as the students embark upon certificate courses in science.

5.5 Certification in science: The path to disenchantment

A number of themes emerge with respect to the period S3 to S6:

- ➢ difficulty of science;
- ➢ teaching of science;
- ➢ relevance of science (see Appendix 5.6a and Appendix 5.6b).

The key trend that emerges within the science curriculum is that there is a progressive disengagement with science. The positive experience of S1 and S2 integrated science (see Figure 5.3) encourages many to undertake certificate courses (n = 28):

> *I really enjoyed my 1st and 2nd year science which is why I choose to carry it on into my Standard Grades.*
>
> [BEd 1 student]

However, this enthusiasm undergoes a significant transformation throughout the period S3 to S6 (see Figure 5.4). A significant number of students continue to express positive attitudes to science (n = 73); however, there are a number of students (n = 56) recording negative attitudes towards science. This transformation is, in part, linked to the perception that science courses become progressively more difficult (n = 51):

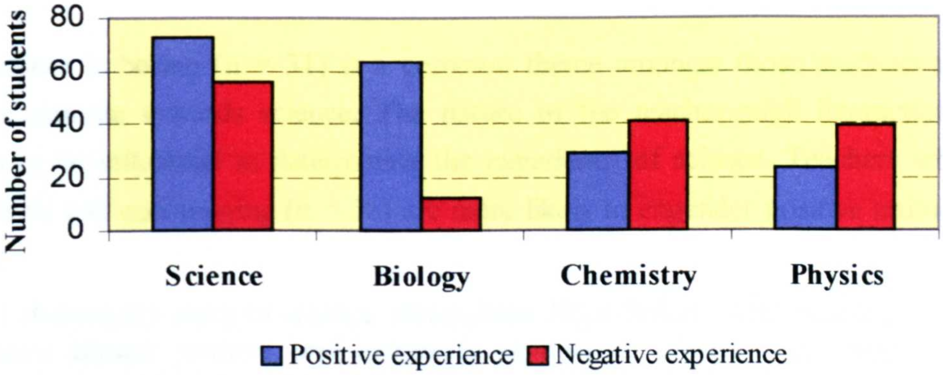
> *found Physics and Biology easy in 3rd and 4th year and slightly more difficult in Higher*
>
> [PGCE student]

and

I did enjoy science up until 5th year when I did Higher Physics and I found it really difficult.

[BEd 3 student]

Figure 5.4: Students' experience of certificate science



Another significant trend evident in the data is that there are differential experiences of the sciences. The students have generally more positive experiences of biology (n = 63) when compared to the physical sciences (n = 52). For each of the physical sciences more students express negative attitudes towards Chemistry (n = 41) and Physics (n = 39) when compared to those who express positive attitudes. Additionally the perception that the physical sciences are seen as being difficult is compounded by the perception that they are also theoretical (n = 11) and mathematical (n = 14):

some of the theoretical concepts are highly complex and difficult to understand as they could not be demonstrated in practice

[BEd 4 student]

and

Physics and Chemistry I found very difficult, so very mathematical

[BEd 1 student]

and

at Higher Level I found Chemistry to be quite difficult with all the formulae involved.

[BEd 2 student]

Despite concerns that the mathematics of Physics and Chemistry may present them with difficulties:

I was keen to do Physics but I was advised not to as I am not so good at Maths -- but I feel Physics is contextualised so it might have helped me with Maths.

[BEd 4 student]

The level of difficulty, although important, does not necessarily determine whether the experience of a subject is negative:

I did Physics which I found difficult but I still enjoyed it

[BEd 1 student]

and

I didn't like science in High School as it was very boring.

[BEd 2 student]

That science is boring (n = 31) is a common theme amongst those students with a negative attitude towards science. The nature of the teacher-pupil interaction also appears to be influential in determining the experience of science. Teachers who are enthusiastic and encouraging (n = 56) are more likely to engender positive attitudes to science:

I thoroughly enjoyed science throughout High School. The teachers were always positive and extremely supportive, always organising support sessions for our own benefit

[BEd 3 student]

and

my teacher, who was the same for both Standard Grade and Higher, was very supportive and took time to explain theories which were more difficult to understand.

[BEd 4 student]

Clearly these teachers sought to encourage and support the students who, despite the difficulties they encountered, developed positive attitudes to science. Of the fifty-four students who identified the good quality teacher-pupil interaction as being an important influence some fifty-one of them expressed positive attitudes to science. Unfortunately poor teacher-pupil interaction is evident amongst those students with negative attitudes towards science (n = 69):

I found Standard Grade Chemistry difficult due to the teaching -- there was little interaction with the teacher and I found it boring

[BEd 4 student]

and

my science teacher read from a textbook and would not let us do any experiments. It was boring.

[PGCE student]

Among this group of students some fifty-seven express negative attitudes to science. Some students express a concern, although we have no way of knowing how justified these concerns are, that science teachers are élitist (n = 15):

I felt my teacher (Chemistry) always assumed a level of knowledge that pupils just did not have

[PGCE student]

and

science was for scientists when I was at school and a no-go area for those whose understanding was minimal.

[BEd 3 student]

More worryingly, there are a small number of students (n = 4) who were exposed to negative gender stereotypes with respect to Physics:

my teacher had the opinion that girls shouldn't do any kind of science

[BEd 1 student]

and

my teacher was constantly picking on / teasing me as I was the only girl in the class and so I dropped out as Physics was no longer giving me any enjoyment.

[BEd 1 student]

The methodology deployed also appears to be critically important in determining the nature of the students' experience. Involvement in practical activities (n = 56) and investigative work (n = 12) appears to engender positive attitudes:

there was a lot of practical work and we were all involved in working things out and planning our experiments. The difficulty gradually increased but the lessons remained enjoyable

[BEd 1 student]

and

I enjoyed the practical activity and the investigative aspects.

[BEd 3 student]

A number of students (n = 12) expressed negative attitudes to science as a result of an absence of practical activities in the teaching they experienced. Interestingly there was a small number of students (n = 5) who indicated that they did not enjoy being involved in practical activity. Some students (n = 14) identified not only the practical activity but also the nature of the pupils involvement in that activity, 'we were all involved', as being important:

science was taught in whole class and group contexts which was effective

[BEd 1 student]

and

we were taught by whole class teaching. We would firstly, when we started a new topic, listen to the teacher and take notes, complete worksheets etc. Once the ground work was done we would plan and prepare an investigation, carry out that investigation and record the results. I thoroughly enjoyed science in High School as we were constantly engaged and challenged.

[BEd 3 student]

The converse of this, namely a lack of involvement in lessons, is linked to negative attitudes to science teaching (n = 8). The students also indicate that the methodologies which they experienced as pupils are relevant to the children they teach (n = 13):

the majority of my experiences were good as they were 'hands on' and practical which, for me, enhanced my understanding

[BEd 4 student]

and

there has to be a practical nature to any science activity as it has been well documented that children learn better by 'doing'.

[BEd 4 student]

Directive teaching methodologies with a heavy reliance on textbooks and worksheets are associated with negative attitudes to science teaching (n = 33):

I hated science at school. The teachers made it boring and uninteresting. We as pupils were never allowed to participate in activities and all the work was done from worksheets or notes dictated to us

[BEd 1 student]

and

we spent a lot of time copying notes from overheads.

[BEd 1 student]

These directive methodologies are linked with teaching which focusses on examinations. This leads to teaching which is 'rushed' (n = 9) and consequently to a lack of understanding:

experiments were rushed and many areas left me confused and unsure of how results came about. No time for reflection!

[PGCE student]

One of the students expressed an awareness that the science being taught in schools is 'known' science:

I have a fairly positive experience as I remember lots of hands-on experiments in science. However, although I enjoyed these I was looking to get the result the teacher told me I would get. Therefore I was not drawing my own conclusions.

[BEd 4 student]

Finally the relevance of science (n = 20) is related to the nature of the students' experience. The relevance of biological science are generally more positive (n = 18) when compared to the physical sciences:

I really liked this type of science (Human Biology). It was based only on the functions of the human body and didn't touch on plants

[BEd 1 student]

and

I enjoyed Biology because I liked the human side of it and enjoyed learning how the body functioned.

[BEd 3 student]

However, only two students indicated that the physical sciences were relevant:

I found Physics interesting and useful (e.g. wiring a plug).

[BEd 1 student]

The relevance of science teaching can also be related to whether the lesson objectives have been shared (n = 9):

I enjoyed Chemistry, probably due to the practical aspect. However, I was never sure, and I am still not, why I was doing whatever I was doing -- possible because it never was tied into my own life -- I could never see the relevance.

[PGCE student]

5.6 Teaching primary science: A glimpse of a way forward?

A number of students (n = 87) provided an insight into their experience of teaching primary science (see Appendix 5.7a and Appendix 5.7b). Although the number of students is small several important themes emerge from their responses. Concerns raised regarding the implementation of 5-14 Science identified in the Assessment of Achievement Programme Reports in Science (SOEID, 1998; SEED, 2000c) are, to some extent, confirmed in that the students indicate that there is a lack of teaching in primary science (n = 27):

in my school experience there was no science covered in my Primary 7 class .. during the whole eight weeks I was there.

[BEd 2 student]

Eight weeks appears to be a considerable time for a Primary 7 class to be without any teaching in science when one considers that these pupils will soon move to the secondary school. It could be argued that these pupils are not being provided with a continuity of experience. However, it is important to be cautious here in that many primary schools 'block' curricular time:

I have seen little or no science in my school experience so far, taught by any of the teachers. I think this was due to the topic areas that were being studied at the time.

[BEd 2 student]

In this arrangement time will be blocked for part, or all, of a term to take forward learning in a particular curricular area (*e.g.* 5-14 Social Subjects). Thus pupils will be immersed in learning related to that curricular area or 'topic'. This effectively reduces the time available, if indeed there is any, for other curricular areas (*e.g.* 5-14 Science). In such a 'topic-driven' structure it is more likely that time will be blocked at other times during the course of the year. It is worthwhile to note that 5-14 documentation (SEED, 2000a; SEED, 2000b) does not provide an educational rationale for such a topic approach[5.3]. The discontinuity of experience with respect to learning in the various curricular areas, which such an approach entails, is not considered. It would be interesting to examine how much pupils make sense of such a fragmentary experience.

From Primary 1 to Primary 7 it is recommended that there should be five topics per year to utilise the time allocation of 15 per cent for Environmental Studies (SEED, 2000b). Topics may vary in length with longer topics lasting around six to seven weeks and shorter topics lasting from two to four weeks. With regards to curricular equity (*i.e.* fulfilling the recommended time allocations to curricular areas) this would appear to an efficient use of time. However, there is no requirement that all curricular areas should be blocked during the course of any given year such as Primary 7. Planning documents relating to 5-14 Environmental Studies suggest that all curricular areas should be experienced each year. However, the recommended time allocations refer to the entirety of the pupils' experience in the primary school. As such it is possible to provide pupils, in any given year of their primary schooling, with a skewed experience of the curriculum:

> *while on placement science was not taught as the teachers were unsure of the subject. I was assured that the pupils would be taught in large blocks later in the year to ensure 5-14 was catered for.*
>
> [PGCE student]

This PGCE student found herself in a primary school where unfortunately science appears to be the 'Cinderella' subject. In this school science seemed to be taught merely to make sure that '5-14 is catered for'. As a rationale for science education this is woefully inadequate. Furthermore if the teachers are unsure of science at the time of the students placement then what is likely to change to make them teach it in a positive manner later in the year? The concern is that this may be replicated in a number of primary schools with pupils being taught very little science. It was seen in an earlier section of this chapter that a number of students (n = 40) had little experience of science when they were pupils. It is also evident that, as pre-service student teachers, some of them have had little experience of science teaching whilst on their teaching placements:

> *science at the moment, from my experience, is not occurring in the curriculum as much as it should be*
>
> [BEd 4 student]

and

[5.3] This topic appears to be a flexible curricular device. During the initial stages of the primary school topics are seen as a vehicle to take forward an integrated approach to the curriculum. This is thought to be particularly suited to younger pupils. As the pupils grow older these topics incorporate a variety of teaching approaches ranging from thematic topics, cross-curricular integrated topics through to subject-centred topics.

I have seen very little science on placements.

[BEd 3 student]

These students have experienced several placements across a range of primary schools yet their experience, along with other students (n = 27), is remarkably similar with respect to the paucity of science teaching.

A number of students who observed science teaching whilst on their placements indicate that this tends to be teacher led (n = 10) relying heavily upon textbooks (n = 7):

> *found that some teachers are not keen to teach science. When done it was more a case of teacher telling facts rather than investigating and experimenting*

[BEd 2 student]

and

> *science was delivered straight from worksheets and the children did not participate during the lesson.*

[BEd 2 student]

Again the number of students is small, but the evidence is supportive of findings from the Assessment of Achievement Programme (SEED, 2000c) that science teaching in the primaries tends to be dominated, particularly in the lower stages of the primary, by teacher-led methodologies where the teacher carries out any experiments undertaken. Furthermore there is a reliance upon commercially produced resources.

All is not doom and gloom as there are a number of important positive themes to emerge from the data. Firstly teaching does take place despite the reservations expressed regarding the methodologies used by some teachers. A number of students (n = 19) have had a positive experience of science teaching in the primary school indicating that they were impressed by the enthusiasm and expertise of some teachers who tend to be:

male teachers or young, newly-qualified teachers.

[BEd 4 student]

A small number of students (n = 4), who observed science teaching, indicated it was a specialist science teacher from the secondary school who provided an experience of science for both teachers and pupils in the primary school:

> *the Primary 7 class had a science teacher from the local High School visit every Thursday afternoon. He was extremely informative and the children really enjoyed it.*

[BEd 3 student]

Contacts such as the one identified above, although not a new idea, may be one of the ways forward in promoting science in the primary school. However, such contacts between primary and secondary schools are not very common in Scotland.

Encouragingly the students (n = 24) themselves have taught science lessons and many of them (n = 13) have enjoyed this experience. Furthermore it is clear to a number of students (n = 20) that the pupils enjoy science particularly when it involves practical activities (n = 13):

> *I highly value the importance of hands-on work with opportunities for investigation and collaboration which will permanently influence children's understanding of, and attitudes towards, science*
>
> [BEd 4 student]

and

> *children, on the whole, enjoy science particularly when they are involved in experimenting and looking at problems. The children I have seen also enjoy the discussion of experiments and also recording and reporting their findings.*
>
> [BEd 4 student]

Another encouraging observation made by a small number of students (n = 7) was that they learned from teaching science whilst on their placements:

> *at school science was never portrayed as a fun or exciting subject. I feel that I was never encouraged to do well and ask questions. However, I have learned that science can be fun!*
>
> [BEd 2 student]

The significance of these students' engagement with teaching science is that there is no requirement for them to do so whilst on their placements. It is possible to go through their four years without having taught science, and indeed some students may choose this path. Consequently few students will have been observed teaching primary science. In addition the teaching of primary science involves considerable effort on their part as many primary schools have little by way of resources, and many teachers are unable to support the students as a result of their own lack of confidence in teaching science. That so many from this small sample have engaged in science teaching and, what is more important, enjoyed the experience is a very positive outcome. Clearly the task we face is how to encourage as many students as possible to see the teaching of science as something they look forward to whilst on their placements.

5.7 Concluding remarks

Pre-service primary students have been participants in an 'apprenticeship of observation' (Abell and Smith, 1994). Throughout their schooling they have been exposed to science teachers' attitudes and teaching strategies which are likely to influence the way they teach. Consequently it is vital that we determine the nature of the views they bring with them, at the outset of their careers in teaching, in order to identify those views which require to be changed over time. We cannot expect the students who have been inducted into an objectivist orientated science to magically transform into teachers who adopt more learner-centred, constructivist orientated approaches '*simply by being told*'. Experienced teachers find themselves in conflict between facilitating a more active role for learners whilst at the same time having a fear of losing control over the pupils' learning (Jofili and Watts, 1996). The active involvement of learners in the process of teaching and learning may be the goal for teachers; however, this may be in conflict with their own experiences as passive learners as well as their own preferred teaching styles (Huibregste *et al.*, 1994). The shift in authority between the teacher and the learner which is explicit in the constructivist perspective is a difficult transition for teachers to make (Rieber, 1993).

Research would suggest that:

- teachers' knowledge is constructed through personal and practical experience;
- modification of practice takes place through an interaction of previous learning and new classroom experiences;
- the lessons teachers learn about effective teaching are lessons they learn in practice;
- teachers' understanding about teaching accumulates and changes slowly.

[Adapted from Louden and Wallace, 1994, p.654]

To facilitate a process of change will require teacher trainers to support their students in reconstructing their own knowledge of science as well as what constitutes effective practice in science teaching. Such a change requires a more structured response in order that we may develop in the students '*the ability explicitly to consider and talk about the intelligibility, plausibility and fruitfulness of conceptions*' (Hewson and Thorley, 1989, p.545) with a view to enhancing the quality of the primary science classroom interactions which they provide. This is a much deeper response to the application of learning theory in the classroom than that offered by 'learner-centred Romantics' (Watts and Jofili, 1998).

Craven and Hand (2002) argue that it is possible to facilitate development of naïve conceptions of science through engaging students in dialogic interaction where they are encouraged not only to articulate their current views of science but to argue and defend personally held views, using evidence, as well as accommodating alternative views which are supported by evidence. Carey *et al.* (1989) argue that through an appreciation of the student teachers' understanding of the nature and purpose of scientific inquiry and subsequent observation in the classroom we may be better placed to suggest focussed classroom-based intervention. Herein lies the seeds of a strategy for the development of pre-service primary science education courses.

Prior to engaging in classroom observation it is first necessary to explore other related aspects of the students' views on teaching and learning in primary science. The next section of the research will examine the students' stated confidence levels in taking forward the 5-14 science curriculum.

CHAPTER 6 TEACHING 5-14 PRIMARY SCIENCE

6.1 Attitude measurement

The second domain examined in the questionnaire, developed for this research, concerned itself with examining the student teachers' attitudes to the key components of 5-14, namely teaching the attainment outcomes as well as the individual knowledge and skill strands, discussed in Chapter 3. The questionnaire was used to gain an insight into the student teachers' attitudes as, being a conceptual construct, attitudes cannot be directly observed. According to Borg and Gall (1989) attitudes have three principal components:

- *cognitive* - consisting of the individual's thoughts, beliefs or knowledge about the attitude object, and
- *affective* - consisting of the individual's positive or negative feelings about an attitude object
- *conative* - consisting of the individual's behaviour or predisposition to act toward the attitude object in a particular way.

These three components are each dependent, to a degree, on the others and are thought of as being in a state of dynamic equilibrium with the environment. Thus a change in one of the components (*e.g.* an increase in knowledge about the attitude object) may lead to change in the other components. This is of interest in educational research in that a change in attitudes may lead to different actions with the aim of providing effective teaching and learning experiences.

A number of attitude scales have been developed to measure what an individual believes, perceives or feels about themselves, others, activities, institutions, or situations (Gay and Airasian, 2003). Among the key scales which have been developed are:

- *Thurstone-type scales*

These scales require respondents to express agreement or disagreement with a series of statements that represent different points of view on a topic being examined. The statements express positions along a scale with apparently equal intervals between them. This technique presents problems during the construction phase in that it is time-consuming. In addition the selection of the statements is open to criticism of bias on the part of the 'judges' -- those undertaking the selection of the statements (Thomas, 1978). Furthermore doubts have been raised regarding the comparability between one scale and another (Oppenheim, 1992).

- *Likert-type scales*

These scales require respondents to select one of five possible responses (*e.g.* strongly agree, agree, uncertain, disagree, strongly disagree) to a statement. Likert-type scales are simple to construct and permit a crude ordering of respondents in terms of attitudes. It is possible to examine several aspects of the topic being examined simultaneously by arranging the pool of statements under several headings -- this information can be withheld from the respondents in order not to sensitise them to the nature of the attitude objects being examined. Another major advantage of this type of attitude scale is that it is the respondent who determines the weighting of their response, rather than the researcher as in the Thurstone-type scale.

➤ *Osgood's Semantic differential scales*

These scales require respondents to give a quantitative rating, in relation to the topic being examined, on a variety of bipolar adjectives (*e.g.* good-bad). These scales usually have five to seven intervals with a neutral value assigned a score value of 0. The basic premise of this technique is that the function of language is to convey meaning. Thus language is used to differentiate between concepts and to measure their meaning. The respondent's response, in relation to the scale, gives an indication of both the direction and intensity of the attitude. These attitude scales offer interesting insights into the subjective semantic world of the individual (Oppenheim, 1992). It is also possible by averaging sets of ratings to obtain insights into how groups of respondents perceive the concept being explored. The main problems with this technique is that only one attitude object can be examined at a time. If several attitude objects are to be examined then it becomes necessary to use several scales. Thus the key problem is that the bipolar scales are not directly transferable to different attitude objects (Thomas, 1978). Attitude scales are used in educational research because of their possible predictive value. This study adopted the Likert-type attitude scale because this technique has a higher predictive value when compared to the other scales (Borg and Gall, 1989).

6.2 Likert technique

The research question being explored in this section is how confident are the students in implementing 5-14 primary science? A 5-point Likert-type scoring technique was used to indicate levels of confidence, amongst students, in teaching the sciences:

1 - Very confident
2 - Confident
3 - Confident with support
4 - Not very confident
5 - Not confident even with support.

Student confidence levels were examined in relation to teaching:

- the three science attainment outcomes;
- the knowledge and skill strands for each of the attainment outcomes;
- the attainment outcomes within three broad age-related planning cycles; and
- the skills necessary to engage in investigative work in science.

The approach developed was a refinement of earlier research by Harlen *et al.* (1995) looking at confidence levels in the teaching of science amongst primary school staff. There have also been a number of questionnaire studies on teachers' attitudes to new curricular initiatives in England (Wragg *et al.*, 1989; Bennett *et al.*, 1992) and more specifically science (Carré and Carter, 1990). In Scotland (Harlen and Holroyd, 1995; Holroyd and Harlen, 1996) carried out studies with a focus on the science and technology curricula.

The earlier research of Harlen *et al.* (1995) looked at the specific content of the science curricula. I have chosen not to look at the specific content of the science curriculum as it is likely to introduce a source of confusion amongst pre-service students and lead to a skewing of the results. For although pre-service students are expected to cover the three science attainment outcomes as well as the knowledge and skill strands within each attainment outcome, they are not expected to cover all of the content identified. The earlier survey questionnaire conducted by Harlan *et al.* (1995) elicited confidence levels amongst primary school staff in relation to content some of which was taught at the secondary school stage. Consequently the results produced indicated low levels of confidence. My research focusses its attention at the aggregate level of the attainment outcomes and their related knowledge strands to determine the level of confidence, in relation to curricular areas with which pre-service students should be familiar. There was no attempt to specify content during this phase of the research.

6.3 Attainment Outcomes and Knowledge Strands

Section 2 of the questionnaire examined the pre-service students' confidence levels in teaching 5-14 primary science. Participants were asked to indicate their confidence levels in terms of the five-point Likert scale. Confidence levels were examined with respect to the three attainment outcomes each of which was further sub-divided with relation to the three knowledge strands as follows:

<u>Attainment outcomes</u>	<u>Knowledge strands</u>
➢ Living things and the processes of life [Biology component]	• variety and characteristic features • the processes of life • the interaction of living things with their environment
➢ Energy and forces [Physics component]	• properties and uses of energy • conversion and transfer of energy • forces and their effects
➢ Earth and space [Chemistry component]	• the Earth in space • materials from Earth • changing materials.

The initial treatment of the data resulted in the production of frequency tables (see Appendix 6.1, Appendix 6.2 and Appendix 6.3). These were further processed through the calculation of a 'confidence index'. Harlen *et al.* (1995) included the calculation of a 'confidence index' in their research. Although my research also includes reference to a 'confidence index' it has been calculated differently as I have chosen not to replicate the methodology outlined in the paper by Harlen *et al.* (1995). The technique, developed by Harlen *et al.* (1995) introduced a multiplicative weighting to the frequency scores. The multiplier effect serves to enhance the differentials in responses in order to identify patterns, whilst retaining the integrity of the data, between the various knowledge strands within each of the attainment outcomes.

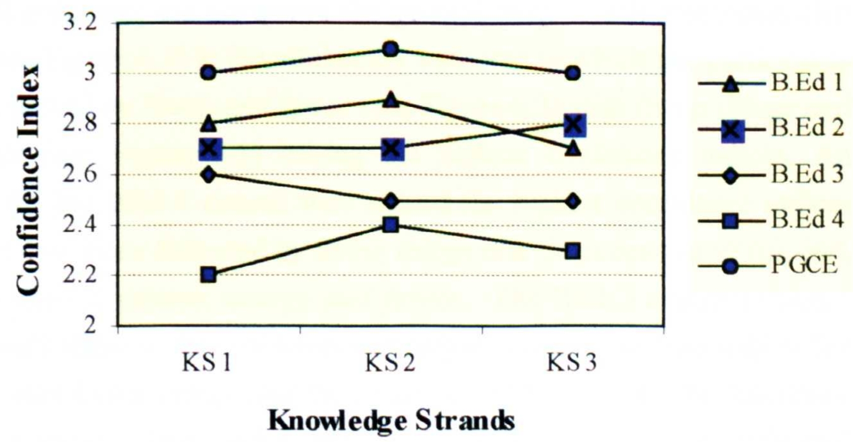
The 'confidence index' was calculated by multiplying the frequency entered under 1 by 5; 2 by 4; 3 by 3; 4 by 2 and 5 by 1. Thus the greatest 'weight' was applied to those expressing the greatest degree of confidence and the least 'weight' to those expressing the least confidence. Summation of the resultant products gave the 'confidence index' which fell within the range 100 to 500. An even distribution of responses would give a median index of 300. Thus an index within the range 100-300 indicated low confidence whilst an index in the range 300-500 indicated high confidence. It is not clear why they would wish to introduce a '*reverse weighting*' to calculate the 'confidence index' other than to link a large number with high confidence. In their attitude scale, as well as in my research, a low number indicated high confidence (*e.g.* 1 - Very confident whereas 5 - Not confident even with support). Harlen *et al.* (1995) argued that this was not a statistical test but rather a means to assist with the identification of patterns and in this respect it is a useful for descriptive purposes.

Figure 6.1: Attainment outcomes and knowledge strands for physics component: Energy and forces

KS 1:
Properties and uses of energy.

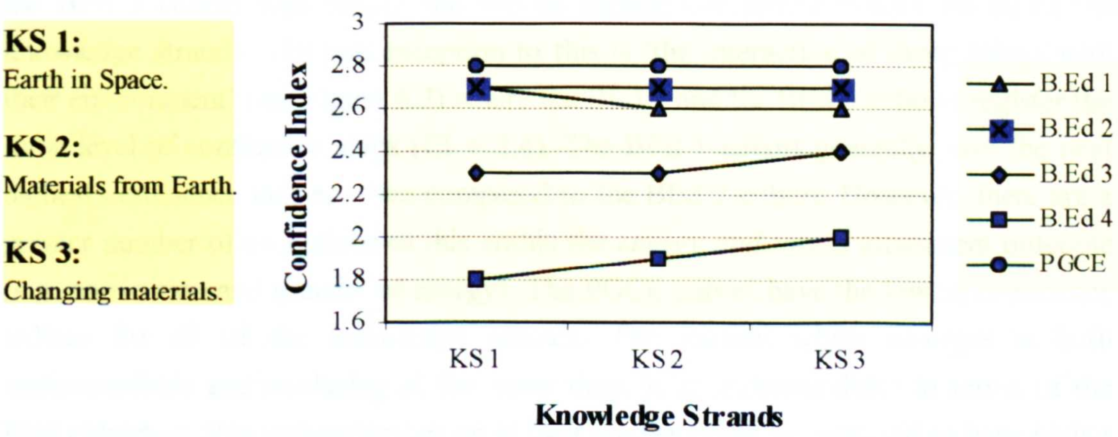
KS 2:
Conversion and transfer of energy.

KS 3:
Forces and their effects.



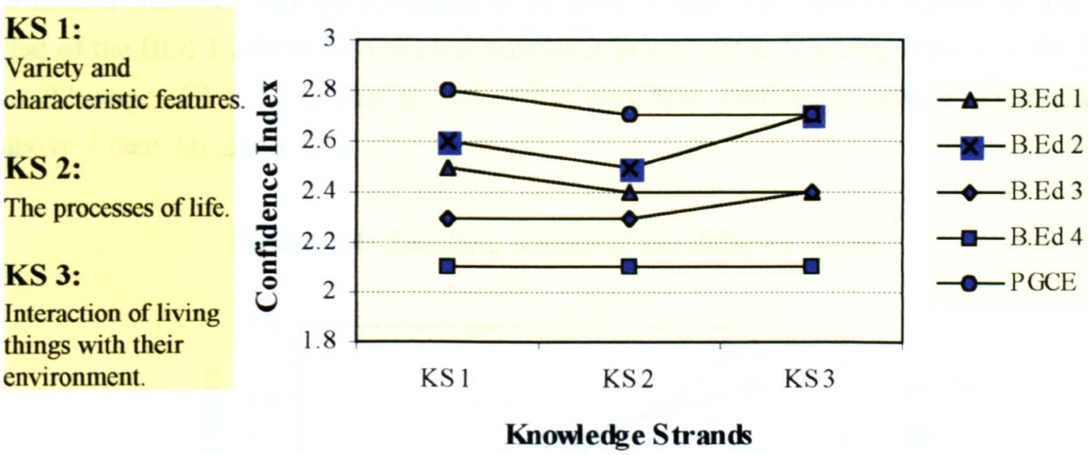
I have chosen to calculate a 'mean confidence index' (Wragg *et al.*, 1989; Carré and Carter, 1990 and 1993; Stark and Gray, 1999) from the frequency data (see Appendix 6.1, Appendix 6.2 and Appendix 6.3) which are presented here in graphical form. The lower the value for the confidence index then the higher the students' confidence; any value under 3 indicates that the students are positive with respect to the attainment outcome, knowledge strand, or skill being examined. A number of patterns emerge from an analysis of the data. Firstly it is evident that, with a few exceptions, confidence indices for the various knowledge strands are under 3. This would suggest that the various student cohorts are confident that they have the necessary knowledge and skills to teach science. An exception to this is the PGCE cohort who register a confidence index of 3.1 for the knowledge strand 'conversion and transfer of energy' in the *energy and forces* (see Figure 6.1) attainment outcome. This is surprising in that this group was the best qualified in terms of the number of students with a Higher level pass in both Physics and Chemistry (see Figure 4.3 and Figure 4.4). Indeed 50% of all of the students with a double Higher level pass in these subjects comes from the PGCE cohort (see Figure 4.6).

Figure 6.2: Attainment outcomes and knowledge strands for chemistry component: Earth and space



When the attainment outcomes are compared the general trend which emerges is that *energy and forces* (see Figure 6.1) is the attainment outcome in which the participants are least confident followed by *Earth and space* (see Figure 6.2) with *living things and the processes of life* (see Figure 6.3) having the highest confidence indices. An exception to this is for the BEd 4 cohort who record the highest confidence indices with respect to *Earth and space* followed by *living things and the processes of life* and, in common with the general pattern, *energy and forces*. The BEd 3 cohort exhibit a similar pattern, although there is little difference in terms of the confidence indices for the *Earth and space* and *living things and the processes of life* attainment outcomes. This general pattern mirrors that which emerges in relation to the participants' qualifications at Higher level. The analysis indicated that the participants were least well qualified in Physics at both Standard Grade and Higher level.

Figure 6.3: Attainment outcomes and knowledge strands for biology component: Living things and the processes of life

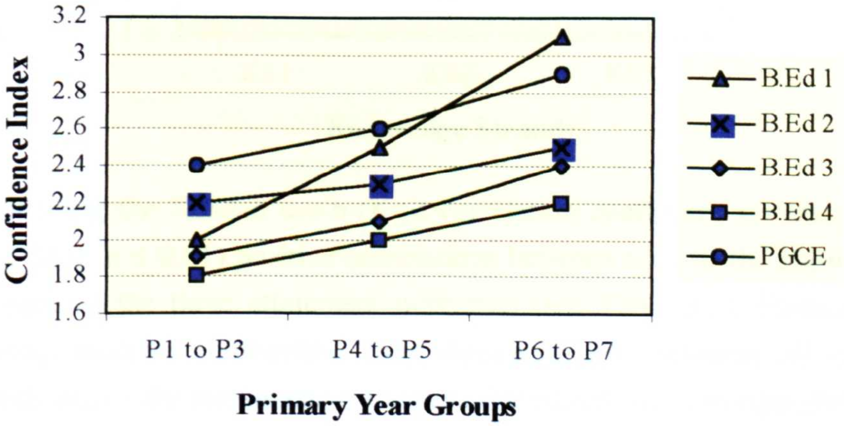


When the individual student cohorts are examined there is, once more, a consistent pattern to the data. The BEd 4 cohort record the highest confidence indices for all three of the knowledge strands within each attainment outcome. This group is followed by the BEd 3 cohort who record the second highest confidence indices for all of the knowledge strands. The one exception to this is 'the interaction of living things with their environment' (see Figure 6.3) where the BEd 1 and the BEd 3 cohorts register the same level of confidence index (CI = 2.4). The BEd 1 cohort generally have the next highest confidence indices when compared to the BEd 2 cohort. However, there are a greater number of exceptions to this within the *energy and forces* attainment outcome (*e.g.* conversion and transfer of energy). The PGCE cohort have the lowest confidence indices for all of the knowledge strands. The pattern which emerges is both understandable and confusing at the same time. It is understandable in terms of the BEd cohorts in that groups further on in their studies could be expected to have higher confidence indices when compared to those who have just embarked on their studies. However, this does not appear to hold for the BEd 1 and BEd 2 cohorts. Again this is to some extent understandable in that the BEd 1 cohort is generally better qualified in Chemistry and Biology (see Figure 4.4 and Figure 4.5) when compared with the BEd 2 cohort. This may explain their higher confidence indices for the Biology and Chemistry components of 5-14 primary science. There is little difference in terms of their respective qualifications in Physics where the BEd 2 cohort return slightly higher confidence indices for the *energy and forces* attainment outcome.

6.4 Primary teaching stages and teaching investigative skills

Confidence indices were determined for teaching science at the various stages within the primary school (see Figure 6.4). The three stages correspond to the broad curricular planning stages of infants (P1 to P3), juniors (P4 to P5) and seniors (P6 to P7). It is evident from an examination of the data that the student cohorts are generally confident that they can teach science in all three stages. The only exception to this is that of the BEd 1 cohort who are less confident in relation to teaching science in the P6 to P7 stage (CI = 3.1). This is one of the very few confidence indices which rises above 3 (see Appendix 6.4).

Figure 6.4: Teaching science at the different stages



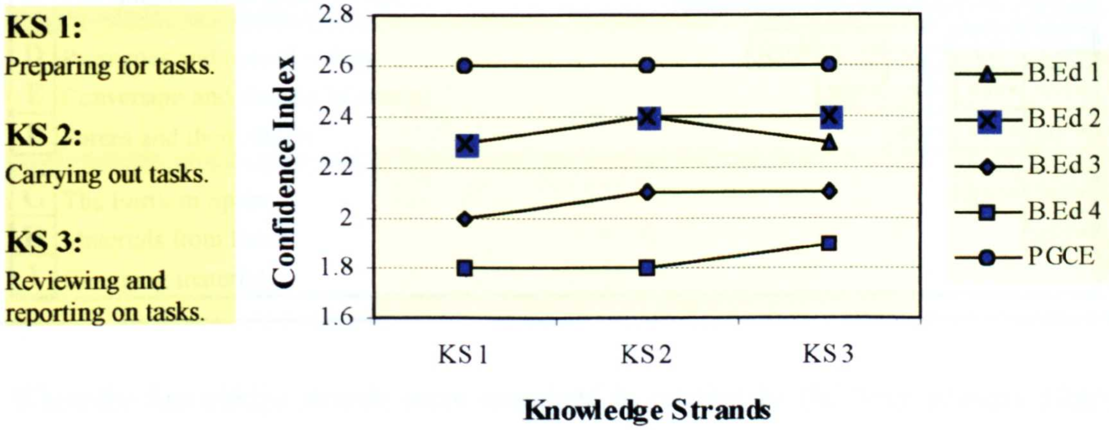
An examination of the three stages, for the entire student cohort, reveals that the students are more confident with respect to P1 to P3 (CI = 2.1) followed by P4 to P5 (CI = 2.3) and finally least confident in teaching science in P6 to P7 (CI = 2.7). This is a consistent pattern across all of the individual student cohorts. The BEd 4 followed by the BEd 3 then the BEd 2 cohorts register the highest confidence indices for all three stages. The PGCE cohort registers low confidence indices. The BEd 1 cohort is the only group for which there is a wide variation in their confidence indices.

The students also expressed their confidence in terms of developing the pupils' abilities in investigative work (see Figure 6.5). When the individual student cohorts are examined the pattern of decreasing levels of confidence indices that emerges, with respect to the investigative skill strands, is similar to that evident for the knowledge strands in the three attainment outcomes. Thus the BEd 4 cohort records the highest confidence indices for the three investigative skill strands:

- preparing for tasks;
- carrying out tasks;
- reviewing and reporting on tasks.

The BEd 3, BEd 1 and BEd 2 cohorts, in that order, have decreasing levels of confidence. The PGCE cohort record the lowest confidence indices for all three of the investigative skill strands (see Appendix 6.5).

Figure 6.5: Developing the pupils' abilities in investigative skills



When examined, using the Kendall tau-b ($K\tau_b$) correlation coefficient statistic, there were strong (*i.e.* all at $p \leq 0.01$) positive associations between each of the knowledge strands *within* each of the three attainment outcomes (see Table 6.1). Furthermore there were strong positive associations (see Appendix 6.6) between all of the knowledge strands *across* the attainment outcomes. The pattern that emerges, *for each of the attainment outcomes*, is as follows:

- the strongest correlations are found between the knowledge strands within each of the attainment outcomes;
- the intermediate correlations are between the knowledge strands across those attainment outcomes which form the most common combinations of school-based qualifications (*e.g.* Physics with Chemistry followed by Biology with Chemistry);
- the least strong correlations are between the knowledge strands of the Biology and Physics attainment outcomes.

This is a consistent relationship for the BEd 4 and PGCE cohorts. The BEd 2 cohort exhibited a similar pattern apart from the knowledge strands 'variety and characteristic features' (biology) and 'Earth in space' (chemistry). Additionally many of the correlations are recorded at the $p \leq 0.05$ level (see Appendix 6.6). The BEd 1 and BEd 3 cohorts have non-significant statistics between the *energy and forces* (physics) and *living things and the processes of life* (biology) attainment outcomes. This is consistent across all of the knowledge strands in these attainment outcomes. The BEd 3 cohort have further non-significant statistics between the three knowledge strands of the *energy and forces* (physics) attainment outcome and the 'Earth in space' (chemistry) knowledge strands.

Table 6.1: Associations *within* and *between* the knowledge strands

	Knowledge strands:	A	B	C	D	E	F	G	H	I
A	Variety and characteristic features		.85**	.81**	.31**	.26**	.28**	.41**	.45**	.45**
B	The processes of life			.85**	.29**	.27**	.28**	.40**	.45**	.43**
C	The interaction of living things				.30**	.24**	.27**	.42**	.46**	.43**
D	Properties and uses of energy					.85**	.86**	.51**	.55**	.55**
E	Conversion and transfer of energy						.85**	.48**	.53**	.55**
F	Forces and their effects							.49**	.51**	.50**
G	The Earth in Space								.84**	.79**
H	Materials from Earth									.85**
I	Changing materials									

When the knowledge strands were examined in relation to the three primary stages strong positive associations were apparent (see Table 6.2). Once more this relationship is consistent for the BEd 4 and PGCE cohorts (see Appendix 6.7). The BEd 1 cohort records only two non-significant associations with respect to the 'processes of life' (biology) knowledge strands, with the P4 to P5 stage being significant at the $p \leq 0.01$ level. The BEd 2 cohort records non-significant associations for the P1 to P3 stage and the *living things and the processes of life* (biology) and *energy and forces* (physics) attainment outcomes. The BEd 3 cohort records the greatest number of non-significant associations (*i.e.* 16 out of 27) when comparing age stage and knowledge strands.

Table 6.2: Associations between knowledge strands and primary age stages

Knowledge strands:	P1 to P3	P4 to P5	P6 to P7
Variety and characteristic features	.31**	.42**	.42**
The processes of life	.35**	.40**	.37**
The interaction of living things	.35**	.40**	.36**
Properties and uses of energy	.29**	.45**	.5**
Conversion and transfer of energy	.28**	.43**	.5**
Forces and their effects	.30**	.43**	.46**
The Earth in Space	.39**	.45**	.45**
Materials from Earth	.39**	.46**	.47**
Changing materials	.38**	.45**	.45**

When the knowledge strands were examined in relation to the knowledge and skills necessary to develop the pupils' abilities to engage in investigative work (see Table 6.3) there were strong positive associations (*i.e.* all at $p \leq 0.01$) discernible. This was a consistent relationship evident in the data for the BEd 1, BEd 4 and PGCE student cohorts (see Appendix 6.8). The BEd 2 cohort exhibited a similar pattern of association albeit with a few statistics recorded at the $p \leq 0.05$ level. Once more the BEd 3 cohort exhibited a 'pattern' of non-significant associations; with only two of the twenty-seven statistics calculated being significant.

Table 6.3: Associations between knowledge strands and investigative skill strands

Knowledge strands:	**Preparing for tasks**	**Carrying out tasks**	**Reviewing and reporting**
Variety and characteristic features	.42**	.44**	.40**
The processes of life	.43**	.45**	.40**
The interaction of living things	.40**	.45**	.41**
Properties and uses of energy	.40**	.37**	.37**
Conversion and transfer of energy	.39**	.37**	.35**
Forces and their effects	.40**	.35**	.37**
The Earth in Space	.49**	.48**	.50**
Materials from Earth	.48**	.48**	.49**
Changing materials	.48**	.49**	.47**

6.5 Concluding remarks

There is little evidence that the students within my study lack confidence with regards to teaching primary science. The responses obtained from the questionnaire survey are positively framed in all of the aspects of primary science examined:

- attainment outcomes and knowledge strands;
- primary teaching stages;
- investigative skills strands.

Thus a lack of academic qualifications does not appear to have an adverse effect upon the students' confidence to teach primary science (Symington and Hayes, 1989).

Research evidence suggests slightly contradictory findings in relation to primary teachers' views on teaching primary science. Generally science is an area in which primary teachers have, in the past, been less confident (Wragg *et al.*, 1989; Bennett *et al.*, 1992; Harlen, 1997). Studies linked to the National Curriculum, carried out as part of the Leverhulme Primary Project, found that confidence in teaching science was initially low (*i.e.* eighth out of ten curricular areas) in 1989 (Wragg *et al.*, 1989). This study reported on the views of 901 primary teachers. A follow-up study in 1991

(Bennett *et al.*, 1992), with a smaller sample frame of 433 teachers, indicated that confidence had grown (*i.e.* third out of nine curricular areas). This growing confidence was attributed to increased teacher experience of the curriculum, an increased allocation of resources and the removal of ambiguity through a greater degree of specification in statutory orders (Carré and Carter, 1993). Harlen (1997) reported the findings of a survey of 524 teachers which found a similar, albeit less marked, trend with respect to the 5-14 science curriculum. Between 1993 and 1996 the confidence rating for 5-14 primary science increased slightly from ninth to eighth place out of eleven curricular areas. In these studies it was noted that the growth in confidence was strongest with regards to the process skills rather than those areas related to knowledge and understanding. Appleton's (1995) study of 139 students embarking upon a pre-service primary teacher education course indicated that the student cohort did not feel that their teaching of science would be competent and as a consequence lacked confidence. However, the students' views outlined in my study did not exhibit a similar lack of confidence. Carré and Carter (1993) argued that neophyte teachers are likely to have a greater degree of confidence that practising teachers. This is due to their on-going exposure to newer ideas about teaching science, applications of subject-matter knowledge and the incorporation of process skills into their teaching strategies.

The students expressed more confidence in taking forward the biology component and are slightly less confident with regards to the physics component of primary science. This pattern of confidence ratings, in relation to the attainment outcomes, is similar to that found by Harlen (1997) where, although teachers' think themselves competent to teach science, they acknowledge that support is needed with respect to the physical sciences (Carré and Carter, 1990 and 1993). The fourth Assessment of Achievement Programme (AAP), carried out in 1996, incorporated a questionnaire to elicit the pupils' views on their learning experiences in science (Stark and Gray, 1999). The highest pupil confidence indices, for all three age groups surveyed (*i.e.* P4 -- 8 to 9 years, P7 -- 11 to 12 years and S2 -- 13 to 14 years), were recorded for the biological component of primary science. The physics component received the lowest confidence indices for the younger children whilst the older children (*i.e.* P7 and S2) returned the chemistry component with the lowest indices. It was also observed that confidence indices decrease with age in the biology and chemistry component whilst the physics component remained relatively stable (Stark and Gray, 1999). Piborn and Baker (1993) identified a similar decline in confidence for children between the ages of 9 to 13 with 13 to 14-year-olds generally feeling unsuccessful in science. Johnstone (1991) has speculated that the growing abstraction and complexity of scientific concepts present problems as the children cannot 'experience' them; children find the more concrete concepts easier to grasp. Although not part of my research focus it is nevertheless interesting to note that the pattern of teacher and pupil confidences coincide. Rather than the complexity of scientific concepts being the 'problem' there may be a 'teacher-effect' with the anxieties that teachers have about teaching science being reflected in the pupils' learning experiences in science. The nature of this linkage requires further research.

The pattern of the student teachers' confidences in teaching primary science mirrors the pattern observed in the data in relation to the students' qualifications and their experience of school science education. Another key pattern identified was that those BEd students nearing the completion of their courses are generally more confident than those at the start of their courses. Surprisingly the PGCE (Primary) students are the least confident despite being the best qualified. Carter *et al.* (1993), in a small-scale study of 53 PGCE (Primary) students, found that self-rated confidence increases during the course. As this questionnaire was delivered towards the end of the first term, and it was not possible to deliver a further questionnaire, it is interesting to speculate that a similar improvement in self-rated confidence would have been detectable for the group studied in this research.

A number of researchers have questioned the validity of improved confidence levels amongst primary teachers:

> *any perception of an improved competence to teach the concepts of science .... may be ill founded.*
>
> [Mant and Summers, 1993, p. 106]

However, it can be argued that subject content and confidence are only a few factors which inform teacher judgement. Teachers act according to what they think (Hewson and Hewson, 1989). Consequently it is important to explore student teachers' perceptions, as to the strategies best suited to developing conceptual understanding of science in children, as teachers require the skill:

> *to be able to translate a science concept into appropriate and useful instructional representations to enable children to assimilate abstract ideas.*
>
> [Carré and Carter, 1990, p. 339]

The next section of the research explores the students' views on how best to take forward teaching and learning in primary science. The rhetoric of teaching and learning is examined in terms of the objectivist and constructivist frameworks.

CHAPTER 7 PEDAGOGIC SKILLS

7.1 Pedagogical content learning

There is a body of '*deficit knowledge research*' (Brown *et al.*, 1998) which indicates that many students embark upon primary teaching pre-service courses with little background in science (Fensham *et al.*, 1991). Research adopting a '*deficit model*' has shown that many teachers lack content knowledge in science, on phenomena such as day and night, the seasons and the Earth's place in the Universe (Summers, 1994; Summers and Mant, 1995a), with their thinking being at the same level as the children they teach (Kruger and Summers, 1988). This research attempts to establish a link between subject knowledge, or lack of it, and classroom practice (Wragg *et al.*, 1989) or the subject content being taught and the quality of learning outcomes (Sander and Morris, 2000). Central to this is the assumption that an academic background in a subject is necessary to teach the subject effectively in the primary curriculum (Poulson, 2001). Some findings have been unequivocal (Osborne and Simon, 1996; Watt, 1996) asserting that teachers with sound subject knowledge teach better. Official HMI reports have also emphasised good subject knowledge as being a critical component of effective teaching (DES, 1985). More recently this has been supported by OfSTED reports (1998 and 1999) which identify deficiencies in teachers' knowledge of science as being a key contributor to inadequate teaching of primary science. These findings are understandable as one would intuitively expect the subject knowledge of the teacher to be an important factor in determining the effectiveness of teaching.

However, it has been argued that the knowledge needed to teach in the primary is not necessarily the same as that needed to be successful in obtaining an academic pass in science at upper secondary or university degree courses (Askew *et al.*, 1997). Research examining other areas of the primary curriculum has indicated, in relation to work with ninety teachers of numeracy, that there is no clear link between a lack of subject knowledge and the teacher's effectiveness to teach the subject (Askew *et al.*, 1997). Zuzkovsky *et al.* (1989) found that there was no significant difference, in terms of student outcomes, when the teaching inputs of specialist and non-specialist primary school teachers were compared. Appleton (1995) is also doubtful of a simple causal relationship between sound subject knowledge and effective teaching. Furthermore gaps which exist in the teacher's knowledge base are not irretrievable. Research on the knowledge and practices of 225 teachers, with respect to literacy teaching, suggested that a lack of subject knowledge is not necessarily an impediment to effective teaching (Poulson, 2001).

Although the research outlined above looks at different areas of the primary curriculum, and as such may not be strictly comparable, it nevertheless highlights the notion of contextualised knowledge which is similar to that of pedagogically situated knowledge (Brown *et al.*, 1998). The essential features of such knowledge is that teachers have sufficient knowledge to take forward classroom learning, they are competent in terms of *knowledge in use*. They are perfectly competent with respect to the knowledge they need to know within the classroom context. However, the same knowledge decontextualised (*i.e.* outwith the classroom) presents them with difficulties; they have problems with *knowledge as a system* (Poulson, 2001). Arguably it is unrealistic to expect primary teachers to possess the necessary 'cognitive cargo' (Golby *et al.*, 1995) to extend children throughout the 5-14 curriculum. Indeed there is a danger that exposing teachers' lack of subject-matter knowledge and misconceptions will have a debilitating effect by simply reinforcing teachers' awareness of gaps in their knowledge and thus entrench negative views such as teaching the physics component of primary science is hard (Smith, 1992).

Such research focusses upon subject knowledge; what Fenstermacher (1994) refers to as the knowledge base. Other researchers have explored the teachers' practical knowledge within classroom contexts. Schwab (1978) conceptualised this distinction in terms of:

- *substantive structure*: concepts, facts, theories and how these are organised within an inter-related scientific framework (*i.e.* that it is so);
- *syntactic structure*: the procedures, especially investigative strategies, which relate to the ways in which knowledge claims are validated (*i.e.* why it is so).

The ways by which teachers select and teach content to pupils through utilising a subject-specific pedagogy is what Shulman (1987) has referred to as pedagogical content knowledge (PCK). Within this conceptualisation content knowledge is seen as significant in the development of an effective pedagogy as:

> *the teacher can transform understanding, performance skills, desired attitudes or values into pedagogical representations and actions. These are ways of talking, showing, enacting, or otherwise representing ideas so that the unknowing can come to know, those without understanding can comprehend and discern, and the unskilled can become adept.*
>
> [Shulman, 1987, p. 7]

Pedagogical content knowledge is required by teachers in order to achieve conceptual change in children. This enables them to blend content and pedagogy into an understanding of how scientific topics, issues and problems can be organised, represented, adapted, interpreted and translated into teaching to meet the diverse needs of the children. Often this is achieved with the teacher providing additional examples, or analogies which enable children to comprehend the unknown by linking it to the known. This is only possible if the teacher has a grasp of both the substantive and syntactic structure of science. Where this is lacking, children are likely to encounter a 'closed pedagogy' (Osborne and Simon, 1996) in which scientific experiences are unrelated and there is a failure to extend children's knowledge and understanding due to an inability, on the part of the teacher, to make connections. Pedagogical content knowledge forms only part of a much larger framework required for good teaching which includes:

- content knowledge: substantive and syntactical structures;
- pedagogical content knowledge: representation and analogies;
- general pedagogical management, classroom management and organisation;
- curriculum knowledge: science in the curriculum;
- knowledge of learners: theoretical knowledge related to child development, motivational strategies, *etc.*;
- knowledge of educational contexts, dynamics of pupil interaction, groupings, *etc.*;
- knowledge of context of education and institutional learning.

However, Shulman's (1987) work was related to secondary school teaching where subject-specific teaching, delivered by teachers qualified in the subject, is the norm. There was no claim that this work was directly applicable to primary school teachers who are expected to teach the full range of subjects whilst not being qualified in most, if not all, of these subjects. Despite this deficit knowledge research has continued fuelling the 'discourse of derision' (Goodson, 1983; Alexander, 1995). This section of my research will examine the students' views of teaching and learning with specific reference to primary science.

7.2 Methodology

The research question being explored in this section attempts to determine what are the students' perceptions of effective teaching and learning strategies in implementing 5-14 primary science? Thirty-seven randomly distributed statements (see Appendix 7.1) were produced using the "*set of principles to underpin appropriate and effective science education*" (SCCC, 1996, p. 2) outlined in the SCCC consultative document on Science and from the TIMSS (SOEID, 1997) research findings. The statements fall into one of four categories which include:

- classroom methodology;
- resourcing lesson;
- investigative approaches;
- organisation.

The statements generated from these papers, within each of the domains, were framed as favourable and unfavourable attitudes. Each domain had several statements framed in opposite directions (see Appendix 7.2) to facilitate a degree of verification of the respondents' attitude during analysis. The attitudes of the students, in relation to these statements on teaching and learning strategies, are examined deploying a 5-point Likert continuum:

1	—	Strongly agree
2	—	Agree
3	—	Uncertain
4	—	Disagree
5	—	Strongly disagree.

7.3 Teaching and learning in science

Frequency tables were produced for each of the thirty-seven statements examining the students' views on the teaching and learning process in science (see Appendix 7.3). The mean values of the recoded categories were calculated and reassigned as follows:

- response categories 1 and 2 as '*Agree*';
- response category 3 as '*Neutral*';
- response categories 4 and 5 as '*Disagree*'.

7.3.1 *Classroom methodology*

Eleven of the statements examined the students' views on methodological approaches to teaching science (see Table 7.1). These statements can be further sub-divided according to:

- the locus of control;
- pupils' experience;
- significance of talk;
- significance of factual knowledge;
- procedural considerations.

The methodological approach advocated by the students places the pupil at the centre of the learning experience. However, the majority of students (83%) indicated that it is the teacher's role 'to identify the focus of science lessons'. However, the direction that the lesson takes is subject to a greater degree of flexibility in that almost all of the students (94%) assert that the pupils should be encouraged to 'identify the questions to ask during science activities'. A smaller group of students (49%) indicated that 'pupils should choose the way to examine scientific problems'. Clearly this places the locus of control more with the pupils than the teacher.

Furthermore the pupils' experience of science is seen as important in science lessons with the students (78%) advocating that pupils should be encouraged to talk about and explore their ideas on scientific issues prior to the commencement of activity in science. The linkage between the science in lessons and the pupils' experience is also deemed to be important with students (79%) supporting the position that 'science lessons should be relevant to the everyday experience of the pupils'. This is consistent with a constructivist pedagogy with the children's ideas providing an important input to the teacher's programme of science lessons.

Table 7.1: Teaching and learning in science -- Classroom methodology

Statements:	Agree	Neutral	Disagree
Science lessons are largely about the development of factual knowledge	52	25	23
Pupils should be taught to concentrate during science lessons and not to talk	14	15	71
Science should start with pupils talking about and exploring their ideas on scientific issues	78	18	4
The most important aspect of science is that pupils follow the procedures given	36	34	30
Science lessons are more about the development of skills rather than facts	31	49	20
Science is made easier by the fact that there is little need for discussion and debate	8	25	67
Science lessons should be relevant to the everyday experience of the pupils	79	15	6
The teacher must identify the focus of science lessons	83	14	3
Pupils should choose the way to examine scientific problems	49	39	12
Scientific knowledge is not in any way different from other forms of knowledge	49	34	17
Pupils should be encouraged to identify the questions to ask during science activities	94	5	1

Note: Data (n = 479) expressed as a percentage. See Appendix 7.4 for more detailed data.

Statements which examined the significance of talk in science lessons indicate that students generally wish to engage pupils in dialogue. Students (71%) disagree with the notion that 'pupils should be taught to concentrate during science lessons and not to talk'. In addition some two-thirds (67%) of the cohort do not accept that 'science is made easier by the fact that there is little need for discussion and debate'. Thus the students accept that pupils will engage in talk, hopefully related to the activity being undertaken, and that this is an important aspect of the learning experience they provide.

A less clear attitudinal perspective is evident in relation to the students' responses to the nature of scientific knowledge in science lessons. Students (52%) generally support the position that 'science lessons are largely about the development of factual knowledge'. However, the 'development of skills rather than facts' results in the greatest percentage of students (49%) adopting a neutral position. The nature of scientific knowledge presents problems for the students with forty-nine percent indicated that 'scientific knowledge is not in any way different from other forms of knowledge'. Although unsure of the nature of scientific knowledge they, nevertheless, appear to advocate a child-centred approach to science lessons. There is a possibility of some ambiguity here in that some students may not have been familiar with '*forms of knowledge*' as a conceptual construct. However, it is unlikely that this would have had a significant impact of the findings.

7.3.2 *Resourcing lessons*

Nine of the statements examined the students' views as to how science lessons should be resourced (see Table 7.2). The statements were further sub-divided according to:

- the focus of activity;
- the production of notes;
- the provision of resources;
- the nature of experiments.

The students (74%) indicate that the primary source of materials for teaching science should not be 'based around textbooks and worksheets'. Furthermore 'pupils should be allowed to use resources to discover scientific principles for themselves' is advocated by eighty percent of the student cohort. This relates back to the confusion that students have with regards to the nature of scientific knowledge. During this process of '*discovery*', some eighty percent of the students, indicate that pupils should 'develop their own notes through observation and practical activity'. The converse of this, namely that 'teachers should supply notes for pupils to copy', is rejected by forty-seven percent of the students.

The materials used in science activities can be provided from 'everyday materials' (94% of students) with pupils being given 'responsibility for identifying resources to carry out experiments' (67% of students). However, the students (64%) see it as part of their role to 'devise experiments using available resources'. Practical activities do not present problems for the students with respect to safety. The majority of students (77%) disagree that 'it is too dangerous to give pupils access to scientific equipment' and that 'handling equipment safely' (97% of students) is an important aspect of science activities. Clearly safety is a key issue for the students. However, pupil involvement in developing and using resources is seen as an important aspect of science lessons. Furthermore they are keen to make use of published materials (*e.g.* textbooks, worksheets, *etc.*) to assist in structuring the activities they provide. Such an approach would tend to be 'safe' in that learning, with adequate planning, would be known thus restricting the opportunities for pupils to engage in problematic learning (*i.e.* unplanned learning, activities or questions asked by the pupils for which the students cannot provide explanations).

Table 7.2: Teaching and learning in science -- Resourcing lessons

Statements:	Agree	Neutral	Disagree
Teachers should supply notes for pupils to copy	25	28	47
Pupils should develop their own notes through observation and practical activity	80	17	3
Science can take place using everyday materials	94	5	1
Science lessons require the teacher to devises experiments using available resources	64	23	13
Handling equipment safely is an important aspect of science lessons	97	1	2
It is too dangerous to give pupils access to scientific equipment	5	18	77
Science lessons should be based around textbooks and worksheets	7	19	74
Pupils should be given responsibility for identifying resources to carry out experiments	67	20	13
Pupils should be allowed to use resources to discover scientific principles for themselves	80	15	5

Note: Data (n = 479) expressed as a percentage. See Appendix 7.5 for more detailed data.

7.3.3 *Investigative approaches*

Nine of the statements examined the students' views on investigative approaches within science lessons (see Table 7.3). These statements were further sub-divided according to:

- locus of control;
- pupil involvement;
- purpose of investigations.

Table 7.3: Teaching and learning in science -- Investigative Approaches

Statements:	Agree	Neutral	Disagree
Pupils should observe experiments which are demonstrated by the teacher	53	20	27
Pupils should gain direct experience of science through practical activity	96	3	1
Lessons should engage pupils in investigative approaches	97	2	1
Lessons should involve pupils in exploring, observing and ordering	95	4	1
Pupils should be given opportunities to devise methods of testing ideas	88	11	1
Investigative work is inappropriate in science	8	3	89
It is not necessary to engage in practical activity in science lessons	14	9	77
The teacher should plan investigative activities for the pupils	71	18	11
The basic purpose of investigative work is to illustrate scientific theories	39	41	20

Note: Data (n = 479) expressed as a percentage. See Appendix 7.6 for more detailed data.

The locus of control rests with the teacher as is evident from students (53%) agreement with the statement that 'pupils should observe experiments demonstrated by the teacher'. Additionally, the teacher is seen as having sole responsibility for planning the 'investigative activities for the pupils' (71% of students). The students have positive attitudes towards practical activities in general as well as investigative work in particular. The majority of students (77%) disagree that it is 'not necessary to engage in practical activity in science lessons'. Furthermore the majority (89% of students) also disagree with the view that 'investigative work is inappropriate in science'. This is consistent with the students' views on the engagement of pupils in practical activities, namely that 'pupils should gain direct experience of science through practical activity' (96% of students). In addition the vast majority of students (97%) agree that 'lessons should engage pupils in investigative approaches'. These investigative approaches involve practical activity which seeks to engage pupils in science-related process activities such as 'exploring, observing and ordering' (95% of students) as well as devising 'methods of testing ideas' (88% of students). Finally the link between investigative work and scientific theories is less clear with the majority (41% of students) adopting a neutral position. Some thirty-nine percent of students do see this as being an important relationship. Chapter 5 examined the extent of the students' understanding with respect to the nature of science. The findings of this chapter further supports the contention that the students have difficulty in understanding what constitutes scientific theory.

7.3.4 *Organisation*

Eight statements examined the students' views on how science lessons should be organised (see Table 7.4). These statements can be further sub-divided according to:

- curricular integration;
- class grouping;
- pupil interaction;
- evaluation of outcomes.

The students have no firmly held views as to whether science should be integrated with other areas of the curriculum (*i.e.* topic work) or taught as stand-alone lessons. There are slightly more students (37%) who agree with the statement that 'science needs to be related to other areas of the curriculum' when compared with those students (24%) who disagree. The students are equally unsure as to whether 'science should be taught as separate lessons' with those that disagree (34% of students) being slightly greater than those that agree (26% of students). Two observations are important here. Firstly that students generally have little control as to how science is taught, as this has been decided at Local Authority and School level. Secondly their apparent confusion as to the nature of science manifests itself in terms of how best to teach science.

Slightly more students (38%) disagree than agree (22% of students) with the proposition that 'whole class lessons should be the norm in science'. The preference amongst the students (51%) is for 'group activity with only some whole class work'. This preference for group work is reflected in the students' views on the importance of pupil interaction. The majority of students (67%) disagree with the view that science should be a solitary activity with the 'pupils working by themselves'. The converse of this, namely that, science is an 'ideal opportunity for pupils to work collaboratively in groups' is the preferred option of almost the entire student cohort (97%). Clearly science lessons provide a vehicle for group interaction. However, the research methodology did not facilitate an examination as to how the students organise learning in other areas of the curriculum. It would have been interesting to determine what were the similarities and differences.

The outcomes of science lessons also provides an opportunity to examine the role of the teacher and the child vis-à-vis the learning process. The role of the teacher is unclear with the majority of the students (38%) agreeing with the proposition that 'teachers should direct pupils towards the correct scientific answers to problems'.

This would suggest that the pupils are merely 'discovering' the known. This is not to say that the answers arrived at may be wrong, but rather they are not as expected. Perhaps more revealing in this process is that most students (76%) indicated that the 'pupils should engage in evaluation of science lessons for themselves'. Thus it is for the pupil to say whether they have achieved the learning outcomes specified for a given science lesson.

Table 7.4: Teaching and learning in science -- Organisation

Statements:	Agree	Neutral	Disagree
Science lessons are an ideal opportunity for pupils to work collaboratively in groups	97	3	1
Science lessons should mostly involve pupils in working by themselves	8	25	67
Whole class lessons should be the norm in science	22	40	38
To be effective, science needs to be related to other areas of the curriculum	37	39	24
Science lessons should consist mostly of group activity with only some whole class work	51	36	13
Science should be taught as separate lessons	26	40	34
Pupils should engage in evaluation of the outcomes of science lessons for themselves	76	18	6
The teachers should direct pupils towards the correct scientific answer to problems	38	35	27

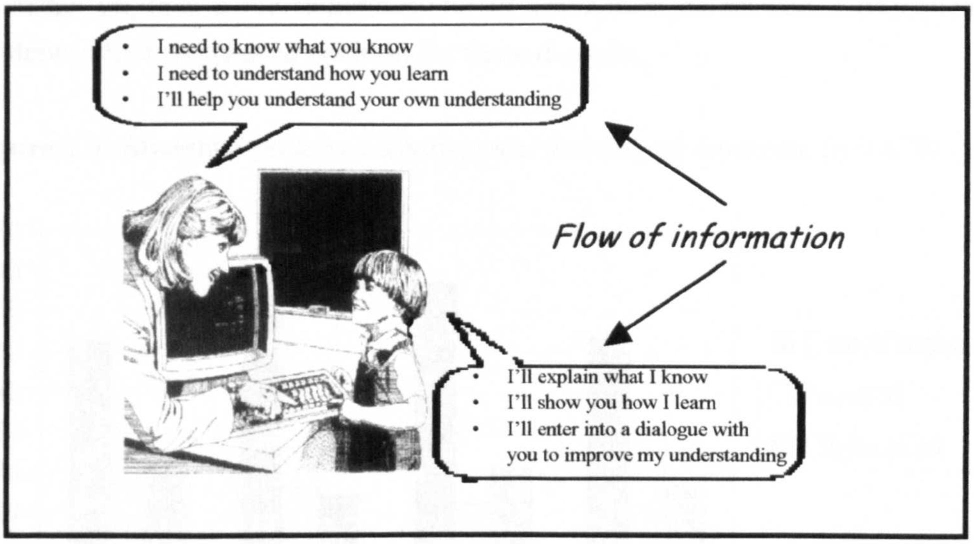
Note: Data (n = 479) expressed as a percentage. See Appendix 7.7 for more detailed data.

For each of the four domains the attitude statements were recoded using SPSS. This procedure enables statements which were framed in opposite directions to be framed in the same direction by transposing the candidates' responses (*i.e.* 1 to 5, 2 to 4, no change to 3, 4 to 2 and 5 to 1). The mean values of the recoded categories were calculated and reassigned as follows:

- response categories 1 and 2 as '*constructivist*';
- response category 3 as '*neutral*';
- response categories 4 and 5 as '*objectivist*'.

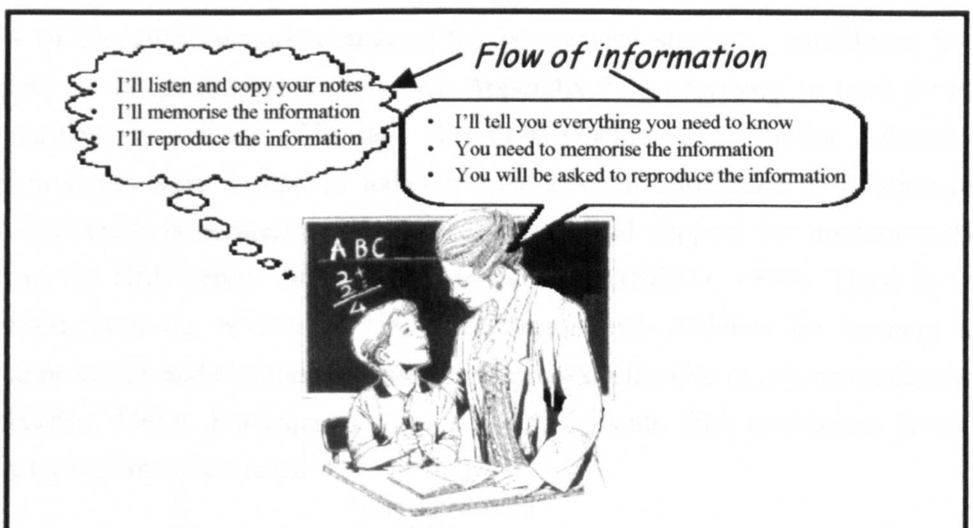
The 'constructivist', or more loosely the pupil-centred approach, is one where the locus of control is with the learner. The teacher acts as a facilitator rather than an instructor, with the teacher-as-learner, and the pupils being active participants in the learning experience. Within such a framework dialogue is a two-way process with the teacher as concerned with the pupils' understanding, as they are with the students' learning about primary science (see Figure 7.1). The 'objectivist' framework is one where the locus of control is outside the learner. Teaching is an induction process into the 'correct' understanding with the teacher-as-expert directing the pupils' learning experience. Pupils are expected to act as passive receivers of information within such a framework (see Figure 7.2).

Figure 7.1: A constructivist classroom



[Adapted from Kinchin, 2004]

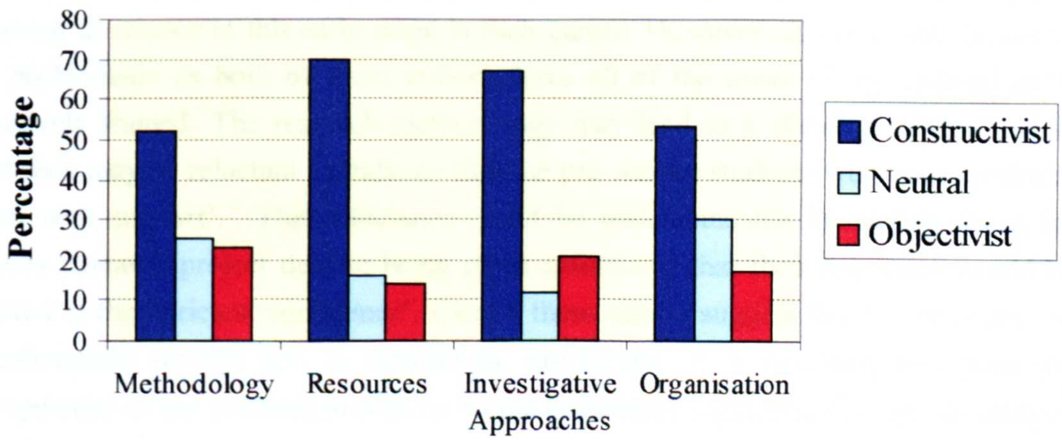
Figure 7.2: An objectivist classroom



[Adapted from Kinchin, 2004]

When the students responses are examined it is evident that they articulate their role within the teaching-learning process as constructivist (see Figure 7.3). All four domains are framed as constructivist with more that fifty percent of all the students, in each domain, indicating that this is their preferred teaching-learning environment. The *resourcing of lessons* and *investigative approaches* to learning are two areas where the students clearly see pupils as being involved in the learning experience. There are, as has been discussed earlier, some exceptions to this particularly with respect to planning investigative activities and devising experiments using available resources. There are fewer students stating a preference for a constructivist framework with respect to *classroom methodology* and *organisation* as some of the statements within these domains requires some understanding of the nature of science. Consequently more students adopt the neutral position for these domains.

Figure 7.3: Students' preferred teaching and learning environment (n = 479)



7.4 Professional Skills

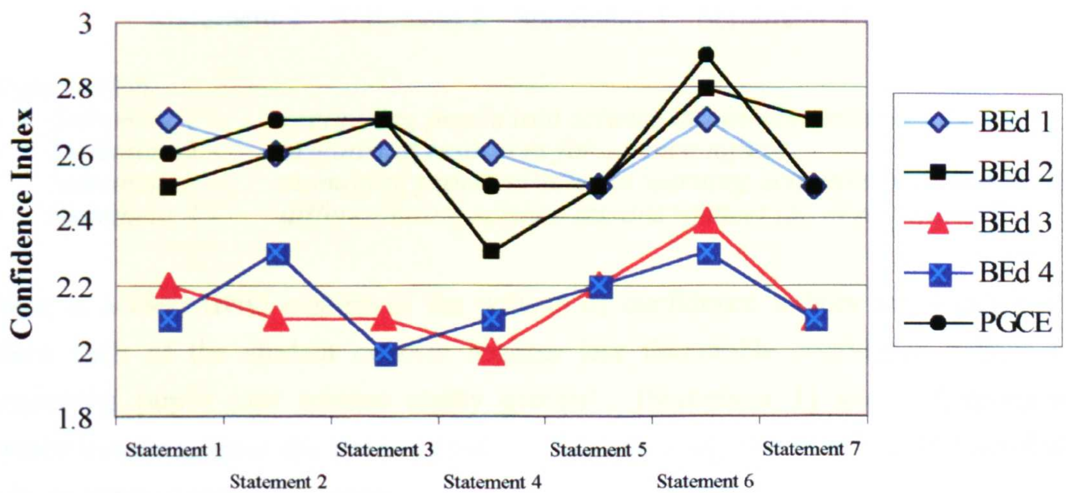
Section 4 of the questionnaire examined the pre-service students' confidence levels with respect to the professional skills (see Appendix 7.8) necessary to take forward pupils' learning in science. Through the deployment of a 5-point Likert-type technique students were invited to indicate their level of confidence in relation to a series of statements generated on professional skills and support for implementation drawn from the HMI report *Improving Science 5-14* (SEED, 1999). These in turn were derived from the review of UK and international evidence on learning and teaching approaches and techniques which have proved effective in raising standards in science (Harlen, 1999). Participants were asked to indicate their confidence levels in terms of a five-point Likert scale:

1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

The data is summarised in Figures 7.4 to 7.7 (see Appendix 7.9 to Appendix 7.13 for frequency and confidence indices tables). These were further processed through the calculation of a 'confidence index' (Harlen *et al.*, 1995). A number of patterns emerge from an analysis of the data. Firstly it is evident that the confidence indices (CI) are in the range 1 to 3. This would suggest that the various student cohorts are confident that they have, or will develop with support, the necessary professional skills to teach science. The lowest confidence index to be registered is for an *organisational* skill by the PGCE cohort namely that of 'differentiating science lessons to meet the needs of the pupils' (CI = 3).

The pattern of responses obtained is somewhat bewildering in that the students were not asked to project forward to the end of their courses, but rather to record their level of confidence with respect to the professional skills necessary to teach science. Implicit in this is that it would not be reasonable to expect the BEd 1 and BEd 2 cohorts to possess all the necessary professional skills to take forward teaching and learning in science at this early stage in their career. However, this does not appear to be problematic as both of these cohorts have all of the areas of professional skills positively framed. The research methodology may lead to a skewing of response in that they may be reluctant to indicate that the pre-service students were 'not confident even with support'. This reluctance could be understandable in relation to an in-faculty research project despite being given assurances that their responses would be treated in the 'strictest confidence'. Clearly these results suggest that the responses to questionnaire surveys are, in themselves, insufficient. It is necessary to assess the competence of the students in relation to the confidence expressed through an analysis of what they do.

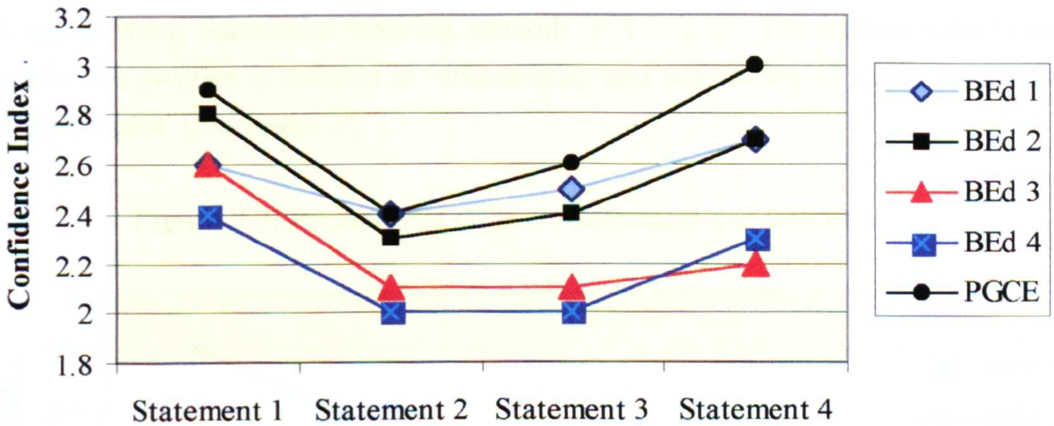
Figure 7.4: Professional skills -- Planning



Planning
- *Statement 1 -* *focusing the teaching of science on knowledge and understanding,*
- *Statement 2 -* *focusing the teaching of science on skills,*
- *Statement 3 -* *using the assessment process to plan group learning in science,*
- *Statement 4 -* *using whole class teaching to introduce and consolidate work,*
- *Statement 5 -* *developing homework linked to science topics,*
- *Statement 6 -* *anticipating likely areas of confusion in relation to scientific concepts,*
- *Statement 7 -* *developing 'thinking skills'.*

The skills of *planning* (see Figure 7.4) and *organisation* (see Figure 7.5) are generally positively framed. For the professional skill of *planning* the category of 'anticipating likely areas of confusion in relation to scientific concepts' [Statement 6] is identified by all the year cohorts, particularly the PGCE cohort (CI = 2.9), as a problem area. The BEd 2 cohort have the greatest variation, in terms of their confidence indices, between the statements. The BEd 2 cohort seem to be confident (CI = 2.3) that they can 'use whole class teaching to introduce and consolidate work in science' [Statement 4]. This confidence may reflect the focus of their school placement which will involve them in teaching, under the supervision of the classroom teacher, by themselves and not, as in BEd 1 sharing teaching tasks with another BEd 1 student -- paired teaching.

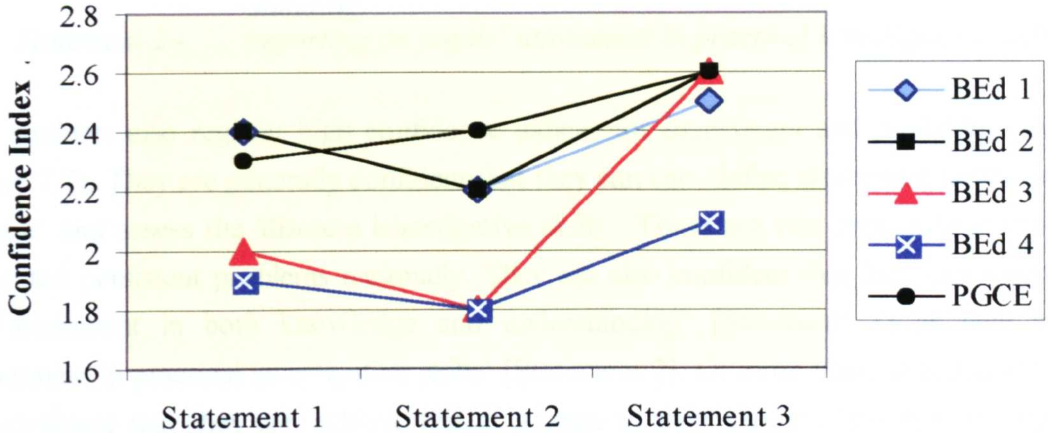
Figure 7.5: Professional skills -- Organisation



Organisation:
- *Statement 1 -* *organising pupils into science attainment groups,*
- *Statement 2 -* *organising resources for science topics,*
- *Statement 3 -* *managing practical science learning activities in different ways,*
- *Statement 4 -* *differentiating science lessons to meet the needs of pupils.*

There is a clear trend evident in the pattern of confidence indices for *organisation* where each of the student cohorts register less favourable confidence indices for 'organising pupils into science ability groups' [Statement 1] and 'differentiating science lessons to meet the needs of pupils' [Statement 4]. The PGCE cohort see these skills as areas of potential concern.

Figure 7.6: Professional skills -- Interaction with pupils

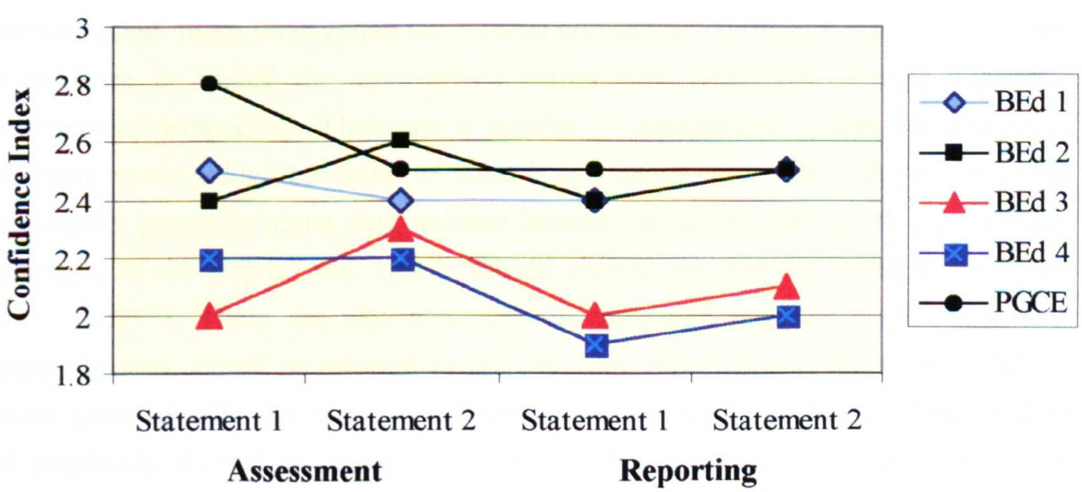


Interaction with pupils:

- *Statement 1 -* *using interactive teaching methods with ability groups in science,*
- *Statement 2 -* *assisting pupils in carrying out science investigations,*
- *Statement 3 -* *encouraging and responding to pupils' questions in science.*

A general trend emerges with skills relating to *interaction with pupils* (see Figure 7.6) with the students being particularly confident that they have the skills to assist 'pupils in carrying out science investigations' [Statement 2]. The BEd 3 and BEd 4 cohorts register the highest confidence index obtained (CI = 1.8) for this particular skill. and in using 'interactive teaching methods' (CI = 2.2). The student cohorts are generally less positive in relation to 'encouraging and responding to pupils' questions in science topics' [Statement 3].

Figure 7.7: Professional skills -- Assessment and Reporting



Assessment:

- *Statement 1 -* *defining attainment targets in science,*
- *Statement 2 -* *assessing the discrete investigative skills.*

Reporting:
- *Statement 1 -* *reporting on pupils' attainment in knowledge and understanding,*
- *Statement 2 -* *reporting on pupils' attainment in practical investigative skills.*

The students also register high confidence indices for *assessment* and *reporting* (see Figure 7.7). They are generally confident that they can can 'define attainment targets in science' and assess the 'discrete investigative skills'. These are two areas which have presented persistent problems nationally. They are also confident that they can report on 'attainment in both knowledge and understanding' [Statement 1] as well as 'attainment in practical investigative skills' [Statement 2]. Of more interest is that they are confident that they can achieve this at a stage in their career when they are still coming to terms with the content of the curriculum and, more importantly, strategies which used in appropriate contexts can lead to effective teaching and learning. What appears to being measured here is the rhetoric of aspiration which may, or may not, be translated into the classroom. I suspect that this rhetoric is estranged from reality.

When the individual student cohorts are examined there is, once more, a consistent pattern to the data. The BEd 4 cohort generally register the highest confidence indices followed by the BEd 3 cohort. There are a few exceptions to this particularly with respect to planning skills. These cohorts are followed by the BEd 2 and BEd 1 cohorts for whom there is little to separate them. Once more there are a few exceptions to this general pattern. Finally the PGCE cohort generally record, with a few exceptions, the lowest confidence indices. This pattern mirrors that discernible with respect to teaching the attainment outcomes.

The students' responses, with respect to teaching and learning (see Appendix 7.14) were examined, using the Kendall tau-b ($K\tau_b$) correlation coefficient statistic. Although the evidence is limited the associations within each pedagogic domain support a constructivist perspective. There are a number of associations within the domain of *classroom methodology* but none of these is consistent across the cohorts. However, the students generally agree that 'science lessons should be relevant to the everyday experience of the pupils' and 'pupils should choose the way to scientific problems' ($K\tau_b$ = 0.27**). There are also a number of intriguing negative associations (*e.g.* 'science lessons should be relevant to the everyday experience of the pupils' and 'the teacher must identify the focus of science lessons' -- $K\tau_b$ = -0.22**) where positive and negatively framed statements are associated suggesting a constructivist focus; however, this observation is based on only a limited number of associations.

Within the *resourcing lessons* domain there are two positive associations across all of the cohorts. These are 'pupils should develop their own notes through observation and practical activity' with 'science can take place using everyday materials' ($K\tau_b$ = 0.24**). The students' disagreement to the statements that 'it is too dangerous to give pupils access to scientific equipment' with 'science lessons should be based around textbooks and worksheets' ($K\tau_b$ = 0.27**) outlines a constructivist perspective. This is also supportive of the earlier association which suggest that science should be based around practical activity. The *investigative approaches* contains a number of associations across all of the cohorts including:

- 'pupils should gain direct experience of science through practical activity' with 'pupils should be given opportunities to devise methods of testing ideas' ($K\tau_b$ = 0.27**) and more confusingly ' investigative work is inappropriate in science' ($K\tau_b$ = 0.27**). However, this latter statement was negatively framed giving rise to a positive association, (*i.e.* constructivist) when it is recoded;
- 'lessons should engage pupils in investigative approaches' with 'lessons should involve pupils in exploring, observing and ordering' ($K\tau_b$ = 0.58**) and 'pupils should be given opportunities to devise methods of testing ideas' ($K\tau_b$= 0.39**).

The only association to span most of the student cohorts within the domain of *organisation* is that of 'science lessons are an ideal opportunity for pupils to work collaboratively in groups' with 'science lessons should consist mostly of group activity with only some whole-class work' ($K\tau_b$ = 0.2**). The few associations discussed here suggest that the students see teaching and learning within the constructivist paradigm. There is additional evidence to support this assertion; however, it is dispersed rather than being consistent across the student cohorts.

When the students' responses, with respect to professional skills (see Appendix 7.15), were examined using the Kendall tau-b ($K\tau_b$) correlation coefficient statistic it was evident that there are strong positive associations between the individual skills examined. Indeed the data for the entire sample reveals a 100% coverage of positive associations (*i.e.* all at $p \leq 0.01$). This pattern is also discernible with respect to the PGCE's data. The BEd 1 (3%), BEd 2 (7%) and BEd 4 (5%) have a number of non-significant associations (*i.e.* percentage in brackets). The BEd 3 (58%) cohort has the largest number of non-significant associations. Only one association is consistently non-significant across several student cohorts namely that between 'organising pupils into science ability (attainment) groups' and 'organising resources for science topics'; non-significant for the BEd 2, BEd 3 and BEd 4 cohorts.

7.5 Concluding remarks

Although the statements on teaching and learning have been framed in terms of the objectivist and constructivist perspectives I do not suggest that there are particular classroom techniques which are exclusive to constructivism (Millar, 1989; Watts, 1998). However, I do suggest that it is possible for teachers to adopt a 'constructivist approach' to their teaching and that this entails a particular methodological approach (Bliss, 1995) although this does not preclude transmissive strategies, if they are appropriate. Matthews (1997) describes this as pragmatic or pedagogical constructivism in which science education, given that the knowledge base is agreed and verified, should be taken forward by whatever methodological approach that is deemed to be effective. Such a pragmatic approach focusses upon good teaching rather than adopting a purist position with respect to constructivist epistemology.

My research suggests that there is a dissonance between the students' experience of science and their intentions, as teachers, as to how they propose to teach science. Their experience was predominately within the objectivist perspective namely a content-centred, textbook-based and transmissive pedagogy (Louden and Wallace, 1994). However, the students' perception of as to what constitutes effective teaching and learning is framed in terms of a constructivist perspective with the pupil placed at the centre of the learning experience. They see science in terms of the 5 E's (Bybee, 1997):

- *Engage*

  The students indicate that there is a connection between past and present learning. The pupils have an important role to play in identifying the questions to ask. As the locus of control resides more with the pupils than the teacher the pupils are more likely to become involved in the learning experience.

- *Explore*

  The students indicate that the pupils should gain experience of science by being directly involved in activity. This activity should involve the pupils in practical and investigative work making use of science-related process skills (*e.g.* observing, ordering, *etc.*). The teacher facilitates this experience by providing materials and guiding the focus of the activity.

- *Explain*

  The students indicate that language is important in sharing understandings and communicating meaning. Learners support each other through group activity as a vehicle to articulate their observations and ideas. The teacher provides the language of science, following direct experience, which helps to frame the pupils' experiential base.

- *Elaborate*

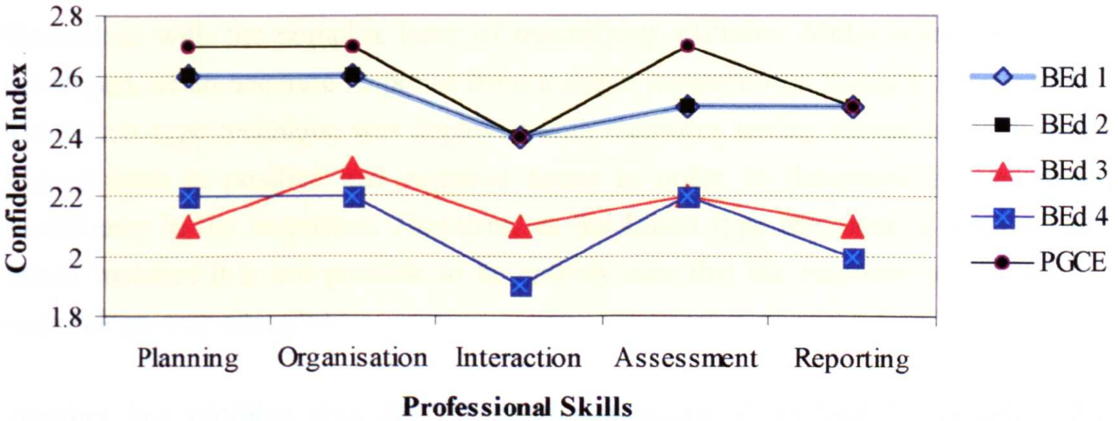
  The students indicate that what pupils learn in the classroom should be relevant and applicable to the 'real world'. The pupils' learning should provide a starting point for further inquiry and new understandings.

➢ *Evaluate*

The students indicate that the pupils should be involved in the evaluation of learning outcomes and in the testing of their ideas. Thus they recognise that assessment is an important aspect of the learning process as a means of determining that pupils understand the concepts being explored.

[Adapted from Bybee, 1997]

Figure 7.8: Professional skills



The students are confident that they possess the necessary professional skills to take forward pupils' learning in primary science. There is little variation in the pattern of aggregate confidence indices across the professional skills (see Figure 7.8). The only consistent pattern to emerge is that the students are more confident, when compared against the other professional skills, that they can interact with the pupils. There is a consistent pattern of high confidence indices for all of the student cohorts. The PGCE cohort registers one confidence index of 3 for 'differentiating science lessons to meet the needs of the pupils'. These findings are surprising in that the students' pedagogical knowledge is, at this early stage in their professional lives, incomplete. Research suggests that teachers are unable to transform their teaching simply by being told, but rather through personal and practical experience and that this is a slow and ongoing process (Louden and Wallace, 1994). Thus this pattern of high confidence indices across the student cohorts raises concerns that the methodology may be failing to elicit 'authentic' responses in that the rhetoric of intention may not be reflected in the actuality of practice.

The questionnaire raised a number of issues with regards to response validity and informant reliability. In the quantitative phase of the research face validity was to a large extent dependent upon '*professional judgement*' in so far as the questions measure what they say they measure. Although formed by the researcher, research evidence would confirm this; as would '*expert witness*' in that corroboration was undertaken by professionals, who have expertise in the field, so preserving objectivity and avoiding personal subjectivity. Several experts were used to independently evaluate the question banks giving a high degree of objective consensus as to appropriate measures. However, this will remain subject to challenge.

The reliability of the data gathered from these measures had a degree of internal consistency within each domain in that there are sets of questions to facilitate cross-verification. This was deemed necessary as most of the measures concerned themselves with the complex issue of quantifying attitudes. Multiple measures were developed, as an accurate response from a single measure was thought to be unlikely. The Likert-type technique was deployed with measures testing similar attitudes being framed both in positive and negative terms in order to determine the degree of consistency in the responses. However, as the Likert-type technique is a direct self-report measure it is not possible to be entirely sure that the response set reflects the respondents true attitudes.

Another key problem with the Likert-type technique is its lack of reproducibility (Oppenheim, 1992) in that it is possible to obtain the same score from a variety of response patterns. Furthermore the central or '*neutral*' value can be misinterpreted both by the respondent and the researcher. Is it the result of a combination of positive views coexisting with negative views on the same issue? (*e.g.* the students' views on pupil active involvement in experiments may be dependent upon the context of when it is safe). Alternatively this selection may reflect a genuine response in that the respondent has a lack of knowledge and/or expertise in the area being examined, or does not have any strong views to report.

Foster (1996) argues that there is preliminary drive for consent which is typified by '*impression management techniques*'. The researcher is keen to encourage participation as they no doubt see 'potential benefits' arising from the research. However, the possibility of beneficial outcomes cannot be used to persuade participation. Clearly there is a tension in this social interaction between the researchers desire to access information whilst, at the same time, protecting the right of the participants to freely permit access. This tension must be acknowledged in the consent protocol. The '*sponsorship*' of the Faculty of Education, raised a concern that agreements to participate could not be taken as implying the informed consent of all the students. The power relationship between the various levels of gatekeepers and participants may lead some of those involved feeling constrained to participate once corporate consent has been given. A particularly sensitive aspect of the research methodology was that the names of students were sought in the survey questionnaire, in order to facilitate follow-up observation of selected students. In such a situation it is important to be aware that consent is a process which requires frequent renegotiation over time making it *provisional* rather than a *once-and-for-all* prior event. Thus research which involves social interaction consists of a series of phased events with the pursuit of consensus agreement marking the interface between these events. It is essential that the researcher is aware that there may be a history, outwith the control of the researcher, which only becomes evident during the course of the research. Accordingly assurances offered that any findings will be anonymised such that students will not be identified are critically important. However, there remained a question as to the '*authenticity*' of the responses. To minimise this effect the students were informed as to the purpose of each phase of the research and their role in the research process:

> *honesty and openness should characterise the relationship between researchers, participants and institutional representatives.*
>
> [BERA, 1992, para 9]

The next section of the research will outline the observational schedule developed to facilitate an exploration of the classroom practice of students teaching primary science.

CHAPTER 8 CLASSROOM OBSERVATION

8.1 Systematic Observation

Questionnaires provide an insight into the student teachers' aims as well as providing a global description of their teaching in terms of the strategies they are likely to deploy. However, questionnaires and interviews cannot be relied upon to show what teachers actually do in the classroom. These are merely teachers' descriptions of '*what they say they do*'. Frequently there are discrepancies between what people say they do and what they actually do and think. It is necessary to obtain data which meets the criteria of objective reality (Walker and Adelman, 1986) rather than relying on the student teachers' expressed subjective reality. The methodology of systematic observation allows the researcher to record what they see happening rather than relying solely on what student teachers say is happening. Systematic observation allows us to go beyond '*anecdotal evidence*'; enabling the researcher to examine the practice of teaching:

> *we question the quality or usefulness of much evidence on teaching methods when it is obtained mainly through the use of questionnaires.*
>
> [Galton *et al.*, 1980, p. 8]

Systematic observation involves a

> *scheme that specifies both the events that the observer is to record and the procedure to be used in recording.*
>
> [Anderson & Burns, 1989, p. 136]

The observational schedule which I developed was used to explore the nature of the pedagogical framework evident during primary science lessons. Another key objective was to determine the characteristics and extent of dialogue evident in the observed lessons. This required the behaviours to be defined in an unambiguous way so that the system can be used by other researchers. The observers become observation instruments (Anderson and Burns, 1989) as determined by the conceptual framework of the research. The piloting of the schedule seeks to reduce the need, by the observers, to interpret; their role is to record predetermined behaviours. Rosenshine and Furst (1973) refer to such identifiable behaviours as '*low-inference*' measures. This is both a strength and a weakness of the methodology. Pre-specified coding systems are concerned with what can be categorised or measured (Simon and Boyer, 1974) providing detailed and precise evidence. Such a methodology facilitates the clear operationalisation of concepts which are subjected to precise measurement. However, without a sound conceptual framework a structured observation system may result in little more than frequency counts of the minutiae of teacher and pupil behaviours.

8.2 Observational research

The coding system developed is the lens through which the research seeks to observe teacher-pupil interaction in the classroom (Bakeman and Gottman, 1986). In this research an observation schedule was developed to generate quantitative data on teacher-pupil interaction during science lessons. In constructing the schedule I made use of an extensive body of literature on this technique. A number of general studies have been carried out in the UK in an attempt to describe and understand the events that take place in the classroom. Early work was influenced by Flanders' Interaction Analysis Categories (Flanders, 1970) system with its ten categories and quasi-continuous three second time-sampling frame. The FIAC system did not form part of a project but rather was an observational system which could be used in a variety of research projects. A key finding of early studies using the FIAC system was the two-thirds rule (Croll, 1986) in which two-thirds of the time in the classroom involves talk and two-thirds of this is teacher talk.

This system has been criticised for focussing on a narrow range of behaviours chosen for their ease of coding rather than for their conceptual view of teaching and learning. Despite this the categories of teacher talk and pupil talk remain relevant and can provide a wealth of information about the teaching process. It has been argued that the system only provides a partial view of what happens in the classroom:

> *the easier the system is to use, the less justice it does to the complexity of events in the classroom.*
>
> [Cavendish *et al.*, 1990, p. 10]

However, all attempts to describe the social world involves selection, leading to a process of abstraction in which those elements thought to be relevant are investigated. This is not a criticism of the system merely a recognition of what it sets out to do.

The first large scale study in the UK was the Observational Research and Classroom Learning Evaluation carried out by researchers at Leicester University between 1975 and 1980 (Galton *et al.*, 1980). The ORACLE Project adopted a process-product model whereby an observational schedule was deployed to determine the relative effectiveness of different teaching approaches (*process*) in terms of pupils' learning (*product*). The ORACLE Project involved researchers using a teacher record (Boydell, 1974) and a pupil record (Boydell, 1975) developed in earlier studies. The observation was carried out by a single observer who observed the teacher and eight preselected pupils. They used a form of instantaneous time sampling which results in a series of snapshots of classroom behaviour and interactions (*i.e.* what is happening at that moment in time) every twenty-five seconds. Each pupil was observed for approximately four minutes (*i.e.* ten recordings). The data gathered through the observation of classroom behaviour and interaction was supplemented by questionnaires and tests of basic skills. The ORACLE Project detailed an asymmetry of experience in the primary classroom with the teacher being engaged in a plethora of individual interaction which absorbs as much as 80% of lesson time (Croll, 1986). The pupils' experience is largely one of solitary work with only 2.5% of their time involving them in one-to-one interaction with the teacher, a further 15% of their time involves them interacting with the teacher as part of the class audience (Galton *et al.*, 1999).

Following on from the ORACLE Project there have been a number of studies carried out to monitor the impact of the introduction of the National Curriculum in England and Wales. These include the Primary Assessment, Curriculum and Experience (PACE) Project (Pollard *et al.*, 1994), Implementation of the National Curriculum in small primary schools (INCSS) Project (Galton and Fogelman, 1998) and Provision in small schools (PRISMS) Project (Galton and Patrick, 1990). The methodology developed as part of the PACE Project combined both quantitative and qualitative observational techniques, carried out as different observational events, along with questionnaires and interviews to gather data. This would allow for a degree of triangulation not available in most observational studies. Together these studies indicated that there was a fall in the percentage of time taken up by individual teacher-pupil interaction and a concomitant increase in whole-class teaching since the findings of the ORACLE Project. Galton *et al.* (1999) argue that this change can, in part, be explained by methodological differences as the data gathering techniques used by the various projects are not strictly comparable. However, it is also arguable that the introduction of the National Curriculum with its

> *emphasis on subject specialisms reinforced by testing, has tended to focus teachers' minds on the delivery of content rather than process.*
>
> [Galton *et al.*, 1999, p. 24]

Additionally teachers have also experienced some pressure from the Office for Standards in Education (OfSTED) to change the way they teach.

In Scotland, during this period, the Scottish Education Department funded the Scottish Council for Research in Education (SCRE) to conduct the Teaching Strategies in the Primary School Project (Powell, 1985) between 1974/75 and again in 1977/78. The SCOTS schedule was developed as part of this project. The original intention of the project was to compare the impact of '*traditional*' and '*progressive*' teaching styles on pupil learning outcomes. However, this was abandoned in favour of an attempt to look at the pattern of activity in the primary classroom. This led to a lack of conceptual clarity which was compounded by the use of high inference measures, some of which required discussion with the classroom teacher in order to agree the coding. The data obtained on teachers' actions were subjected to cluster analysis in an attempt to identify teaching styles. These styles were then correlated against pupil performance, determined by a series of tests on a variety of learning outcomes (*e.g.* arithmetical ability, application to work and attitudes to learning). Seventeen clusters or '*styles*' were identified none of which was significantly related to the learning outcomes tested.

More recently the SOEID funded SCRE to conduct the Teachers' and Pupils' Days in the Primary Classroom Project (McPake *et al.*, 1999) which ran from 1996 to 1998. This project attempted to describe events in Primary 1, Primary 4 and Primary 7 classrooms in Scottish schools following implementation of the 5-14 Guidelines. No attempt was made to judge the quality of teachers' work or of pupils' learning as in previous studies. Instead the key focus was to

> *establish 'baseline' data relating to teachers' and pupils' activities in the classroom ..... and to explore teachers' and pupils' views on their classroom experiences.*
>
> [McPake *et al.*, 1999, p. 2]

Thus a major study at the end of the 20th Century was attempting to establish the baseline of classroom practice. The lack of knowledge in terms of relevant and reliable data leads to the '*hazards of knitting with fog*' (Bryce and Stark, 1992) in relation to 5-14 Environmental Studies, of which science education is a part. The observational schedule developed by SCRE required two observers one of whom focussed on the teacher while the other focussed on 'target' pupils. This approach was adopted to minimise the loss of data inherent in frequent switching between subjects when only one observer is present. Furthermore the presence of two observers, with different foci, enhances the interpretation of events. The schedule was completed using a partial interval time-sampling technique with a one minute interval. This technique requires the observer to record all events which take place during the recording interval. Each event is recorded only once negating the possibility of obtaining information of the frequency of the events. Furthermore events which are concentrated at particular points during the course of the lesson are likely to be under counted relative to those which occur throughout the lesson. This technique, in common with many observational techniques, presents serious difficulties in determining the sequence of events. However, it is possible to locate events during the course of the lesson.

The methodology also drew upon the approach developed in the PACE Project of incorporating both quantitative and qualitative observational techniques. However, in the Teachers' and Pupils' Days in the Primary Classroom Project the quantitative and qualitative techniques were integrated into the same observational event. Additionally the observations were synchronised to facilitate cross-checking. The predetermined shifts in focus between the target pupils during and observational event were designated as break points. At these points the observer would switch from the structured schedule and write-up 'general' observations of the target pupil. The observer focussing on the teacher would also write-up 'general' observations on the teacher. These detailed descriptive accounts were used to provide additional depth to the subsequent analysis by using qualitative data to illustrate quantitative data. The observation phase of the research was complemented by interviews of both teachers and pupils. Digital cameras were also used to record 'critical incidents' which were then used as a focal point for exploring each participants' thinking in relation to what was happening in the classroom at that point in time.

There has been a number of studies which have examined science education in the classroom. The Science Teacher Observation Schedule (STOS) was used to examine the processes of science teaching (Eaggleston *et al.*, 1976). An attempt was made to determine a set of learning experiences which might constitute a method of teaching. These included:

- Type I (*Teacher directed, theoretical and heuristic*)
  Teacher-dominated transactions with a high frequency of teacher initiated questions. The orientation is towards science as a problem-solving activity;
- Type II (*Teacher directed and didactic*)
  Teacher's questions focus on factual recall as well as the application of facts and principles. the pupils look to the teacher as a source of confirming facts. The orientation is towards science as non-practical and fact acquiring.
- Type III (*Pupil directed, practical and heuristic*)
  Higher level of pupil participation and pupil initiated questions. The orientation is towards science as formulating and testing hypotheses through experimental procedures as well as acquiring and confirming facts.

These 'styles' were then correlated against pupil outcomes (*e.g.* attainment of pupils, attitudes) making STOS a process-product type study. It was found that no one style is universally more successful across all subjects suggesting that a flexible approach is needed, incorporating both direct and indirect teaching methods, which is matched to the ability of the pupils and the skills which the teacher seeks to develop in the pupils. The use of this schedule was linked to the new developments brought about by the Nuffield science curriculum development. This sought to introduce discrete science courses for the top 20% of the ability range either as an alternative or to supplement the 'O' level science course.

The schedule consisted of 23 categories based around a basic dichotomy of events initiated by the teacher (*i.e.* teacher talk) and events initiated and/or maintained by the pupil (*i.e.* pupil talk and activity). A three-minute time sample was used with events being coded once. Although the events can be located in time there is no possibility of determining the sequence or duration of these events. An additional methodological problem arose with respect to one section of the observation schedule which required the observer to decide as to the nature of the question being asked by the teacher. This presents problems with reproducibility through the use of high-inference measures (Rosenshine and Furst, 1973). Despite methodological weaknesses this project did nevertheless conceptualise teaching styles in terms of intellectual transactions as determined by the pupils' responses. Generally teachers who make low levels of cognitive demand on their pupils will not make use of practical methods in which pupils hypothesise or design experiments. Another tentative conclusion was that teachers select a style which best suits the pupils they are teaching. Thus Style II is used with male pupils of above average levels of attainment in Chemistry as, it was reasoned, they require little by way of concrete practical work to understand the subject matter. Style III is appropriate for pupils with below average levels of attainment in Chemistry (girls) and Physics (boys) and appropriate for all girls in Biology. The key idea contained in the coding of the schedule was not to infer intent on the basis of teacher talk alone but rather on the ensuing transaction:

> *the purpose of this procedure is to focus on the thought processes of pupils as they were evoked by the teacher, rather than the teachers' utterances taken at their face value.*
>
> [Eaggleston *et al.*, 1976, p. 37]

The Science Process Observation Categories (SPOC) was developed for use in the Primary science teaching action research (STAR) project which ran from 1986 to 1989 (Cavendish *et al.*, 1990). The main aim of this project was to identify the most effective approach when teaching primary science. The view of learning in science adopted by the project was that

> *it is a process of developing ideas, skills and attitudes ..... progressively developed by being tested against evidence.*
>
> [Cavendish *et al.*, 1990, p. 15]

The schedule developed included categories of teacher talk and activities as well as pupil talk and activities. More importantly the schedule looked at dialogue which involved the pupil in:

- observation,
- raising investigable questions,
- hypothesising,
- planning,

- measuring,
- recording and communicating,
- interpreting data,
- reflecting critically.

These process skills were influenced by links to the aims of the Science 5-13 project in developing an enquiring mind and a scientific approach to problems as well as the framework for skills for investigative work detailed in Science 5-16: A statement of policy (DES, 1985):

> *the process skills are the means by which links are made between the ideas the children have based on their earlier experience and the new experiences which they encounter, and the means of testing these ideas to see if they help the understanding of the new experiences.*
>
> [Cavendish *et al.*, 1990, p. 4]

Pre-selected pupils and the teacher were observed using a two minute time-sampling format. Six 'target pupils' were selected to reduce the observational load. The sample was balanced in terms of gender and in terms of teacher assessments of general achievement (*i.e.* high, medium and low achievers). The pupils were observed in a prearranged order for a total of four minutes. Another important feature of this selection process is that whilst the observer made use of teacher assessments of general achievement in identifying the sample the teacher was not informed of the identity of the pupils in the sample. This was to prevent the teacher from giving 'special attention' to the pupils in the sample during the course of the lesson.

More recently Newton and Newton (2000) have examined how teachers encourage causal understanding through dialogue. Their lesson observation in primary science (LOPS) defines discourse in terms of:

- descriptive and factual,
- causal explanation,
- intentional explanation,
- procedures without reasons,
- procedures with reasons,
- predictions.

They argue that a high level of interaction between teachers and pupils is a key feature of lessons with a high standard of achievement. Furthermore:

> *discourse to do with drawing inferences, giving reasons and integrating information depends more on the teacher than the child.*
>
> [Newton & Newton, 2000, p. 601]

8.3 Observation schedule

The teacher observation schedule (see Appendix 8.1) which was developed for my research contained elements of both the SPOC and LOPS schedules. Structurally the observational schedule consisted of six categories:

- structural elements of the lesson,
- teacher dialogue,
- focus of interaction,
- pupil process activity,
- pupil activity,
- pupil grouping.

The observational schedule was developed and piloted with the assistance of the Head of Environmental Education and the Curriculum Studies science tutors who were involved in examining the embryonic schedule in order to:

- explore the meaning of the categories identified in the schedule;
- explore whether the predetermined categories were consistent with their experience of events likely to take place in science lessons;
- explore whether the schedule is feasible in terms of the time available to carry out the research;
- explore whether there were areas of sensitivity (*e.g.* issues related to assessment of student , workload, *etc.*) which could affect the research process.

The other important feature of such observation schedules is the time period used for recording observed behaviours. There are a number of recording formats used in systematic observation studies such as:

- *duration recording* -- the observer records the elapsed time during which target behaviours occur. Such a system restricts the number of behaviours that can be examined at any one time. Generally if several behaviours are to be examined they should not occur simultaneously.
- *frequency-count recording* -- the observer records every instance that a specified behaviour occurs during a specified time frame. It is possible to record several behaviours using a tally sheet as long as these behaviours do not occur at very high frequencies. The higher the frequency of occurrence the fewer the behaviours which can be observed with any degree of accuracy.
- *interval recoding* -- the observer records the behaviour of the target subject at a given time interval (*e.g.* every ten seconds). Behaviours are only recorded once at each time interval. This technique allows the observer to study a range of behaviours as well as the sequence of behaviours over a specified time frame.

My study made use of a twenty-second interval recording, with the teacher as the key subject as well as looking at the activities in which the pupils were engaged. Although not as accurate as formats which concentrate on either duration or frequency-counts this system nevertheless gives an insight into the frequency and duration of behaviours. The duration of behaviours was estimated by multiplying the frequency of a given behaviour by the time interval. The data generated will be used to examine the structure of each lesson in terms of:

- lesson structure,
- teacher-pupil activities,
- engagement with process skills,
- dialogue interaction.

8.4 Recording the observed lessons

The questionnaire phase of my research gave some insight into the extent of the students' qualifications, experience of school science, views on the nature of science and their stated intentions with respect to teaching science. There was a suggestion that the aspirational rhetoric may not be translated into the classroom. The only way to determine if this conjecture is true is to engage in observation of lessons carried out by the students. Wragg (1994) argues that the sub-text of classroom interactions are often deeply buried. In order to elicit meaning it is necessary to probe. It is axiomatic that some phenomena are not directly observable (*e.g.* attitudes, mental processes, *etc.*) and these may be significant during the process of teaching being observed. Systematic observation by itself does not make this possible other than through deploying *high-inference measures* (Rosenshine and Furst, 1973) which may not permit the methodology to be reproduced. The greater the inference the more important it becomes to check out categorisations by using supplementary data collection techniques. Thus to achieve a deeper understanding of what is happening in the classroom it is necessary to examine interactions utilising a variety of perspectives. Accordingly, to enrich data collection, the use of the observation schedule was augmented by an audio recording. Initially I had hoped to record the lesson using a digital camcorder. However, this proved problematic as preliminary contacts at Local Authority level indicated that this would cause '*concerns*'. At this time a number of Local Authorities had placed restrictions, including out-right bans, on the use of any photographic equipment in recording pupil activities. Consequently I suggested an audio recording as a '*back-up*' strategy, and this was accepted by the Local Authorities, who gave their consent for me to approach the specific Head teachers of the schools in which the students in the observation sample had been placed.

Accordingly an audio recording was made of each observed lesson. The classroom teacher was fitted with an Audio-Technica wireless transmitter (Model: ATW - T27) complete with mini-microphone set at 173MHz. Transmissions were picked up by an Audio-Technica wireless receiver (Model: ATW - R03) which was connected to a Coomber PA cassette recorder (Model: 2060 - 2/R). I also had a digital camera available to record aspects of the teaching environment, with the proviso that no children would be included. The audio recording was used in order to obtain a permanent detailed record of a transient event which can then be analysed under less pressurised circumstances. The advantage of the audio recording is that it offers the possibility of obtaining a relatively unfiltered record of all behaviours and transactions which occur in front of the observer. In addition combined with the findings of the questionnaire and observation studies there is the potential for triangulation of methods. However, caution is required in interpreting the behaviours and transactions captured by this methodology as it is

> *easy to be seduced into thinking that the reality of the situation has been captured and that it is adequate to extrapolate from this information.*
>
> [Plowman, 1999, p. 4]

The audio recording was used in order to reach beyond the surface meaning of events and provide an opportunity to capture deeper meaning. A comprehensive understanding of classroom life depends upon the translation of silent languages (Smith and Geoffrey, 1968) which has been termed the hidden curriculum (Snyder, 1971). Patterns of interaction may emerge on listening to the audio recording which were not immediately apparent to the observer nor indeed part of the coding (Swann and Graddol, 1988). Audio recordings facilitate a refocusing of the research questions as they can be re-examined and re-analysed from a variety of conceptual frameworks facilitating retrospective analysis (Bowman, 1994). Further research questions and hypotheses emerge from this analysis suggesting a focus for future data collection. Thus research moves forward by a process of progressive focussing (Foster, 1996).

Following the observation of the lesson the tape recordings were sent for transcription by a professional typist. This written record was checked against the audio recording by the interviewer. Additionally the interviewer's field notes were written up immediately after the interview to provide the contextual back-drop missing on the transcription. The delay in processing this data was kept to a minimum although this proved to be a time consuming process. More importantly the researcher was concerned that if too long a period elapsed before processing the data then there was a danger of a loss and distortion of data. Generally the researcher is suspicious of their ability to recall events accurately if events and time are allowed to intervene between the interview and the write-up.

8.5 Identification of Sample

The data gathered from the questionnaire was used in describing the students' levels of qualifications and confidence in relation to teaching science. The SPSS package was used to score the students' qualifications as follows:

- 0 = no qualification,
- 1 = Standard Grade,

- 2 = Intermediate,
- 3 = Higher,
- 4 = Advanced Higher.

A total qualification score was calculated for each student. The potential range of this qualification score was 0 to 12 although very few exceeded a score of 6. The qualification score was combined with the mean confidence indices to allocate each student to one of four quadrants as follows:

- high level of qualification and high level of confidence;
- high level of qualification and low level of confidence;
- low level of qualification and high level of confidence;
- low level of qualification and low level of confidence.

Three students were chosen for each quadrant for each of the BEd 2, BEd 3 and BEd 4 cohorts making a total of thirty-six students. Four students, one for each of the four categories listed above, from each of the B.Ed 2, B.Ed 3 and B.Ed 4 cohorts, were then invited to participate, on a voluntary basis, in the observation phase of the research. If a student for any given quadrant declined to participate, which frequently happened, then the next student on the list for that quadrant was approached and invited to participate. This proved to be a time-consuming process in that consent had to be sought from a number of individuals (see Appendix 8.2). Time constraints meant that the sample size was restricted to twelve students. The extent to which one can generalise from any findings is severely limited by the small sample size, this concern was discussed with my supervisor prior to conducting the research. Notwithstanding this concern the research would provide an interesting exploration of methodology as well as provide an insight into fruitful areas for subsequent investigation. This invitation to the students took the form of a letter which outlined the purpose of the research, sought the student's participation and indicated that I would telephone them in the following week to discuss this request with them (see Appendix 8.3). Permission to obtain the contact information on these students was sought from and supplied by the Department of Curriculum Studies in accordance with the Dean's approval to carry out the research.

Construction of the sample did not prove to be a straightforward task with a number of students declining to participate or leaving the course after the questionnaire had been completed. Indeed the first three BEd 2 contacts with respect to low qualifications and high confidence were found to have left the course. However, twelve students were eventually identified who agreed to participate. Information on these students' school placements was sought from and supplied, when known, by the secretary of the Department of Curriculum Studies. Once each of the student cohorts embarked upon their school placements they were again contacted by telephone to arrange school visits. The pattern of visits was as follows:

- BEd 2 -- 10-12th February 2003;
- BEd 3 -- 27-29th May 2003;
- BEd 4 -- 17-19th March 2003.

Once the school placements were known, between the period that the students had agreed to participate and their school placement, I wrote to each of the Local Authorities with schools involved in the research to seek their consent to approach the Head teachers concerned (see Appendix 8.4). Once this consent was given I wrote to each of the Head teachers involved seeking permission to visit their school with the aim to observe the student delivering a science lesson. In this letter I indicated that I would telephone them in the following week to discuss this request with them (see Appendix 8.5). Thankfully all of these requests to the Local Authorities and the Head teacher involved proved successful. These requests were given some '*gravitas*' in that I was permitted to use official University of Glasgow headed notepaper. A subsequent letter was sent to the Head teacher informing them of the date and time of the visit once this had been agreed with the student (see Appendix 8.6). I was also made aware, although not directly involved, that the schools had contacted the parents seeking their permission for the children to be present during the observed lesson. Thus this proved to be a protracted process generating a lot of official correspondence prior to the school visits (see Appendix 8.7 for sample). This proved to be manageable; however, it should be borne in mind that my sample consisted of just twelve students. Clearly this presents a significant challenge for large scale classroom-based research, a challenge which I did not have to meet.

8.6 Observation sample

Two of the twelve students who agreed to participate in the observed phase of the research were used to pilot the observation schedule. Ideally I would have preferred to use students not drawn from the sample as part of this pilot. However, the time available for this phase of the research was highly constrained. The pilot phase proved invaluable in terms of raising awareness with respect to the unmanageability of recording the six categories:

- structural elements of the lesson,
- teacher dialogue,
- focus of interaction,
- pupil process activity,
- pupil activity,
- pupil grouping.

The twenty-second recording interval was originally thought to be sufficient to record all of the observed behaviours. However, it became apparent that there was an uneven distribution of activity within the lessons. Periods when there was little change or when there was low activity were relatively easy to record. However, periods of intense activity and change in activity required immense concentration which manifested itself in 'spill-over' into a subsequent recording interval. This 'spill-over' was brought about by the time necessary to think through what behaviours had been observed followed by the time taken to record these behaviours. It became very difficult and tiring to keep pace with the lesson, particularly as these periods could last for several minutes, and consequently the apprehension grew that detail was being lost. However, this did not prove to be disastrous as the audio recording could be used to code two of the six categories, namely:

- teacher dialogue,
- focus of interaction.

The key was to synchronise the timing of the observation and audio recording with a verbal event initiated by the student teacher (*e.g. "Right boys and girls*"). As a result of the pilot the observation schedule was reduced to four categories which proved manageable:

- structural elements of the lesson,
- pupil process activity,
- pupil activity,
- pupil grouping (see Appendix 8.8).

Of the ten remaining students another three do not form part of the observation study. One of the lessons was very poor in terms of classroom management. The classroom teacher eventually had to take over the lesson from the student, at which point my role of observer ceased. Consequently this lesson has not been included as part of the research. Two other lessons have not been included as the audio recordings were of very poor quality. The remaining seven BEd students, identified as T1 to T7, were observed delivering a science lesson, *of their own choice*, during their primary school placements. An audio recording was made of each observed lesson and a transcription of each tape was produced. The seven students who took part in the observation phase of the research had also participated in the questionnaire survey. Indeed their selection for participation in the observed lesson was determined by their responses being matched against criteria determined by the researcher. The students in the sample were identified in terms of their school science qualifications (see Table 8.1) and their stated confidence with respect to teaching primary science. This confidence is in terms of teaching:

- the attainment outcomes (Figure 8.2);
- at the different age stages in the primary school (Figure 8.3);
- the investigative skills (Figure 8.4).

Figure 8.1: Observation sample

T1 = BEd 2
T2 = BEd 2
T3 = BEd 3
T4 = BEd 4
T5 = BEd 4
T6 = BEd 4
T7 = BEd 4

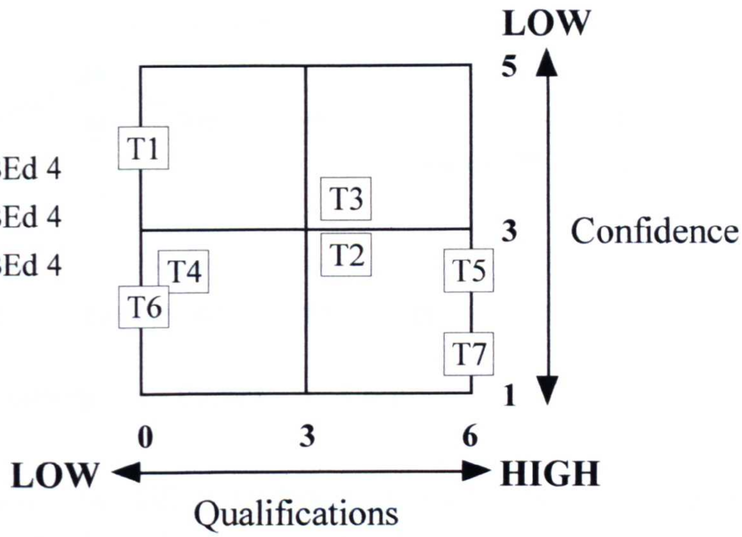
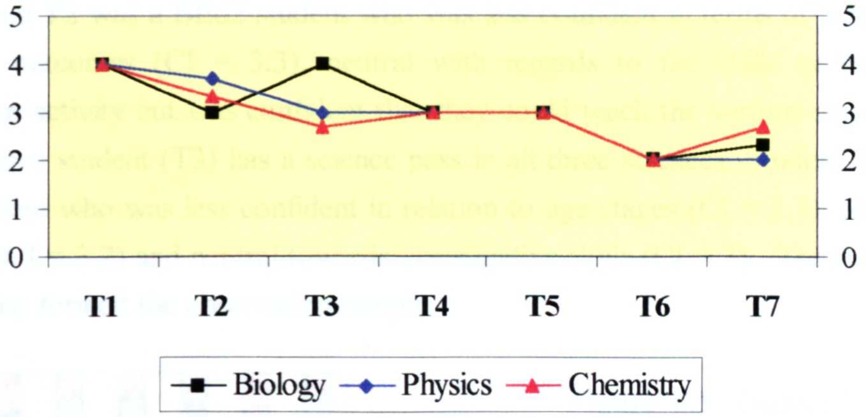


Table 8.1: Science qualifications of observation sample

Student	Physics	Chemistry	Biology
T1	None	None	None
T2	None	Standard Grade	Higher
T3	Standard Grade	Standard Grade	Intermediate 2
T4	Standard Grade	None	None
T5	Higher	Higher	None
T6	None	None	None
T7	None	Higher	Higher

Two of the sample were mature students (T1 and T6) both of whom finished their science education in their second year of the secondary school and consequently they had no school science qualification. Student T1 is in the early stages of her pre-service education (*i.e.* BEd 2) and lacked confidence, recording confidence indices of 4 with respect to teaching the attainment outcomes, pupils at the various age stages and the investigative skills. Student T6 was nearing the end of her degree course and despite having no qualifications in science was very confident with respect to her stated confidence indices of 2 for all the areas examined. Student T4 was a BEd 4 student who had a single Standard Grade pass in Biology. Student T4 was positive about their ability to teach primary science: attainment outcomes (CI = 3), age stages and investigative skills (CI = 2.3).

Figure 8.2: Stated confidence in teaching the attainment outcomes



At the other end of the spectrum two BEd 4 students (T5 and T7), with two Higher level passes, had differing levels of confidence. Student T5 was most confident with respect to teaching the investigative skills (CI = 2) and slightly less confident in terms of teaching the age stages (CI = 2.7) and attainment outcomes (CI = 3). Student T7 was very confident with respect to teaching investigative skills (CI = 1) and the age stages (CI = 1.3); she was less confident with respect to the attainment outcomes (CI = 2.3).

Figure 8.3: Stated confidence in teaching the different age stages

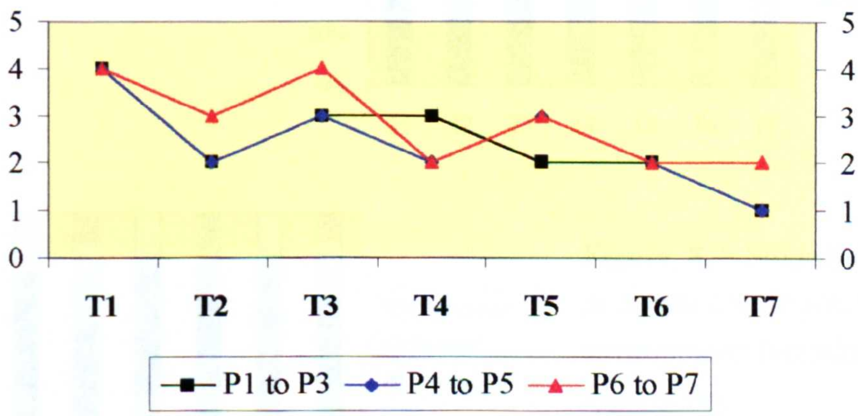
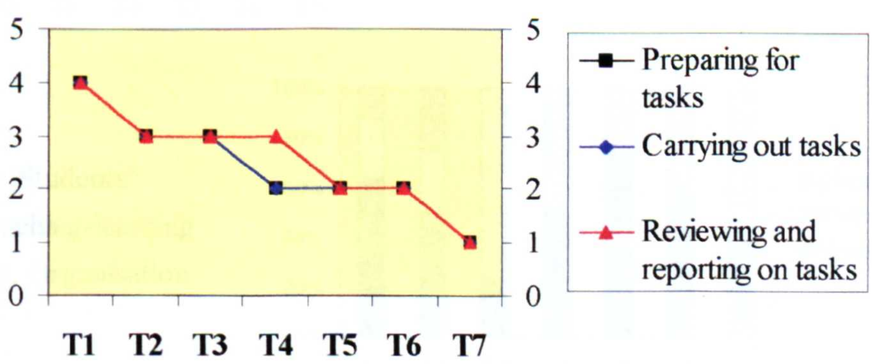


Figure 8.4: Stated confidence in teaching the investigative skills



Students T2 was also well qualified with one Standard Grade and one Higher Level pass. Student T2 was a BEd2 student who was less confident in terms of teaching the attainment outcomes (CI = 3.3), neutral with regards to the skills necessary for investigative activity but was confident that they could teach the various stages (CI = 2.3). The final student (T3) has a science pass in all three sciences. Student T3 was a BEd 3 student who was less confident in relation to age stages (CI = 3.3), attainment outcomes (CI = 3.2) and neutral towards investigative skills (CI = 3). These were the students who formed the observation sample.

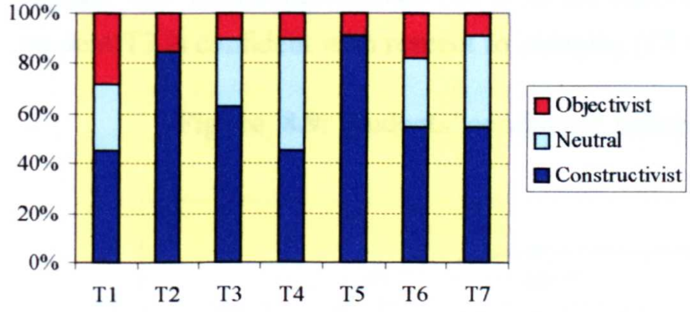


Figure 8.5: Students' preferred teaching-learning environment: *Classroom methodology*

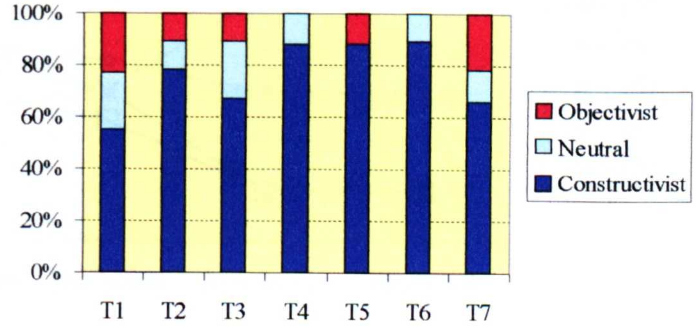


Figure 8.6: Students' preferred teaching-learning environment: *Resourcing lessons*

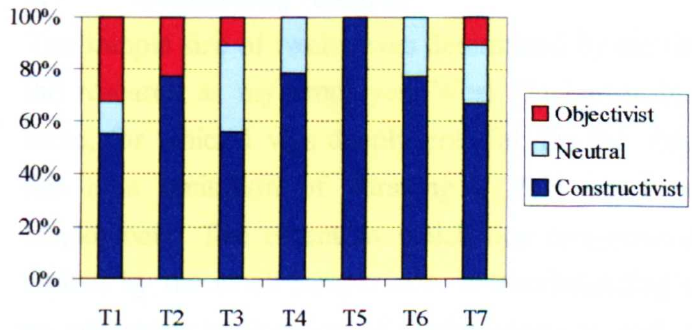


Figure 8.7: Students' preferred teaching-learning environment: *Investigative approaches*

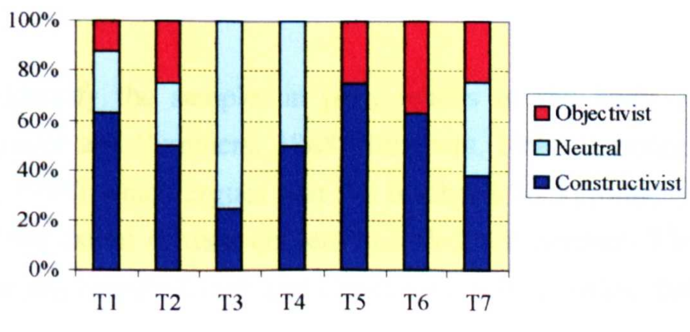
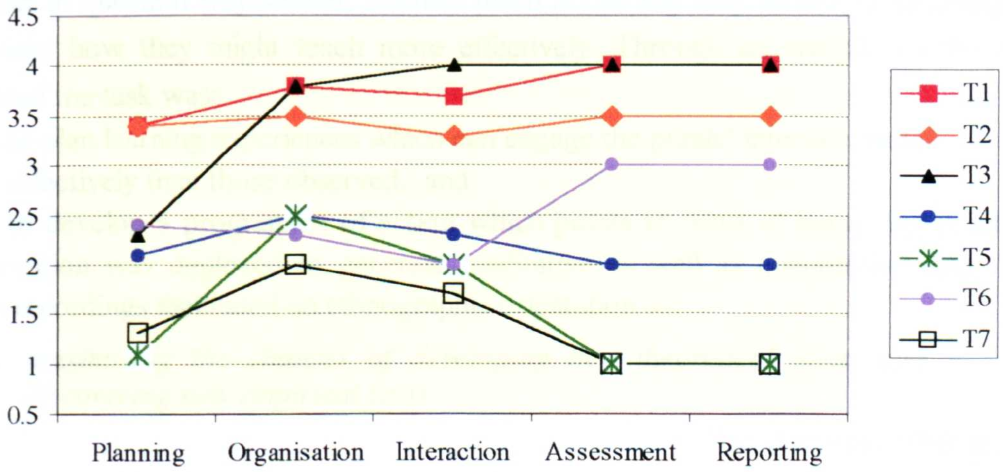


Figure 8.8: Students' preferred teaching-learning environment: Organisation

The students' preferred teaching-learning environments indicate that the constructivist framework is dominant (see Figures 8.5 to 8.8). There are only a few exceptions to this with students adopting a neutral position particularly with respect to *classroom methodology* (*e.g.* T4) and *organisation* (*e.g.* T3 and T4). The objectivist framework does not appear to form part of the students' thinking. An examination of the confidence indices of the students' professional skills indicates some variation (see Figure 8.9). Students T4, T5 and T7 register high confidence with respect to all of the professional skills as does student T6 (CI ≤ 3). The remaining three students generally register low confidence indices (CI ≥ 3) for each of the professional skills, although student T3 is confident with respect to planning (CI = 2.3).

Figure 8.9: Students' confidence indices for professional skills



8.7 Concluding remarks

The sample size of twelve was determined by the time made available for this phase of the research as my employer, West Dunbartonshire Council, had granted six days' leave, for which I was deeply grateful, for the observations to be completed. Clearly this is a limitation of pursuing a PhD on a part-time basis whilst in full-time employment. The extent to which one can generalise from any findings is severely limited by the small sample size. Notwithstanding this concern the research provides an interesting exploration of methodology as well as providing an insight into fruitful areas for subsequent research.

The selection criteria used to identify the sample, in part, relates to the body of 'deficit knowledge research' (Kruger and Summers, 1988; Summers, 1994; Summers and Mant, 1995a; Brown *et al.*, 1998) which argues that the teacher's background in science is significant in terms of the extent of their content knowledge in science. The selection criteria also attempts to incorporate Carré and Carter's (1993) assertion that neophyte teachers are likely to have a greater degree of confidence than practising teachers as they are exposed to newer ideas about teaching science, applications of subject-matter knowledge and the incorporation of process skills into their teaching strategies.

The observation schedule developed for this research was used in order to determine whether:

- the students' limited background in science manifests itself in the primary science lessons observed;
- the high levels of confidence is supported by effective teaching in the primary science lesson delivered by student teachers.

The practical aim of the research was to open the world of the obvious and the routine in order to question why student teachers teach in the way they do and, in so doing, to speculate how they might teach more effectively. Through an analysis of the data gathered the task was:

- to plan learning experiences which can engage the pupils' interests more effectively than those observed, and
- to develop a programme of action which points to ways of improving practice.

Observation was deployed to generate qualitative as well as quantitative data. The audio recordings facilitated an ethnographic orientation so:

> *maximising the chances of developing new theoretical ideas and discovering new empirical facts.*
>
> [Hammersley, 1986, p. 46]

Throughout this research quantitative and qualitative techniques were not seen as mutually exclusive paradigms but rather as complementary in the search for meaning. The key thrust of the research was not to adopt a purist position in terms of the quantitative vs qualitative debate but rather to generate a body of knowledge which indicates to teachers ways to engage in practice more effectively, that is:

> *they should do more of some things and less of others*
>
> [Wragg, 1994, p. 8]

However, this research methodology does raise a number of issues with regards to the validity and reliability of the data gathered:

- *Observation schedule*

The strategy deployed does generate some questions with respect to preventing sensitising subjects to the purpose of the research, The questionnaire was used to inform the next phase of the research. The observation phase of the research presented a number of problems to be overcome. It is important to acknowledge that observation can never provide us with a direct representation of reality. In defining the observational schedule I determined the behavioural events to be captured (*e.g.* what is observed and how these are recorded). The subsequent analysis of the data gathered may well be interpreted in light of my knowledge, theories and values. Consequently the validity of the observation schedule needs to be determined objectively by others. As such the validity of the observation schedule, as an appropriate instrument for observing science lessons, was determined both by an examination of research evidence as well as peer review, namely the Science Tutors in the Department of Curriculum Studies.

I chose not to develop the schedule by engaging in continuous recording of several science lessons. Such a technique does not make use of an observation schedule but rather is used to determine the components of such a schedule. Continuous recording involves the researcher in developing a narrative in chronological order of everything that occurs during a series of science lessons. The protocol (Borg and Gall, 1989) produced can then be analysed to identify significant behavioural patterns to be studied in more depth. However, this was not possible within the constraints of this research. Furthermore such protocols are implicit in the teaching and assessment programmes of the science team involved in the education of student teachers within the Faculty. This introduces the possibility of bias, in that peer review requires past experience to be used in the interpretation of perceptions as to what constitutes the key components of science lessons. However, by engaging in dialogue amongst several professionals, with experience in this field, it is more likely to obtain inter-professional agreement.

Researchers argue that it is necessary to practice using the observation schedule in a variety of classroom situations. However, as academic researchers have no right of access to the school it was decided that the best course of action during the pilot phase of the research was to observe lessons of students who would not be part of the final sample. This was subject to an open dialogue in terms of evaluating the validity of the schedule as a measure of observable behaviours:

> *as you begin to seek agreement with colleagues on the purposes of classroom activities, on how to classify behaviours, and on how to select what is important and what is not, you will be articulating, sharing and seeking agreement on your conceptualisation of the basic nature of classroom relationships.*
>
> [Simpson & Tuson, 1995, p. 34]

➢ *Consent for Observation*

To carry the research forward it was necessary to gain access to the school in order to conduct observations of student teachers' science lessons. It was necessary to obtain permission, from a variety of gatekeepers, to intrude officially into the school system.

For each of the student teachers, who were dispersed throughout the West of Scotland, it was necessary to obtain permission from the Local Authority, Head teacher of the placement school and the teachers with direct responsibility for the student teacher. In addition it was necessary that the pupils' parents were informed. Apart from the logistical problems this presented, there is the major drawback that:

> *key gatekeepers can deny access to observers because they are apprehensive about how the observational data will be used or because they are concerned about the potential disruption the observation will cause.*
>
> [Foster, 1996, p. 14]

Clearly it was important to assure all the gatekeepers, especially the parents, that the education of the pupils would not be hampered. Of vital importance is that all of the data recordings would remain confidential. However, the problem of the power relationships between the various levels of gatekeepers remains:

> *if the authority asks the schools, the request may be seen as an imperative.*
>
> [Simpson & Tuson, 1995, p. 57]

Thus the researcher needs to be sensitive to this situation as there may be a sense of coercion amongst those at the lower levels within the school hierarchy. That this is not the researcher's intention is irrelevant. Informed consent is the 'benchmark'; any indication that participation is not on this basis requires the researcher to question whether they should continue. Lengthy deliberations on whether to forge ahead regardless should be unnecessary; for to do so would be unethical.

➢ *Analysis of Observation Data*

Students may also perceive themselves 'at risk', with their responses being linked to the internal Faculty assessment process and ultimately their career prospects. The profession is small and it is difficult to 'hide' in observation studies. To ensure that the responses given are authentic it is vital that they are provided with assurances as to their complete anonymity and that the data recorded will be kept strictly confidential.

Qualitative techniques present problems in terms of the interpretative process. A key problem was that of contamination (Borg and Gall, 1989) as I had prior knowledge of those being observed presenting the possibility of differential expectation. My knowledge of the student's responses to earlier aspects of the study may serve to corrupt, by contact, the observer's perception of data recorded in other aspects of the study. The observer's expectations can have a significant effect on how they interpret and record what they see and hear. The observed are also affected by the presence of the observer. The observer and the audio recorder cannot but disrupt the normal social interaction within the classroom. The presence of the observer is likely to lead to anxieties and/or expectations which may well change the climate of the classroom. To offset this it was requested that the student teachers introduce the observer and begin with a brief introductory lesson, prior to the recorded science lesson, in order to provide both the observer and the observed time to settle to the new classroom dynamic.

A more critical aspect of reactivity (Foster, 1996) is an attempt by the student teacher to anticipate the intentions of the observer by replicating 'desired' behaviour. Research evidence indicates that the presence of another adult in the classroom may alter what happens. Samph (1976) found that teachers made more use of questions and praise as well as being more likely to accept pupils' ideas in the presence of an observer. The drive to produce a socially desirable response can render observations useless as they may not be representative of actual behaviour. The questionnaire may sensitise the sample of student teachers to the nature of the observational phase of the study. However, the distance in time between the questionnaire and the observation phase reduces the likelihood of this taking place. Of greater significance in determining the validity of the findings was that the study deployed various forms of triangulation. At the level of the individual student data triangulation was achieved by utilising a variety of methodological techniques. There was also a degree of theory triangulation in that the audio recordings were re-examined and re-analysed using a variety of conceptual frameworks. This also permits observer triangulation with the interpretation placed on the data by the researcher being subjected to peer review.

It is essential to retain a sensitivity to the vulnerability of the student in the context of classroom observation, and to offset individuals' predispositions to perceive themselves negatively. It is important for the researcher to go beyond the merely cosmetic of what people look like and to explore sequences with intrinsic interest to the research. However, the reliability of the evidence may be compromised by the students, in order to maintain self-esteem, deployment of strategies to deflect adverse comment. They may seek to deny undesirable traits by fabricating an alternative story or to colour events (Jones, 2002). The problem for the research is that ultimately the relationship between the observer and the observed is an asymmetrical one. Although it is the researcher who determines, to a greater or lesser extent, the focus of the observational schedule; it is the observed who determines the layer of truth they will make accessible. At best we gain an insight into the respondent's favourite self-image.

The sample selected for the observation phase was small and was not subjected to rigorous randomisation. The sample was necessarily small as gathering and processing observation data and subsequent follow-up interviews are labour intensive activities. There was no attempt to justify the sample in terms of its representativeness. Subjects were selected solely in terms of the conceptual sampling framework (see Figure 8.1), introducing the possibility of researcher bias. Why these particular subjects? To some extent this was off-set by a degree of methodological triangulation. However, there remain more questions than can be answered within the scope of this present research. Hopefully, the study does point to ideas and questions which can be followed up. As such it is necessary to remain cautious in making claims which are generalisable to the wider population on the basis of a few in-depth case studies. However, student teachers and teachers themselves might find resonance with their own experience and find it useful to generalise at least some of the findings:

> *recommendations for changes in teaching appears to have more credibility amongst teachers when based on evidence gathered during observation, particularly observations conducted in individual teacher's classrooms.*
>
> [Anderson & Burns, 1989, p. 141]

The next chapter examines the findings from several case studies outlining the practice of the student teachers who make up the sample for the observational phase of the research. These case studies will be used to outline the structural components of the lessons as well as to examine the language of science.

CHAPTER 9 LESSON STRUCTURE

9.1 Observational categories

The observed lessons were used in an attempt to gain an insight into the structural elements of the lessons planned and delivered by seven pre-service students: Student T1 to Student T7. Each lesson was broken down into a continuous series of twenty-second recording intervals (see Table 9.1). The large standard deviation indicates that there was a variation in the lessons in terms of lesson time; this indicates that the results should be interpreted with some caution. The observation schedule was used to gather a variety of data, for each of the recording intervals, throughout the duration of the lesson[9.1]. A complete data set for seven observed lessons was gathered and is examined here. The seven lessons comprise of four types:

- worksheet-driven lessons (Student T1 and Student T4);
- practical activity lessons (Student T2, Student T3);
- composite activity lesson (Student T6);
- craft-based lessons (Student T5 and Student T7).

Table 9.1: Lesson duration and number of recording intervals

Lesson duration	T1	T2	T3	T4	T5	T6	T7
Minutes	45' 40"	47'	39' 20"	36'	47'	48'	73' 20"
recording events (n)	**137**	**141**	**118**	**108**	**141**	**144**	**220**
Descriptive statistics		Σ =	1009	**Ave =**	144.1	**SD =**	36.1

Data from the observation schedule (Cavendish *et al.*, 1990; Newton and Newton, 2000) was processed to gain some insight into the sequence and frequency of the observed elements which included:

- Structural elements of the lesson, further sub-divided as follows:
  - *Previous learning*
    Recapitulation (*recap*) of previous lesson/learning through statement or through questioning. It may also involve the teacher in finding out what the pupils thoughts are on the learning which is the focus of the lesson -- this may be elicited through oral work or written work.
  - *Discussing instructions*
    Teacher discussing with the pupils the nature of the task or the pupils discussing amongst themselves.
  - *Clarification of task*
    Instructions which are provided to support the pupils' understanding of the task. It may be carried out through verbal statements to the class, groups or individuals.

[9.1] The data gathered from each of the observed lessons has been collated into a separate volume of Support Materials. This has been done to provide research students at the Centre for Science Education with a database for further analysis in the future. The material relevant to this chapter includes the observational data and the data on student talk.

- *Organisation of task*
  Any activity associated with setting up the task such as distributing materials. It will also include clearing up after the task has been completed.

- *Task management*
  Activities which are aimed at monitoring the work being undertaken by the class. It will include movement, observation as well as verbal interaction. These may be aimed at keeping the work on track or bringing the task to an end.

- *Results / progress*
  Assessment events, both formal and informal, such as marking.

- *Resource management*
  Activities aimed at ensuring that the pupils have the necessary materials and that they are using them appropriately.

- *Pupil feedback (positive and negative)*
  Verbal interactions which are positively or negatively framed.

- *Recap of learning*
  Recap of lesson/learning through statement, questioning or an assessment event.

- *Non-task management*
  Activities such as taking the register and dealing with interruptions.

➢ Pupil process activity, further sub-divided as follows:

- *Planning*
  Activities in which the pupils are identifying the steps involved in carrying through an investigation (*e.g.* discussion, planning through action, *etc.*).

- *Raising questions*
  Activities which require pupils to identify investigable questions. Dialogue will be central to this process as it may be necessary to reformulate 'how' and 'why' questions into specific questions which can be investigated. This may involve discussion, brainstorming sessions, group work, *etc.* aimed at generating questions to investigate.

- *Hypothesising*
  Activities which require pupils to explain new observations or data using past experiences or learning. It need not be the scientifically accepted explanation. However, the hypothesis should be framed in such a way that it is testable through investigation.

- *Observation*
  Activities which require pupils to make use of any of their senses in gathering data and experience. A key component of this will be what the pupils say in relation to their observations.

- *Measurement*
  Activities which require pupils to quantify some variable. It will usually involve the pupils in using some form of instrumentation. Part of the process will include steps taken to ensure the accuracy of the measurements made.

- *Recording*
  Activities which require pupils to keep records of the work in progress. They may fill in a table, compile their own notes, *etc.* Mostly this will be in a written form; however, it can also include pupils reporting their findings orally.

- *Interpretation*
  Activities which require pupils to engage in finding patterns and associations in the data generated from their investigations. Reaching conclusions is an important aspect of this. Interpretations should be consistent with the data generated.

- *Critical reflection*
  Activities which require pupils to participate in discussions focussed on their findings. The review may look at the notion of the 'fair' test, on how to improve things. This need not necessarily take place at the end of the lesson. It may or may not include the teacher.

➢ Pupil activity, further sub-divided as follows:

- *Writing*
  Activity which engages the pupils in a self-directed written activity such as making their own notes, recording their results, describing what they have found out, *etc.*

- *Copying*
  Written activity which is teacher directed. This may include dictating notes, copying from a textbook, completing a fill sheet, *etc.*

- *Reading*
  Activity which is linked to the science lesson.

- *Oral work*
  Activities when the pupils are engaged on task talk either to the teacher or to other pupils.

- *Using resources*
  Use of science equipment or other resources related to the lesson (*e.g.* computer).

- *Resource management*
  Activity related to the task such as distributing materials, gathering in materials, *etc.*

- *Listening / watching*
  This may involve the pupils focussing on the teacher, other pupils or the activity.

- *Non-active*
  Any periods when the pupils are non-active such as when they are waiting during the register, waiting for the teacher to start or whilst the teacher is engaged on some other non-task activity, *etc.*

➢ Pupil grouping, further sub-divided as follows:

- *Individual*
  The pupils are working by themselves.

- *Group work*
  The pupils are working in groups organised on the basis of ability, or mixed ability or friendship or using no discernible criteria.

- *Whole class*
  The pupils are engaged as a class.

9.2 Worksheet-driven lessons

Student T1 and Student T4 planned lessons which led to the completion of a worksheet following teacher exposition (see Table 9.2). The observed lessons had a simple sequence of structural elements. Each lesson commenced with the student ascertaining the extent of the pupils' *previous knowledge* which was then linked to new learning through a series of student-directed questions. Thereafter much of the student's time focussed on verbal interaction and movement aimed at the *management* and *clarification of task*. There was a coherent pattern as to how this time was arranged in that much of the whole-class interaction, which formed the early part of the lesson, involved student-pupil verbal interaction aimed at *clarifying* and supporting the pupils' understanding of the nature of the task. The transition between whole class and individual activity involved the student in *discussing instructions* and *organising* the pupils for the individual tasks, this involved an element of *resource management*. Once this transition was accomplished the students then involved themselves in verbal interaction and movement aimed at *task management* (*i.e.* monitoring the work being undertaken by the class). Periodically, the students had to deal with non-task orientated behaviour from some of the pupils in the group, necessitating *non-task management*. The final phase of the lesson involved the pupils in completing the worksheets using the resources provided. During this period the student was engaged in *task management* activities which involved both movement around the group, focussed questions to individual pupils as well as providing individual support. The lesson ends with a brief period of organisational activity (see Figure 9.1).

Table 9.2: Frequency of structural elements in the observed lessons

Structural elements	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**ALL**
previous learning	21	4	2	15	14	41	4	14
discussing instructions	1	14	8	10	10	8	30	13
clarification of task	24	15	19	29	2	3	10	14
organisation of task	13	15	10	9	14	3	5	9
task management	19	28	20	30	35	16	25	25
results / progress	-	19	20	-	3	-	11	8
resource management	7	4	-	-	1	5	5	3
pupil feedback	2	-	4	-	1	-	-	1
recap of learning	-	1	13	-	13	13	-	5
non-task management	12	-	3	7	8	12	10	8
n =	**108**	**137**	**118**	**141**	**141**	**144**	**220**	**1009**

Worksheet activity	Practical activity	Composite activity	Craft-based activity

Although these students indicated how they would accomplish an assessment of the pupils' performance in the lesson plan it does not manifest itself in terms of pupil feedback or results/progess. Essentially this is due to the methodology deployed in that events recorded are those which occur at the end of the twenty-second intervals. There were incidents of assessment, but these were so brief that they did not register even with a twenty-second interval.

Figure 9.1: Sequence of structural elements in worksheet-driven lessons

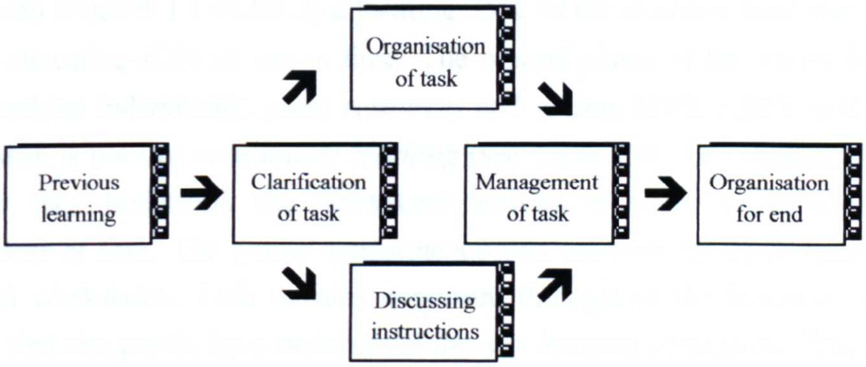


Table 9.3: Focus of interaction in the observed lessons

Focus of interaction	T1	T2	T3	T4	T5	T6	T7	ALL
planning	-	-	-	-	-	-	34	8
raising questions	-	6	-	-	-	-	-	1
hypothesising	-	7	-	-	-	-	-	1
observation	-	10	14	35	-	6	-	9
measurement	-	6	-	-	7	-	-	2
recording	-	11	14	-	-	9	5	5
interpretation	-	15	6	-	-	-	-	3
critical reflection	-	-	-	-	-	-	-	-
non process	100	46	60	65	93	85	61	72
n =	**108**	**137**	**118**	**141**	**141**	**144**	**220**	**1009**

Worksheet activity	Practical activity	Composite activity	Craft-based activity

Investigative-style activities (*i.e.* pupil process activity) do not feature, to any great extent in this type of lesson (see Table 9.3). The pupils were occupied by generic activities (see Table 9.4). It is apparent that the total frequency of pupil activities exceeds the number of recording intervals as it is possible for the pupils to be active, at any given point in time, across several of the categories being recorded. The lesson could be broken down into two distinct phases on the basis of the observed pupil activities. The initial phase of the lesson consists almost exclusively of oral work during which the pupils participate in *listening*, *watching* and *talking* activities with their performance assessed on the basis of their verbal contributions. During this period the students attempted, deploying a question-and-answer approach, to ascertain the extent of the pupils' *previous learning* and use this as a bridge towards new learning. This phase of the lesson involved an *exploration of learning*, with the group taken as a whole (see Table 9.5). The development of the pupils' knowledge base is incremental and the transition between previous and new learning is managed through *clarification of the task*. The allocation of time, for the exploration of learning, was different for each student with Student T1 (B.Ed 2) allocating 35% of the available time and Student T4 (BEd 4) allocating 62% of lesson time. The second phase of the lesson involved the pupils, working individually, *using resources* and *writing* (65% : 38% split). This part of the lesson is used to *consolidate learning* (see Table 9.6). The student observed the pupils as they undertook the worksheet activity in order to monitor progress: *management of task*. The pupils' performance was assessed by an examination of the completed worksheets. *Talk* remains important throughout the lesson as a means of verifying that the pupils have understood the key learning objectives. This lesson also included some time during which the pupils were *non-active* as the student found in necessary to engage in activities aimed at managing inappropriate behaviour.

Table 9.4: Frequency of pupil activities in the observed lessons

Pupil activities	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**ALL**
writing	17	8	13	19	-	13	11	12
copying	-	-	-	-	-	-	-	-
reading	2	2	-	-	-	-	-	1
oral work	39	31	39	19	31	46	49	36
using resources	25	19	12	35	37	14	28	26
resource management	1	6	2	3	-	4	4	3
listening / watching	12	35	30	22	32	8	9	19
non-active	5	-	3	2	-	14	-	3
n =	**165**	**182**	**142**	**298**	**178**	**179**	**384**	**1528**

Worksheet activity	Practical activity	Composite activity	Craft-based activity

Table 9.5: Frequency of pupil groupings in the observed lessons

Pupil interaction	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**ALL**
individual	65	8	16	38	-	17	15	21
group work	-	33	24	-	47	5	36	22
whole class	35	59	60	62	53	78	49	57
n =	**108**	**137**	**118**	**141**	**141**	**144**	**220**	**1009**

Table 9.6: Two-phase lesson

	Phase 1	**Phase 2**
Focus of activity	Exploration of learning	Consolidation of learning
Pupil activities	Talking, listening, watching, *etc.*	Reading, writing, using resources, *etc.*
Resources	Photographs, poster, *etc.*	Worksheets, resource sheets
Assessment	Verbal responses	Completed worksheets
Pupil grouping	Whole group	Individual
Process skills	Observation	Raising questions
Time allocation	35% : 62%	65% : 38%

An audio recording was made during the observed lesson to facilitate a more detailed examination of the discourse of science. The classification of the discourse was determined by what the teacher accepted from the pupil. Thus a question which is framed in terms of a causal relationship may become descriptive if that is the response which the teacher accepts from the pupil. Furthermore within a recording time frame there may be a cluster of questions which are similar, these will be recorded as the same event. The classification consisted of:

- Student dialogue, further sub-divided as follows:
  - *Descriptive / factual (DF)*
    Questioning (DFQ) or telling (DFT). The focus is on eliciting a factual response or passing on some factual information (*e.g.* What happens when... ?)
  - *Causal / explanatory (CE)*
    Questioning (QCE) or telling (TCE). The focus is to explain some event or finding. Causal relationships are central to the area of discourse (*e.g.* Why does this occur?).
  - *Procedural (PR)*
    Questioning (PRQ) or telling (PRT). The focus will be the task. The interaction will seek to elicit from the pupil that they know what to do and possibly why.
  - *Predictive (P)*
    Questioning (PQ) or telling (PT). This will involve the pupils in gauging what is the likely outcome to some action / event.

- Focus of dialogue, further sub-divided in terms of the process skills as follows:
  - *Planning* — What equipment will you need?
    How are you going to keep a record of your results?
  - *Raising questions* — What would happen if ...?
    How can we ...?

- *Hypothesising* — Why do you think... ?
  What do you think ...?
- *Observation* — What do you see. ...?
  What do you smell ?
- *Measurement* — What is the rate ...?
  How long did that take to ...?
- *Recording* — What kind of chart / graph / drawing have you used to ...?
  Can your results be shown in a different way?
- *Interpretation* — Did you find any connection between ...?
  What did make a difference to ?
- *Critical reflection* — How can you show that your idea worked?
  How could you modify your approach?
- *No interaction* — This is when the discourse is about a non-process related matter.

Table 9.7: Nature of student dialogue in the observed lessons

Student dialogue	T1	T2	T3	T4	T5	T6	T7	ALL
descriptive (telling)	60	37	40	39	50	53	51	47
descriptive (questioning)	34	33	37	51	34	38	25	35
causal (telling)	-	-	-	1	-	-	-	-
causal (questioning)	-	-	2	1	-	-	-	-
procedural (telling)	7	25	18	8	17	9	16	14
procedural (questioning)	-	1	-	-	-	-	8	2
prediction (telling)	-	-	-	-	-	-	-	-
prediction (questioning)	-	4	2	-	-	-	-	1
n =	124	175	166	157	175	196	275	1268

Worksheet activity	Practical activity	Composite activity	Craft-based activity

It was decided to treat the data contained within the audio recording differently from the data obtained through observation of the lesson. Previously a twenty-second interval recording format was used with observable behaviours, which were essentially mutually exclusive, being recorded at the end of each recording interval; the generic pupil activities were not necessarily mutually exclusive. The recording format had the advantage of reducing the possibility of recording overload which could have arisen if all behaviours were to be recorded. However, the audio recordings do allow for all behaviours to be recorded as the transcript can be read and reread as necessary. Consequently a modified interval recording format was used with all instances of student dialogue (*e.g.* factual telling), occurring within each twenty-second time interval, being recorded. However, different instances of student dialogue were only recorded once within each time interval.

Both students relied almost exclusively upon *descriptive and factual talk* where the focus of the verbal interaction is to elicit a factual response, or to pass on some factual information (see Table 9.7). This may take the form of a question (34% : 51%), which is invariably a closed question, or more simply the pupil is told (60% : 39%) factual information. A variation of this descriptive and factual talk is talk which relates to the *procedures* necessary to complete the tasks set. Pupils can be told (7% : 8%) or asked a question which seeks to elicit that they know what to do. Student T4 also engaged the pupils in causal explanation (2%) by which she asked, for example, to explain the significance of the sun to plant growth. Most of the student talk (see Table 9.8) did not relate to investigative processes (90% : 65%). However, there was some process talk centred on *observation* (5% : 35%) and on *raising questions* (5% : 0%) with respect to the characteristics of a good site for a dam (Student T1).

Table 9.8: Focus of student dialogue in the observed lessons

Focus of dialogue	T1	T2	T3	T4	T5	T6	T7	ALL
planning	-	-	7	-	-	-	34	8
raising questions	5	6	3	-	-	-	-	2
hypothesising	-	7	3	-	-	-	-	1
observation	5	10	15	35	-	-	-	9
measurement	-	6	-	-	10	-	-	2
recording	-	11	17	-	-	-	5	4
interpretation	-	15	7	-	-	-	-	3
critical reflection	-	-	-	-	-	-	-	-
no interaction	90	46	49	65	90	100	61	71
n =	108	137	118	141	141	144	220	1009

Worksheet activity	Practical activity	Composite activity	Craft-based activity

9.3 Practical activity lessons

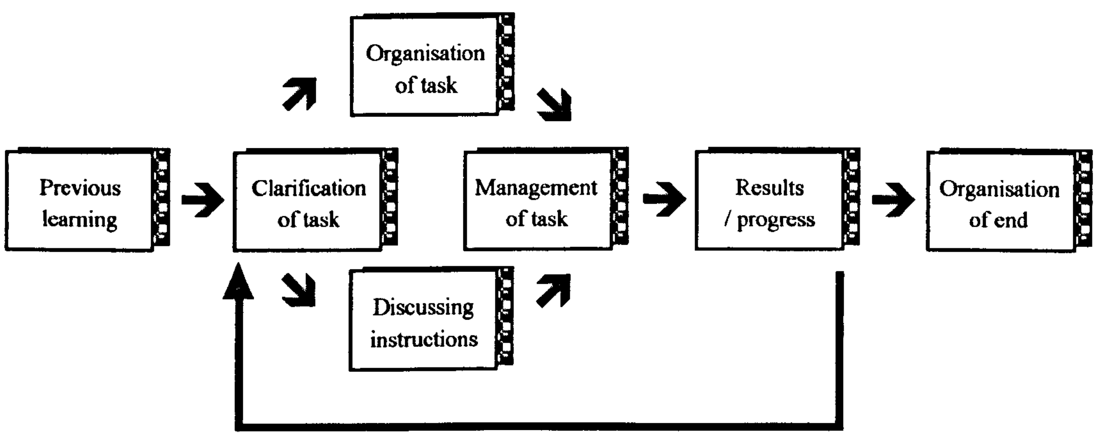
Student T2 and Student T3 planned lessons which structurally commenced with a brief exploration of the pupils' *previous learning* which was relevant to the tasks to be undertaken (see Table 9.2). These lessons required the pupils to utilise an agreed methodological approach on, several materials, giving rise to a cyclical sequence of activity (see Figure 9.2):

- clarification of task,
- organisation of task / resource management,
- discussion of instructions,
- management of task,
- results and progress.

Most of the *organisation for the task* (*e.g.* distribution of materials) took place prior to the start of the lesson, so reducing any time loss due to the distribution of materials, although there were some additional organisational tasks to be undertaken during the lesson. *Organisation for the task* along with *discussing instructions* formed part of a flexible transition strategy in supporting the pupils in their understanding of the task, and meeting the ever-changing requirements of the activity, at a given moment in time.

Each of the component parts of the lesson, especially the transition points, were managed by verbal interaction between the student and the pupils. Furthermore each of the component parts was of short duration, not usually exceeding three minutes. Whilst the pupils were engaged on the investigative activity the student was involved in monitoring their work through movement between the groups engaging in observation as well as verbal interaction (*i.e. management of task*). Each student sought to link two activities, conducting the experiment and the write-up of results. Consequently this lesson involved a range of different and repeating pupil activities, none of which lasted for prolonged periods of time. The cyclical pattern to the lesson structure was linked to the repetition of pupil activity. However, although the experimental methodology remained the same, the change in the substances effectively made each experiment different.

Figure 9.2: Sequence of structural elements in practical-activity lessons



The lessons also incorporated a range of generic pupil activities (see Table 9.4) which further promoted a diverse learning experience. The pupils were involved in:

- preparation,
- investigation,
- reporting.

In preparing for each phase of the lesson the pupils were involved in dialogic interaction (*i.e. listening* and *talking*) which aimed to develop their knowledge and understanding as well as ensure that they were organised to undertake the investigative task. This was largely accomplished as a whole-class activity (59% : 60%) although there was some individual activities (8% : 16%) when the pupils were asked to predict the likely outcomes of the investigative activity. Once the pupils had been supported, in terms of their understanding of the task they were invited to carry out the investigation.

Table 9.9: Multi-phase lesson

	Phase 1	Phase 2	Phase 3
Focus of activity	Preparation	Investigation	Reporting
Pupil activities	Listening, talking	Using resources, watching, writing	Listening, talking
Resources	Poster	Water, tray, materials, *etc.*	Written record
Assessment	Verbal responses	Observation of work Completed worksheet	Verbal responses
Pupil grouping	Whole class Individual (I)	Groups	Individual from group
Process skills	Hypothesising	Observation Recording Interpretation	Recording
Time allocation	59% : 60% 8% : 16% (I)	33% : 24%	

The investigative task incorporated the *use of resources*, *watching* and *writing* activities. The pupils were asked to make a written *record* of their findings. This record of findings also featured in the final phase of the lesson with the pupils *reporting* their findings orally to the rest of the class. The reporting sessions formed part of the assessment strategy whereby the student checked, through verbal interaction, that the pupils had appropriate results and, interestingly, involved the whole class in verifying that the results were consistent with the evidence gathered by the other groups. The student also intended to examine the written record produced on the pupils' worksheets. Thus the pupils were active throughout the lesson engaged in range of activities, each lasting for a short duration, giving the lesson a sense of flow. The investigative activity and reporting was taken forward by the pupils working in groups (33% : 24%). Consequently, this was a multi-phase lesson (see Table 9.9) in terms of the focus of the activities undertaken, with process skills being incorporated into each phase of the lesson.

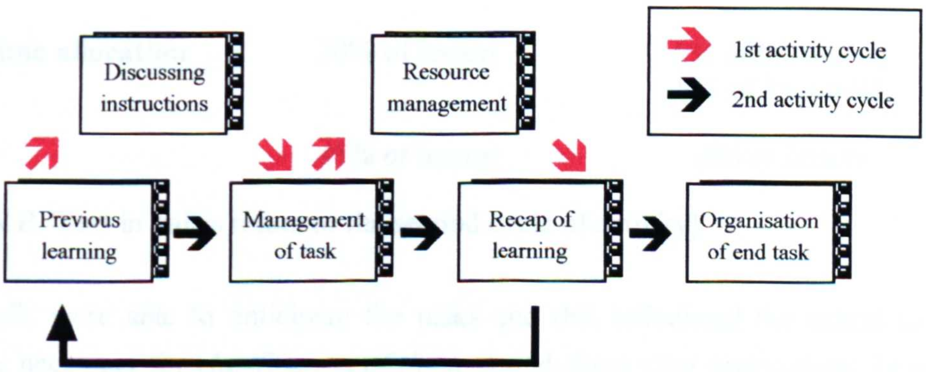
The students continued to make use of *factual talk* (see Table 9.7) through telling (37% : 40%) and questioning (33% : 37%). However, there is also a significant amount of talk related to *procedural* matters (26% : 18%). This is understandable as the pupils need to understand what they have to do in order for the investigative activity to be successful. The unusual feature of the dialogue within these lessons is the engagement of the pupils in *predicting* likely outcomes (4% : 2%). As the lesson contained pupil process activities there was a significant amount of dialogic interaction (54% : 51%) focussed on these activities (see Table 9.8), indeed the only process skill not examined was that of critical reflection.

9.4 Composite activity lesson

Within the structural elements of the lesson (see Table 9.2) there are two activity cycles (see Figure 9.3). Within each of the two activity cycles there were two key phases of activity, the first of which is an *exploration of learning* followed by a *consolidation of learning* (see Table 9.10). Structurally each cycle consisted of:

- previous learning;
- discussing instructions / clarification of task;
- management of task;
- recap of learning.

Figure 9.3: Sequence of structural elements in composite lesson



The observed lesson was heavily influenced by the fact that this was one of a series of lessons. Much of the lesson was taken up with a review of *previous learning*. There appeared to be little intended development of the pupils' knowledge base in either cycle, as these covered material taken from a programme of work in the process of being delivered. However, in the second cycle, the student was willing to respond to pupil-directed questions with respect to electrical circuits in the home which did extend the pupils' knowledge base. Throughout the lesson the pupils appeared to be firmly in control of the knowledge base being explored.

Table 9.10: Repeated two-phase lesson

	Phase 1	**Phase 2**
Focus of activity	Exploration of learning	Consolidation of learning
Pupil activities	Talking, listening, watching, *etc.*	Reading, writing, using resources, *etc.*
Resources	None	Materials for simple battery-powered circuit Worksheet
	None	*Worksheet*
Assessment	Verbal responses	Completed circuit Completed worksheet
	Verbal responses	*Completed worksheet*
Pupil grouping	Whole class	Paired groups (G) + individual (I)
	Whole class	*Individual*
Process skills	None	Observation Recording
	None	*None*
Time allocation	30% of lesson	5% of lesson (G) 9% of lesson (I)
	48% of lesson	*8% of lesson*

[*N.B.* Text in italics refers to the second cycle of activity]

The pupils were able to anticipate the tasks and this influenced the extent to which time was necessary for *clarification of the task* and *discussing instructions*. In addition there was only a limited amount of time spent by the pupils in completing the tasks set. Indeed the practical element of the first task, which involved the construction of a battery-operated circuit, was completed inside twenty seconds by one pair of pupils. The follow-up task, drawing the completed circuit, was completed inside two minutes by the pupils. Organisation of the task, involving the distribution of materials, was not necessary as all of the resources had been put in place prior to the commencement of the lesson. The pupils' performance was determined by the student observing the pupils progress as well as through an examination of the completed worksheets. Each cycle was then completed by a *recap* of the key learning outcomes. Following completion of the task there was a tidy up (*i.e. resource management*) which led into the *recap* session. This lesson also included some time during which the pupils were *non-active* as the student found in necessary to engage in activities aimed at managing inappropriate behaviour.

The pupils' involvement with process skills was limited to producing a *record* (9% of the lesson time) of their battery-powered circuits on the worksheet provided (*i.e.* draw and label their completed circuit). In addition to the process activities there are a range of generic pupil activities (see Table 9.4) evident in the lesson. That the pupils were engaged in the lesson, is evident by the spread of generic pupil activities. Structurally there was a '*listening / watching*' phase, which corresponded to the whole class activity (78% of the lesson) during which there was considerable student-pupil *talk*, followed by a '*writing*' phase which formed the individual pupil activity (17% of the lesson). There was also some practical work, accomplished as part of a paired group (5% of the lesson time) during which the pupils *used resources* (see Table 9.5).

Student T6 relied exclusively upon *factual talk* (see Table 9.7) with 91% of all dialogic interaction being linked to providing (*i.e.* telling) or eliciting (*i.e.* questioning) factual information; the remaining 9% of talk related to providing information about *procedures* to facilitate pupil understanding of what they had to do to complete the tasks set. Structurally this lesson is similar to that of the worksheet-driven lesson apart, that is, from the repeated cycle of activity.

9.5 Craft-based lessons

The observed lesson has a simple sequence of structural elements (see Figure 9.4). Within this sequence the lesson contains two key phases of activity, the first of which is an *exploration of learning* (see Table 9.11). This phase of the lesson involves all of the class in a question-and-answer session during which the student attempts to elicit the pupils' *previous learning* which is relevant to the topic to be explored. The development of the pupils' knowledge base is incremental and the transition between previous and new learning, borne out of a practical activity, is managed through *clarification of the task.*

In establishing a link between previous learning and the task to be undertaken the student had laid the foundations for a more detailed examination of the 'nuts-and-bolts' of the task. Student-directed questioning leads the pupils in *discussing instructions.* The students' intended outcome for this part of the lesson was the development of an 'agreed method'. This phase of the lesson consists almost exclusively of oral work during which the pupils participate in *listening*, *watching* and *talking* activities with their performance assessed on the basis of their verbal contributions. Dialogic interaction was factual in nature with the student simply telling the pupils the answer or asking questions which lead to a known answer. There was also a substantial input of talk linked to procedural matters (*i.e.* the pupils know what to do and why).

Figure 9.4: Sequence of structural elements in craft-based lessons

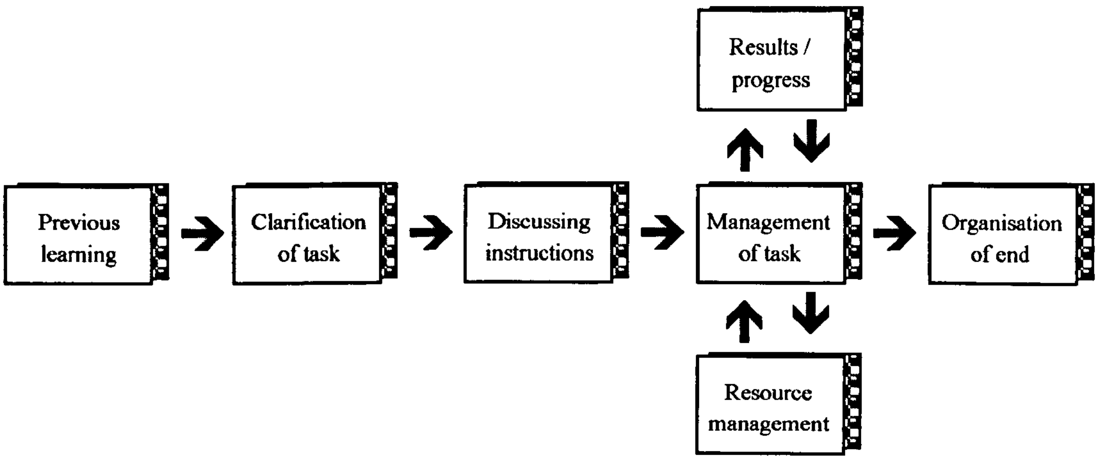


Table 9.11: Two-phase lesson

	Phase 1	Phase 2
Focus of activity	Exploration of learning	Consolidation of learning [Practical activity]
Pupil activities	Talking, listening, watching, *etc.*	Reading, writing, using resources, *etc.*
Resources	Blackboard	Worksheets, Materials for artifact
Assessment	Verbal responses Agreed method	Completed artifact
Pupil grouping	Whole group	Paired groups + individual (I)
Process skills	Planning	Recording, measurement
Time allocation	53% : 49%	47% : 36% of lesson 0% : 15% (I)

The transition between agreeing the 'method' and embarking upon the practical activity was abrupt. *Resource management* (*i.e.* provision of resources) commenced at this point and continued, as required, throughout the period that the pupils were engaged on the task. The practical or craft activity forms the basis of the second phase of the lesson which has as its focus a *consolidation of learning*. The student observed the pupils as they undertook the practical activity in order to monitor progress: *management of task.* The end phase of the lesson saw the student spending some time reviewing the *result / progress* of individual groups whilst the other groups continued with the task. The lesson ended with the resources being returned (*i.e. organisation of task*). The pupils' performance was assessed by an examination of the completed artifact.

Student T7 introduced the pupils to process skill activities (see Table 9.3) through student-pupil dialogue. A considerable amount of time was given over to *planning* (34%). This was developed by one of the pupils in each pair drawing the circuit whilst the other pupil *recorded* (5%) the agreed methodology. Student T5 introduced the pupils to measuring (7%). The rest of each lesson (93% : 61%) involved the pupils in non-process activities. Both lessons incorporated whole-class, group and individual activities (see Table 9.5). Agreeing the methodological approach formed the main part of a whole-class activity (53% : 49%). Student T7's groupwork consisted of an individual task (15%) during which time the outcomes of the whole-class interaction were recorded. This was followed by collaborative work in both lessons during which each group sought to construct an artifact (47% : 36%).

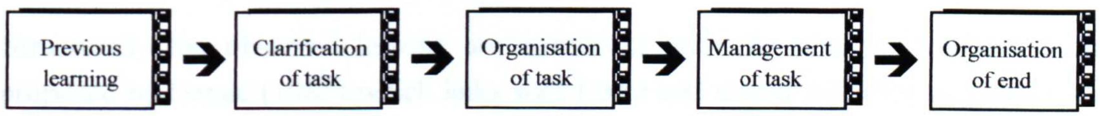
The lesson also incorporated a range of generic pupil activities (see Table 9.4). In preparing for each phase of the lesson the pupils were involved in dialogic interaction, *listening* (32% : 9%) *and talking* (31% : 49%) which aimed to develop their knowledge and understanding as well as ensuring that they were *organised* and would follow the agreed methodology in undertaking the activity. The outcome of this dialogic interaction was recorded in *writing* (0% : 11%) on a worksheet and in the pupils' science jotters. The construction task incorporated the *use of resources* (37% : 28%) supported by *talking*. Thus the pupils were active throughout the lesson engaged in range of activities each of which took considerable periods of time to complete.

Both students were heavily reliant upon *factual talk* (see Table 9.7) with 84% : 76% of all dialogic interaction being linked to providing (i.e. telling) or eliciting (i.e. questioning) factual information; the remaining talk related to providing information about *procedures* (17% : 24%) to facilitate the pupils' understanding of what they had to do to complete the task set. The focus of the dialogic interaction, for Student T7 (see Table 9.8), was limited in terms of the process activities being confined to *planning* (34%) and *recording* (5%) with the remainder of student talk being non-process related. The main focus of talk for Student T5 was linked to the measurement activity (10%).

9.6 Concluding remarks

The pre-service students indicated that their preferred pedagogical framework was constructivist in orientation (see Chapter 7). However, an awareness of learning theory does not necessarily translate into practice. Consequently, the purpose of this chapter has been to look beyond *what they think and say they do* in order to examine *what they actually do*. Lessons generally consisted of a simple sequence of structural elements (see Figure 9.5). Within this sequence the lesson contains two key phases of activity, the first of which is an *exploration of learning*. This phase of the lesson involves all of the class group (see Figure 9.6) in a question-and-answer session during which the student attempts to elicit the pupils' *previous learning* which is relevant to the topic to be explored.

Figure 9.5: Sequence of structural elements in generic lesson



The development of the pupils' knowledge base is incremental and the transition between previous and new learning is managed through *clarification of the task*. This phase of the lesson consists almost exclusively of oral work during which the pupils participate in listening, watching and talking activities with their performance assessed on the basis of their verbal contributions (see Figure 9.7). *Organisation of the task*, involving the distribution of materials, precedes the second phase of the lesson which is focussed on a *consolidation of learning*. During this part of the lesson the pupils worked individually (see Figure 9.6) using the resources provided. The student observed the pupils as they undertook the activity in order to monitor progress: *management of task*. The pupils' performance was assessed by an examination of the completed worksheets, reported findings and artifacts. These structural elements follow a similar pattern, with some cyclical variations and group work in lessons with a practical focus.

Figure 9.6: Frequency of pupil groupings in the observed lessons

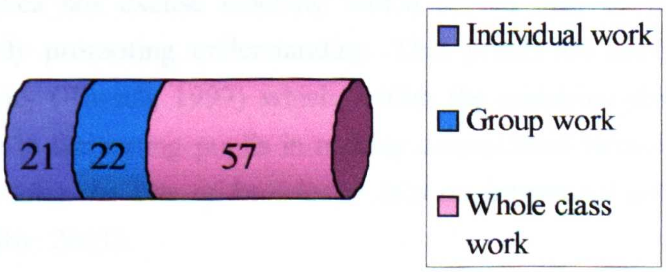
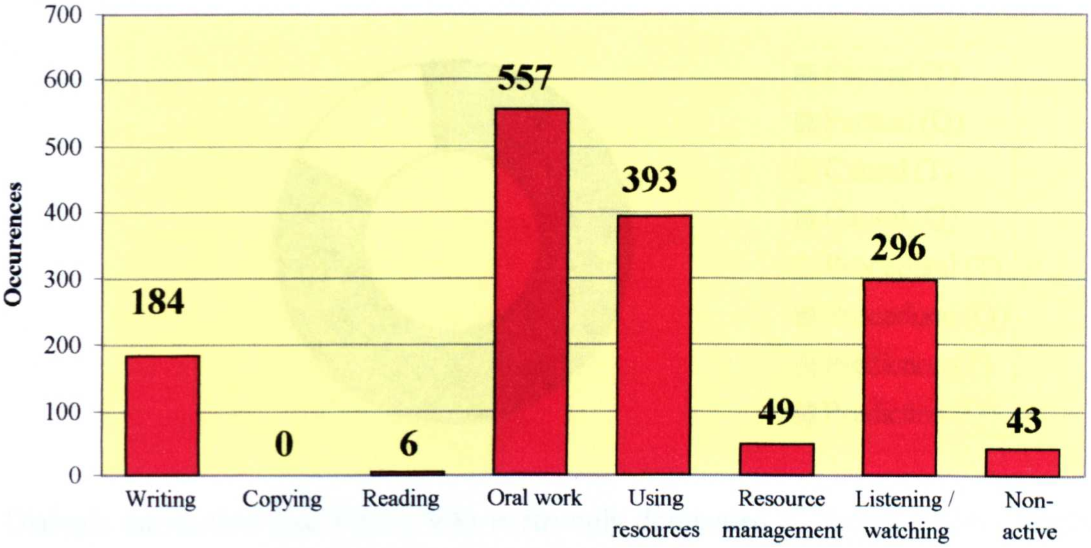


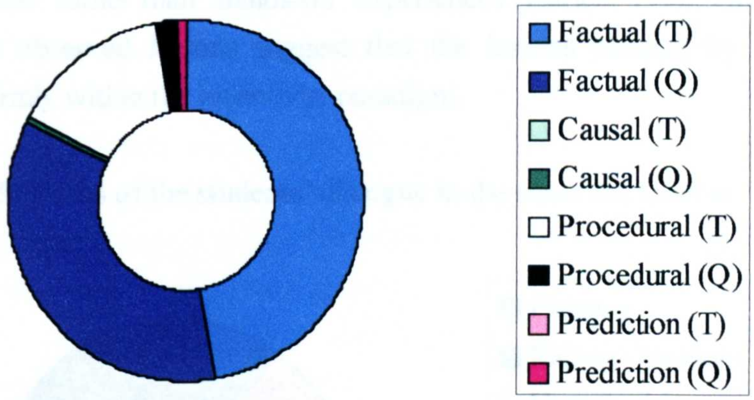
Figure 9.7: Frequency of pupil activities in the observed lessons



Structurally the observed lessons are consistent with the nine instructional events proposed by Gagné (1985) which links with Carré and Carter's (1990) suggestion that there is a generic pedagogy within the primary school, as opposed to subject-specific teaching pedagogies. This would be an interesting area for a follow-up research project. The significance of the structural elements discernible across the lessons is that lesson planning is strongly teacher dominated. The constructivist framework argues that in order to bring about conceptual understanding new experiences must challenge existing conceptual frameworks. To achieve this it is essential to ascertain the children's current state of thinking (Hollins and Whitby, 2001). Within the observed lessons previous learning is considered en passant, having little real impact upon what follows in the lesson.

The observed lessons were wedded to the objectivist paradigm, as pupils are simply retracing the steps outlined by the teacher's plan. Planning is important and difficult, as the classroom teacher is expected to prepare a programme of teaching which meets the 5-14 curricular objectives. In addition the primary school teachers work within a number of constraints such as a lack of resources and limited available time (Young, 1994; Wadsworth, 1997), to meet the multifarious demands placed upon them. However, this does not excuse teaching which serves only to provide knowledge without necessarily promoting understanding. That pupils are unable to follow their own line of enquiry (Russell, 1997) which, within the constructivist paradigm, would be more effective in facilitating pupils in making connections between their 'islands of knowledge', "*weaving the bits of knowledge into an integrated and cohesive whole*" (Hollins and Whitby, 2001).

Figure 9.8: Nature of pre-service students' dialogue in the observed lessons

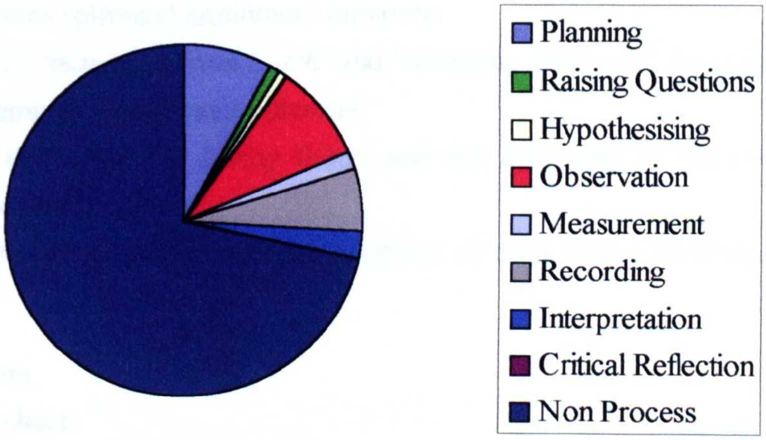


Dialogic interaction (see Figure 9.8) is strongly dominated by factual (82%), teacher-dominated talk, with some talk being procedural in nature (16%). This strong bias towards descriptive and factual talk rather than causal explanation (1%) and prediction (1%) has implications for the development of understanding in science lessons (Newton and Newton, 2000). The discourse of science appears to be dominated by 'recitation' (Newton *et al.*, 1999) with dialogic interaction focussed on verifying the pupils can reproduce predetermined answers that are deemed to be 'right'. Knowledge is not 'provisional' as the answers are known. The problem with school science is that, by and large, the answers are known. However, this does not mean that teachers should engage in a 'closed pedagogy' (Osborne and Simon, 1996), whereby they do not provide pupils with opportunities, especially during investigative activities, for exploring the "*multiple pathways through an information resource*" (Russell, 1997). As part of this pupils must also be provided with opportunities for discussion in which they are able to reflect on the experiences we provide for them in science education, and what these experiences mean in relation to their conceptual understanding.

Primary science education should be about developing broad conceptual knowledge, skills and understanding so that the pupils can tackle new situations and develop new concepts (Hollins and Whitby, 2001). However, lesson structure combined with dialogue appears to be aligned to the objectivist paradigm, producing a 'closed-loop' pedagogy. This pedagogy consists of teacher exposition followed by teacher-directed questioning which seeks to elicit known answers rounded off by an activity which looks backwards (*i.e.* consolidating learning), so completing the loop. Furthermore the discourse of science involves little interaction in terms of process skills (see Figure 9.9). Most talk is not related to process (72%) with establishing an 'agreed method' (*i.e.* planning -- 8%), observation (9%) and recording (5%) being the main foci for process talk. Process talk tends to be found mostly in practical activity and craft-based lessons.

However, this talk tends to concentrate on the procedural aspects of the activity rather than the development of scientific understanding. Consequently practical activities tend to be mostly 'hands-on' rather than 'minds-on' experiences (Harlen, 1992; Hollins and Whitby, 2001). The observed lessons suggest that the lessons planned by the pre-service students fit firmly within the objectivist paradigm.

Figure 9.9: Focus of the students' dialogue in the observed lessons



The next chapter continues to explore, through an examination of science talk, the dissonance between the students' stated intentions of what should happen in teaching and learning environments, outlined in Chapter 7, and the actuality of the experiences the observation sample of students provide for learners.

CHAPTER 10 SCIENCE TALK

10.1 Introduction

The observed lessons were used in an attempt to gain theoretical and professional insights in terms of the relationship between the students' stated intentions and actual practice with respect to teaching primary science (Tsai, 2002). These lessons were drawn from a range of knowledge strands within the 5-14 science curriculum, including:

- '*properties and uses of energy*' and '*conversion and transfer of energy*' from the Energy and Forces (physics) attainment outcome;
- '*Earth in space*', '*materials from Earth*' and '*changing materials*' from the Earth and Space (chemistry) attainment outcome;
- '*processes of life*' from the Living things and the processes of life (Biology) attainment outcome.

The students provided a range of materials in support of their lesson planning. These materials included:

- lesson plans,
- pupil worksheets,
- pupil resource sheets [10.1].

These materials were requested in the letter sent to the students inviting them to participate in the observational phase of the research. The main purpose was to allow myself to quickly establish the focus of the lesson prior to its commencement. At the time of issuing the letter I did not feel that this was 'problematic' in that lesson plans are a normal feature of the student's planning process. However, on further reflection this may have affected the nature of the lessons observed, in that lesson plans tend to define learning in terms of end products achieved through specific attainment outcomes (*i.e.* pupils will be able to); this is consistent with the notion of a product-based curriculum. It could be argued that such a focus would align the lessons to an objectivist pedagogy in that it is the teacher, rather than the learner, who determines the direction that the lesson takes. This plan tends to 'fix' the teachers' words, questions to be asked and pupil activities in advance. It would be interesting to examine whether not requesting a lesson plan would make a difference to the nature of the lessons observed. For my part I would think not, as lesson planning is a feature of the process of enculturation that takes place across ITE subject departments within the university.

Teaching was carried out in a range of classroom contexts ranging from the traditional,

10.1 The data gathered from each of the observed lessons has been collated into a separate volume of Support Materials. This will provide research students, at the Centre for Science Education, with a database for future analysis. This material includes lesson plans, pupil worksheets and pupil resource sheets.

multi-purpose primary classroom (see Figure 10.1) to the multi-purpose, open-plan primary classroom (see Figure 10.2) which are not specifically designed for science lessons, particularly lessons which involve some experimental work. The importance of the area in which science lessons are taught has been a feature of a number of recent reports such as a 'Science Strategy for Scotland' which states that:

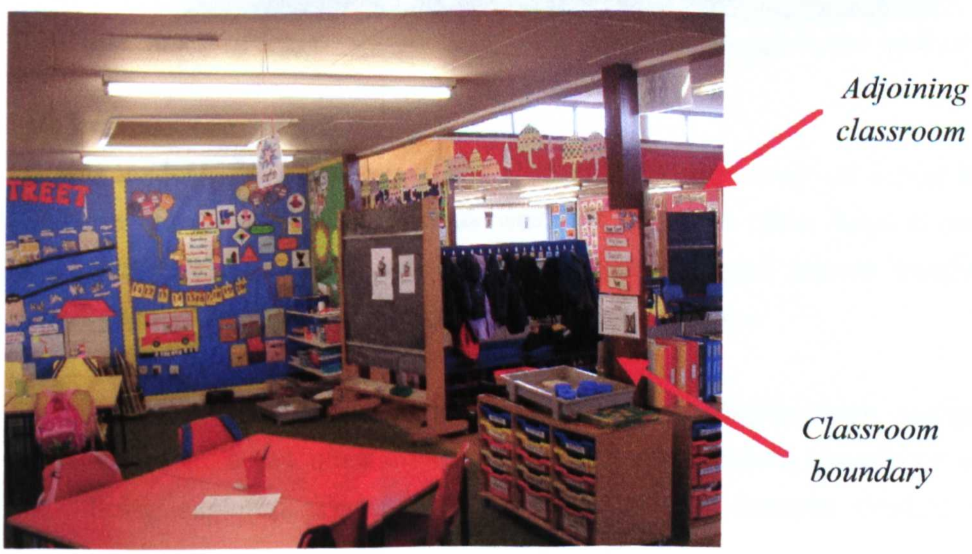
> *science should be taught in a safe, modern environment that promotes effective learning. In many schools, there has been relatively little investment in science equipment and accommodation in recent years*
>
> [SEELLD, 2001, p.31]

The subsequent findings of the Scottish Science Advisory Committee contained within its report 'Why Science Education Matters' recommended that:

> *all primary schools should have a dedicated science room, or in smaller schools dedicated science space, where children can be taken out of their normal classroom environment to engage in science activities*
>
> [SSAC, 2003, p.4]

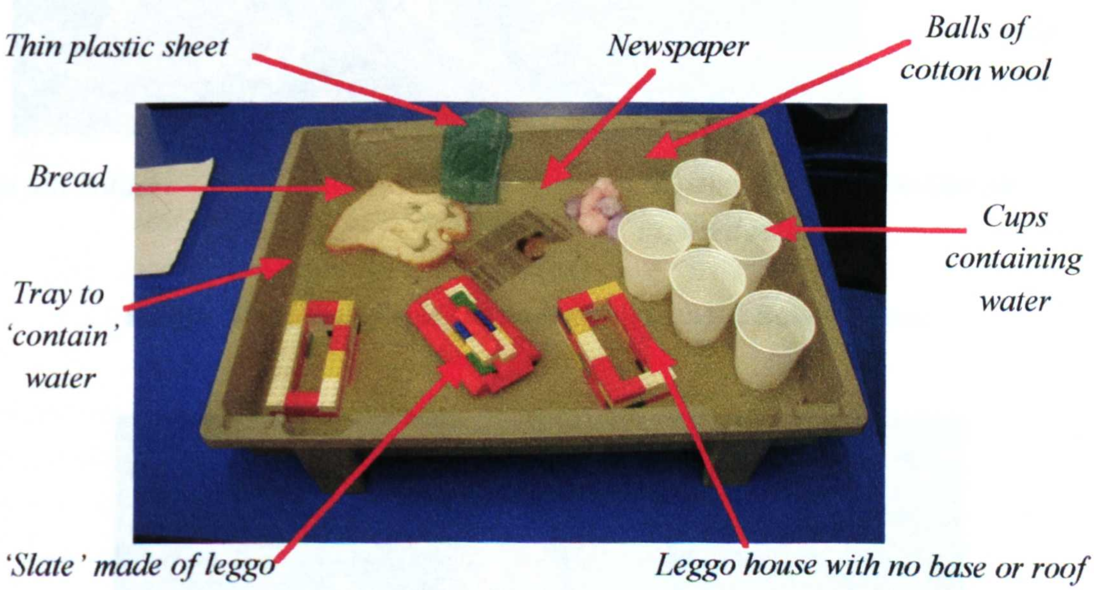
Figure 10.1: Traditional, multi-purpose primary classroom

Figure 10.2: Open-plan primary classroom



The Depute First Minister's, Mr Jim Wallace, response (July 2004) to the SSAC report 'Why Science Education Matters', with respect to this recommendation, indicated that Education Authorities will continue to receive additional funding to support school science up until March 2006. How Local Authorities decide to allocate this funding is a devolved matter. Clearly in schools where space is at a premium it is most unlikely that 'science rooms' will become little more that an aspirational goal. The extent of the funding problem can be illustrated by the paucity of specialised scientific equipment available to the students. Practical science lessons entails students using their imagination to providing most of the resources themselves (see Figure 10.3 and Figure 10.4). Considerations of teaching space and resourcing lessons requires the students to recontextualise knowledge gained and codified in one context to facilitate transfer to another context. In addition the learning experience itself requires active interpretation and reconstruction of the skills and knowledge (Tuomi-Gröhn, 2003).

Figure 10.3: Resources for investigation of 'water-proofness'



10.2 Classroom activity

It was evident, for a number of the students, that the observed lesson was one in a sequence of lessons. The previous work of the class often formed part of a wall display (see Figure 10.5). All but one of the observed lessons involved practical activity with the key activities discernible being as follows:

- *whole-class activity*

  The initial phase of the lesson involved the pupils being engaged, through student-directed questioning, in stating their previous knowledge on the topic being explored. The pupils' performance was assessed through their verbal responses during the question-and-answer session. The outcome of this interaction was used as a link to the next part of the lesson.

Figure 10.4: Resources for construction of 'steady-hands test'

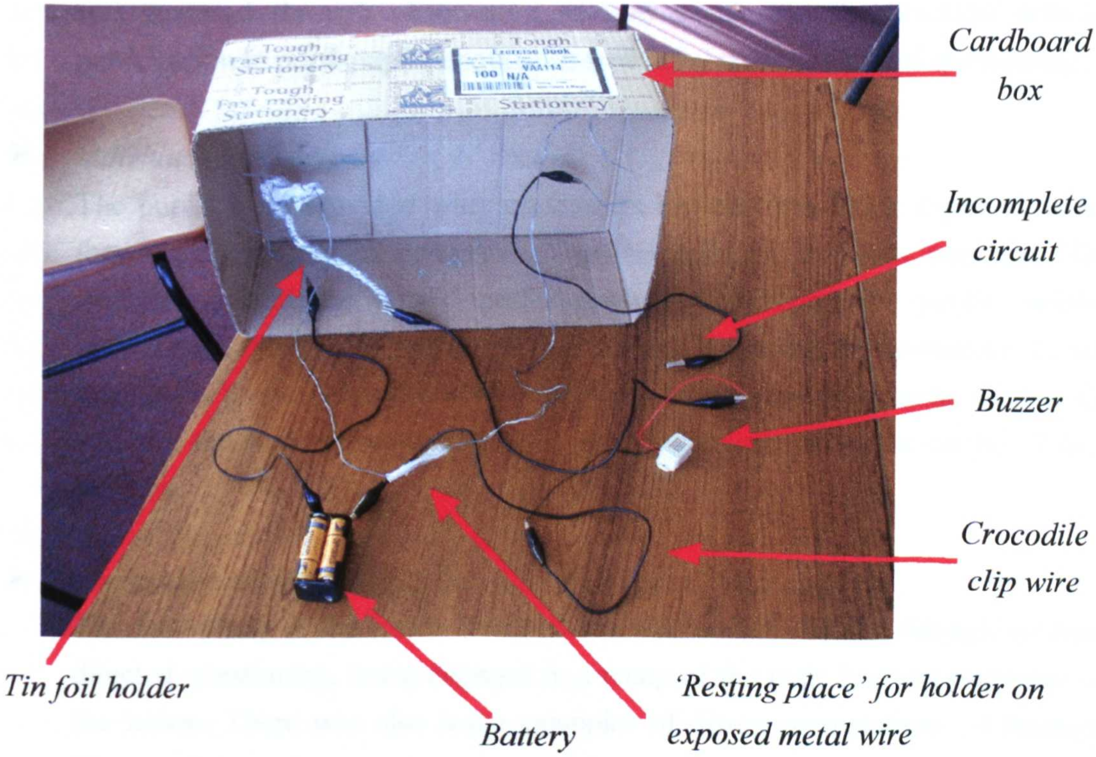
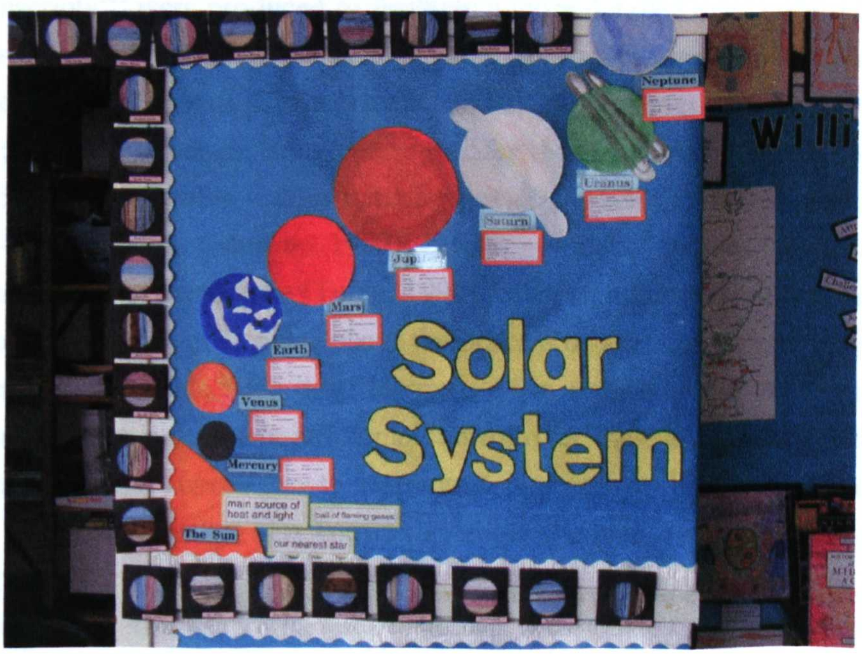


Figure 10.5: Wall display of pupils' work on the Solar System



- group activity

  The class was divided into a number of groups with the pupils being invited to work collaboratively completing the activity using the agreed method (*e.g.* dissolving substances in water, completing a scaled model of the Solar System, constructing a steady-hands test, *etc*). The student would move between the groups engaging them in discussion about their findings. The pupils' performance was assessed through observation as they conducted the practical activity, participation in pupil-pupil discourse as well as by student-directed questioning.

- *individual pupil activity*

  The pupils were provided with worksheets on the topic being explored which they were expected to complete using the resource materials provided. The student assessed the pupils' performance by examining the pupils' written answers and through student-pupil questioning. Following the completion of any practical activity the pupils were engaged in writing up their result. During the write-up the student moved about the groups enquiring as to the nature of their findings.

- whole-class activity

  The final phase of the lesson involved the whole class, largely through student-directed questioning, being engaged in a recap of the main learning outcomes of the lesson. There was also some examples of group presentations of findings. The pupils' performance in this activity was assessed through their verbal responses.

Lesson transcripts[10.2] were produced to facilitate a more detailed examination of student talk focussing upon the science and the nature of the pedagogy deployed to take forward the observed lessons. There is evidence that the observed lessons were planned in advance; with the structure being determined by the pre-service student rather than, as would be the case within a constructivist paradigm, being constructed around the pupils' pre-exisiting ideas (Murphy, 1997). Learning science involves constructing new ways to make sense of experience (Tobin, 1997). Such an approach requires teachers to engage pupils in thinking or learning about the process of learning; as well as processing the material to be learned. Such deep learning, often referred to as metacognition, is necessary in order to give the pupils some control over their learning. For teachers to develop metacognitive approaches to learning it is necessary that they not only have knowledge of the subject, but also knowledge about the teaching and learning process,

10.2 The data gathered from each of the observed lessons has been collated into a separate volume of Support Materials. This will provide research students, at the Centre for Science Education, with a database for future analysis. This material includes a set of lesson transcripts.

what has been called pedagogic knowledge (Shulman, 1987; Harlen, 1992; Qualter, 1999). Teachers need to know science as well as what is necessary to teach and learn science.

Consequently it is insufficient to simply dispense information, or to provide practical activities which merely keep the pupils occupied. Practical activity by itself does not necessarily relate to learning unless it is built upon a known reference point in terms of the pupils' pre-existing ideas; what they have to learn and how this learning should be accomplished (Heywood and Roberts, 2002). Designing activities merely to provide a 'hands-on' experience is insufficient (Harlen, 1992) unless it is supported by dialogue (*i.e.* 'minds-on') which seeks to support understanding (Newton, 2000). What is required are strategies which challenge the pupils' preconceived notions in order that they may revise their views in accordance with accepted scientific thinking (Driver and Bell, 1986; Louden and Wallace, 1994). Otherwise 'teacher telling' of the stated learning outcomes, for any given lesson, is likely to be misconstrued or ignored if this conflicts with the children's pre-existing ideas (McGuigan and Russell, 1997).

10.3 Prior learning

An examination of the pupils' pre-existing ideas is likely to reveal that there are a range of views on any given topic, that there are different levels of sophistication in articulating these views, and that these views may fall short of what they are expected to know. However, pupils often are in possession of learning experiences which are relevant to the topic being explored (see Extract 10.1) exemplified by a P1 class who were aware of 'materials which are good for a roof'. This knowledge, prior to the teaching intervention, is essential in order to inform the pre-service teachers planning such that they may develop learning activities which will bring about progression in the children's thinking (Millar and Murdoch, 2002). This progression can be described in terms of the 'learning demand' necessary to bridge the gap between the children's own ideas and the science to be taught (Leach and Scott, 1995). Bridging the gap will be difficult in this instance as they are going to *pretend* that a leggo brick roof is the same as slate which is likely to cause confusion amongst the pupils.

Extract 10.1

22 T3: What else might we want to use?
23 P: Slates.
24 T3: Slates. Well, I don't have a slate but I do have a roof made from bricks, well leggo bricks so we're going to pretend that's our slates today, right.

It is clear from the lessons observed that the pre-service teachers do not examine the children's views, which are sometimes referred to as 'idiosyncratic conceptions' (Wadsworth, 1997) or 'misconceptions' (Novak, 1977; Driver and Easley, 1978), in any detail. Vosniadou (1991), working with astronomy students, suggests that learners develop one of three distinct mental models which help them to assimilate scientific phenomena:

- intuitive -- based on the world as experienced by the learner;
- scientific -- based on currently accepted scientific thinking;
- synthetic -- based on a combination of intuitive and scientific views.

The latter, synthetic model, leads to the formation of 'misconceptions' in that the learner accommodates aspects of the scientific view without fully discarding their erroneous intuitive view. Effective teaching interventions, following an exploration of what the pupils know, allows for a transition from the intuitive to the scientific view. Ogborn (1997) suggests that effective teaching within the constructivist paradigm should give high priority to making sense to pupils; using what they know and addressing difficulties that may arise from how they imagine things to be. However, most of the observed teaching did not examine prior learning in any meaningful way.

Lessons did commence with a brief exploration of previous learning (see Extract 10.2), but this, at worst, is little more than repetition of the known (Selley, 1999) as evident from a lesson examining the different types of energy. Furthermore there was no attempt to distinguish between new knowledge which was consistent with the pupils' understanding. and new knowledge which was inconsistent with the pupils' understanding (Vosniadou, 1991). This is important in that new knowledge which is consistent with the pupils' pre-existing knowledge can be easily assimilated and presented as factual, utilising the objectivist paradigm. However, new knowledge which is inconsistent with the pupils' conceptual structures cannot simply be told to them, otherwise misconceptions are likely to arise, as the pupils will attempt to reconcile their intuitive views with the scientific view leading to the creation of a synthetic view. To prevent this it is necessary for the students to operate within the constructivist paradigm when designing their teaching intervention. The students are either not aware that the pupils' preconceptions can interfere with science learning (Summers, 1994), or they believe that these preconceptions can be realigned in a manner consistent with the scientific view by the teaching intervention which the student has designed. This is a simplistic view of the relationship between teaching and learning.

Extract 10.2

22	P:	Electrical.
23	T1:	Electrical Robin.
24	P:	Chemical.
25	T1:	Chemical.
26	P:	Kinetic.
27	T1:	Kinetic Andrea.
28	P:	Light.
29	P:	Potential.

However, there was evidence that student-directed questions, deployed at the commencement of the lesson to elicit the pupils' previous knowledge, was developed into an exploration of the pupils' understanding. One of the lessons involved an investigative activity examining what happens (see Extract 10.3) when specified substances are mixed with water. The student was not simply content with obtaining the desired answer (*i.e.* dissolves) but sought to verify that the pupils understood what this meant in terms of observable changes. Here the student is providing the pupils with an opportunity to experience science as an active, social process of making sense of experience.

Extract 10.3

32	T2:	Okay, what happens when you put tea or coffee in a cup, or you mum or dad puts coffee in a cup, what happens when they add the water? Simone?
33	P:	It dissolves.
34-37 38-40 41	T2:	It dissolves. That's a good word. That's the word we were looking for. Who else has heard of that word? Most people, Okay. I'll write it on the board. Okay, when it dissolves, can you still see it in the cup? Can you still see the little granules of coffee, or does it turn into something else.
42	P:	It disappears.
43-46	T2:	It disappears. What does it turn into? What does it look like? Does it still look like the little granules, Simone?
47	P:	It makes the water coloured.

The pupil's response that the substance disappears was accepted; however, although substances may no longer be visible they do not 'disappear' when they dissolve (*e.g.* you can taste dissolved sugar in water). Interestingly, that substances 'disappear' when they dissolve is supported by the curriculum guidelines which state that the solution that forms should be clear if the substance has dissolved. The curriculum guidelines are not scientifically accurate; a powdered iodine crystal, obtainable from a chemist, dissolves producing a dark-coloured solution. There is another inconsistency here for although the student accepted that '*it disappears*', as being the same as dissolving, this is clearly not the case with respect to granular coffee. Coffee does not disappear '*it makes the water coloured*'. The student was able to extricate herself from this cognitive conflict, derived from an adherence to the curriculum guidelines, by shifting the focus to observable changes as an indicator of the substance dissolving (*e.g.* What does it turn into? / What does it look like?). This student-pupil interaction suggests that this student had an understanding of the science in addition to well-developed teaching skills enabling her to shift the focus of the questioning in order to 'scaffold' the pupils' understanding.

In a lesson on the parts of a plant, pupils were able to make connections between previous and new learning which the student used to consolidate learning (see Extract 10.4). Here a pupil makes a connection between light, or a lack of light, and the pale colouration of a plant's roots. This was extended by the student when she answered her own question with respect to an experiment on growing plants in a cupboard. The accuracy of the student's response was challenged by a pupil who indicates that green was detectable in these light-deprived plants. The significance of these observations is that a link is established between the green colouring of leaves (*i.e.* chlorophyll) and sunlight by the pupil. The student used discourse to mediate learning with the pupils engaged in an exploration and development of meaning derived from disparate but linked experiences.

Extract 10.4

36-37	T4:	Down. Have a look at the picture, what colour are the roots there, Paul?
38	P:	White.
39	T4:	They are, they're kind of white aren't they?
40	P:	White and yellow.
41	T4:	They are.
42	P:	It's in a dark place.
43-44	T4:	Right, what colour were our plants that we grew in the dark, Dominic? They weren't green, they were kind of white and yellow and they were a funny kind of colour weren't they?
45	P:	Miss, they had a bit of green.
46-47	T4:	They had a wee bit of green when they'd had a wee bit of light.

In another lesson the pupils, with the support of the student, had been able to provide a detailed description of how to construct a battery-powered electrical circuit based on their previous learning. The impressive feature of this dialogic interaction was that the pupils were able to visualise the circuit and develop an agreed sequence to the steps necessary for its construction. Here knowledge on how to construct a *completed circuit* is not handed-on, nor is it discovered by an individual but rather it is borne out of a social and collaborative process of co-construction (see Extract 10.5). Unfortunately the student failed to establish that a steady-hands test requires the construction of an *incomplete circuit* which is completed only when the holder touches the exposed wire causing the buzzer or light to be activated. Although important this was little more than an oversight on the part of the student as she was aware of this as in an earlier exchange when she supported a pupil's understanding of the task by stating, "*you're trying not to make it light*".

Extract 10.5

256-258	T7:	Sorry? Connect crocodile wire to battery. Right. Okay let's double check this, Kirsten?
259		Our method is first of all, collect the resources that we need then cut holes in the sides of
260		the box using scissors, or you can use a compass, that might actually be better. Number
261		3, our metal wire through the sides of the box. Number four, connect crocodile wires to
262		the metal wires at the sides of the box. Connect one crocodile wire to the battery, connect
263		the other crocodile wire to the buzzer or bulb. Then connect a crocodile wire from the light
264		bulb to the battery, make a holder to go round the wire. Disconnect one crocodile wire
265		from the battery and attach your holder to the metal wire. Then connect the crocodile wire
266-267		to the battery and take the test. Have we missed out anything? Hold on Nicola's speaking.

There appears to be a range of strategies adopted by the students with respect to eliciting the pupils' prior knowledge. For some students this appears to be little more than scene setting prior to their teaching intervention suggesting an objectivist paradigm. However, there is also evidence that a number of students actively explore the learners' conceptions through active experience incorporating discourse. Such an approach is consistent with a constructivist paradigm. Currently there is no mechanism for the students to share their understanding in order that the science tutors can mediate change.

10.4 'Minds on' activity

Student T2 displayed an awareness that science investigations need to involve 'minds on', collaborative activity. During the observed lesson, on the solubility of substances in water, the pupils were given control over their own learning through engaging in discourse amongst themselves and with the student. This activity involved them working in groups examining whether materials dissolved in water according to an agreed method. The pupils were engaging in discussion about what they were observing as the student moved between the groups. Following the completion of the experiment the pupils were engaged in agreeing the outcome and writing up their results during which time the student continued to move about the groups enquiring as to the nature of their findings. The pupils' understanding was further assessed by a reporting session with each group nominating a representative to outline their results to the rest of the class. The student used questions to prompt the pupils to provide more detailed reports. Each group had their results confirmed by the class being shown the transparent beaker in which their experiment had taken place. In this lesson there was an absence of 'teacher telling' as it is the pupils who agree the learning outcomes amongst themselves based on the evidence generated from their observations. The student acts as a guide through utilising probing questions and observational prompts which facilitates movement within the individual pupil's zone of proximal development. In addition the collaborative nature of the activity allows for 'more knowledgeable others' (MKO's) to mediate learning.

Another good example of the student's well-developed pedagogic skills (see Extract 10.6) is evident in an interaction when a pupil is reporting their findings on what happens when coffee was mixed with water. A number of points are evident here. Firstly the pupil's contribution to the work of the class is respected and the student, when some pupils appear not to be listening, takes time for the pupils to remind *themselves* as to how they should treat others. This displays an awareness, by the student, of the importance of creating a quality learning environment in which we have shared rights and responsibilities. Furthermore whilst the student was prepared to accept the descriptive account of the changes that take place they, nevertheless, did not lose sight of the focus of the investigation by asking, "*did it dissolve?*" This was also verified by asking another pupil. Finally the interaction is neatly concluded by Dionne's contribution being acknowledged. This suggests that the student retained their focus on the investigative activity, engaged pupils in the activity as well as promoting a values framework which enables effective interaction between the pupils.

Extract 10.6

312	T2:	Right Dionne?
313	P:	It changed colour.
314-316	T2:	Hands on heads. Sorry Dionne, people aren't listening. What do we use for listening?
317	P:	Eyes, ears and whole self.
318	T2:	Okay, Dionne nice loud voice.
319-320	P:	It changed colour to dark brown and white at the top It went a tan colour.
321-322	T2:	Okay, it went a tan colour on top and dark brown. Did it dissolve?
323	P:	Yes it dissolved.
324-325	T2:	Yes. Look at that, a lovely chocolatey-brown colour. I don't think it would taste very
326		good Scott. So the coffee, did it dissolve?
327	P:	Yes.
328-329	T2:	Yes, okay, fill that out in your table. Okay, Dionne, thank you.

Further evidence of succinct but highly appropriate interaction is evident with respect to the instructions given for the write-up of the pupils' findings (see Extract 10.7).

Extract 10.7

182	T2:	Now what I want you to do when you're doing your experiments is, I want you to write down anything that happens to your water, any changes, if the item goes to the top of the water, if it makes the water cloudy, if it lies on the bottom, if it changes the colour, okay?
183		So you all have to write something, all right?

Another interaction, relating to the notion of a 'fair test' (see Extract 10.8), is interesting in that the student encouraged appropriate responses from the pupils by a series of prompts. Clearly primary science is *known* science and, in a situation where the pupils are struggling, the temptation would be to give them the answer, or at best frame the question in such a way as to obtain a yes or no response. In this situation the student supported and encouraged the pupils to develop their responses. The student's summary at the end of the interaction, despite being the destination she had planned for, nevertheless used the pupils' words and consequently, I would assert, gave them ownership of the final outcome. The pupils have identified the variables to be kept constant rather than being told what to do.

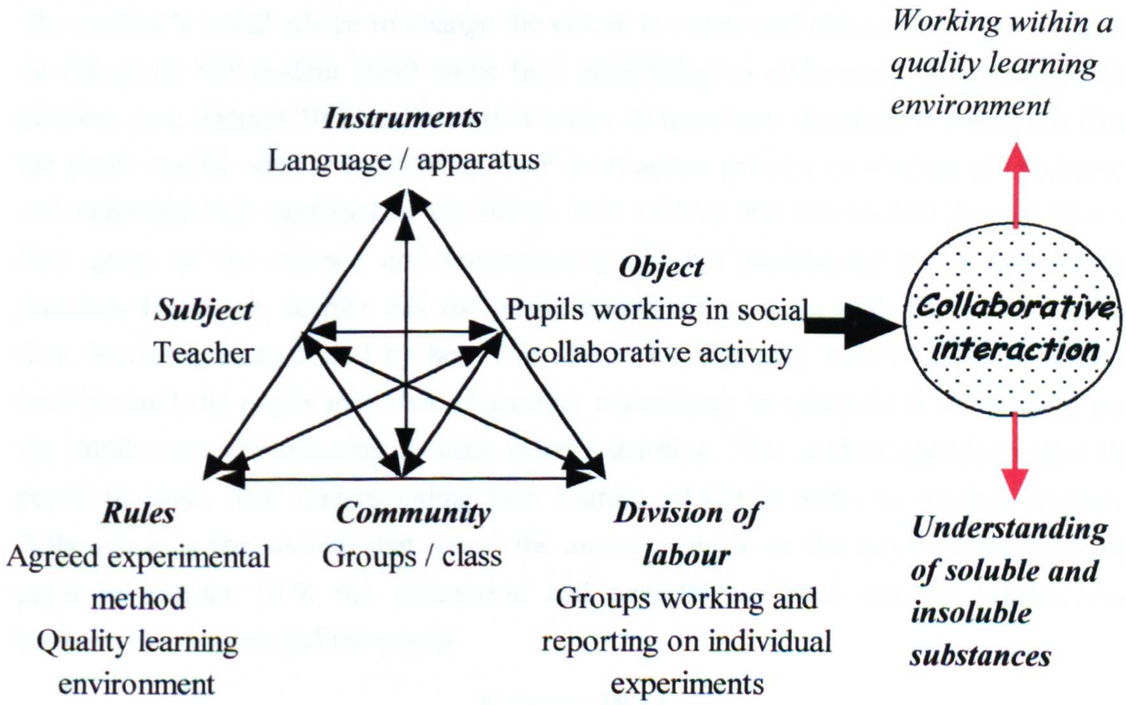
Extract 10.8

114-115	T2:	Now, how are we going to make it a fair test? How are we going to make it a fair test? Megan?
116	P:	[*Unable to transcribe*]
117-118	T2:	Sorry, some people aren't listening. It doesn't matter where the pot is just now, Simone.
119		Okay, Megan say that again.
120	P:	Put the same amount of water in.
121-122	T2:	We're going to put the same amount of water in. Okay, how else are we going to make it
123		a fair test? What happens if I give Christopher three bars of chalk and Jordan only two
124		granules of coffee? Is that fair?
125	P:	No.
126	T2:	No, Jane?

127	P:	It has to be the same amount of coffee.
128-130	T2:	Yes, we have to all have the same amounts. Okay, anything else we have to do? What if Christopher leaves his for half an hour and Jordan only leaves his for five minutes, is that going to be fair?
131	P:	No.
132	T2:	What would we have to do then, Daniel?
133	P:	Make sure we leave them the same time.
134-135 136	T2:	Make it the same time. So we're going to need the same amount of water, the same time and the same amount of the substance. All right, I need another glamorous assistant.
137-138		Okay, Jane out you come. Give everyone a teaspoon.

This lesson can be interpreted in terms of Engeström's (1987) human activity system (see Figure 10.6). Learning is derived through participation in meaningful and collaborative activity. However, vertical transfer of knowledge is also implicit in this lesson, through the student's probing questions and observational prompts. The insight that this student appears to have is that learning is fundamentally a social process (Guile and Young, 2003).

Figure 10.6: Lesson on soluble and insoluble substances



Student T7 also showed an awareness that learning is a shared experience which centres on collaborative, problem-solving activity. Late in the observed lesson, as the pupils completed the construction of their steady-hands test, problems began to emerge (see Extract 10.9). The pupils had constructed a completed circuit and as such the buzzer had been activated. The student sought a solution to this problem, the response given, from a pupil, is prompt and correct. During this lesson one pupil had been periodically indicating that the holder was not 'connected in' to the circuit, and it was this pupil who offered the solution. The student's response to this solution was confused and remained undeveloped as they were overtaken by questions from other pupils.

Extract 10.9

537-538 T7: Boys and girls, will you stop now and look this way. Right, Andrew and Megan have connected all of theirs up but the buzzer's going without them even making their holder
539 yet, what do you think's happened? What do you need to do to fix it?
540 P: Connect one of your wires to the holder.
541 T7: Connect one of your wires to the holder because otherwise because metal acts as a conductor.

Extract 10.10

561 P: Miss XX, our buzzer stops when you put it (*holder*) onto the wire, instead of starts.
562-563 T7: Well, you need to change round your circuit then, don't you. What do you think that's
564 for, what do you need that for to make? Make what?

The problems that other pupils continued to encounter were exacerbated by the student failing to appreciate that the pupils were constructing completed circuits which, when the holder comes into contact with the exposed wire, were being short-circuited. The pupils should have been constructing *incomplete* circuits which were *completed* when the holder came into contact with the exposed wire (see Extract 10.10). The student's initial advice to change the circuit is vague and did not lead to a solution. At this point the student spent some time attempting to understand the nature of the problem (see Extract 10.11). Through a series of questions the student ascertains from the pupil exactly what is happening; there is an active process of sharing of experience and understanding mediated by discourse. It is evident that the student did not have a firm grasp of the science and consequently did not understand the nature of the problem. However, despite this the pupils continued to work with the student rather than becoming exasperated by her. The reason for this may well be that the student incorporated the pupils in a *shared* learning experience; in which both the student and the pupils were contributing to each other's learning. The student openly invited the pupils to share their understanding (see Extract 10.12) in order to reach a solution. Although it is the student that 'sees' the answer, based on the advice offered by the pupil in Extract 10.9, the interaction had nevertheless been one of collaboration between the student and the pupils.

Extract 10.11

570 P: We changed it around and it doesn't work.
571 T7: Right, look you said that this buzzes when it doesn't touch the wire.
572 P: When another wire's touching that, it buzzes like that without touching the wire.
573 T7: It buzzes when it's?
574-575 P: When it's on that without touching the wire. When it touches the wire, it stops buzzing.
576-577 T7: Right, so what do you think you need to change about your circuit? What do you think?
578 Where's your other wire?
579 P: Over there.
580 T7: Right, you said that it stops buzzing.
581 P: When I touch the wire.
582 T7: When you touch the wire.
583 P: When I touch the wire on to that.

584 T7: Of course it's going to connect, isn't it?
585 P: Then when it touches that it stops.

Extract 10.12

613-614 T7: Right, try it with that. Do you think you should have that connected up to something?
615-617 Have you attached your wire yet? Hold on a wee second. Right, connect that up to your
618 battery, connect your battery up to your buzzer. Connect that up to your buzzer.
619 P: It's working!

Student T2 and Student T7 display an awareness that learning involves social and collaborative activity and as such learning cannot be 'taught' to anyone. The students have operationalised this insight by developing activities which involve the pupils in discourse amongst themselves and with the students in order to arrive at agreed learning outcomes. There is also evidence that within such a framework the mediation of learning can be a 'two-way' process.

10.5 Discourse of science

Central to a realignment in children's thinking is the notion that language is critical in supporting learning in science (Parker, 1995; Heywood, 1998) providing the pupils with 'ways of seeing' (Newton *et al.*, 1999). This is not merely having an appropriate set of definitions of important words, or being able to use the words in context, although this is important for a full understanding of the topic being explored. More importantly an appropriate lexicon is essential to support thinking about abstract concepts which are often counter-intuitive and difficult to explain. That science is a 'strange language' (Sutton, 1996), which has rarely been learnt by primary teachers who are expected to teach science is often overlooked by those who develop curricular structures and materials for teaching. Thus dialogic interaction, defined as a "*social activity of making meanings with language*" (Lemke, 1995, p. 8), within science lessons is important in terms of gaining an insight into the extent to which progression in the children's thinking can be said to be taking place.

The students observed appear to lack a detailed scientific vocabulary as well as having difficulty in expressing some of their ideas, even in everyday language. For example, Student T1 had problems developing a vocabulary which adequately describes what she means by the main types of energy (*e.g.* potential is waiting) whilst Student T2 was inconsistent in her attempts to articulate an understanding of what is meant by 'dissolves'. She variously describes 'dissolves' as 'disappears', 'melted' as well as being the same as 'mostly dissolves'. The particular problem arose in relation to the results obtained when sugar was mixed with water (see Extract 10.13). The pupil observed some sediment at the bottom of the beaker and initially stated that the sugar had not dissolved. That some sugar may not dissolve is understandable given that the sugar is being mixed in a small volume of cold water. The unsatisfactory interaction that ensued relates to the student not receiving the *desired response*. The problem here, I would assert, is not so much the student's depth of knowledge, they are aware of the key variables in the investigative activity, but rather a lack of flexibility in utilising their knowledge base. They did not appear to have the confidence to ask, *why this should be so*? The student, rather unconvincingly, suggested a number of explanations for the pupil's observation (*e.g. condensation* on the bottom of the beaker, the shape of the beaker causing the sugar to become stuck). Clearly this result appeared to be a problem which the the student was unable to explain away. The interaction concluded with the suggestion that the student equates 'mostly dissolved' with 'dissolved'. Rather than seeing this as a problem this is merely an interesting result to be pursued in further investigative activity in which the variables are subject to change.

Extract 10.13

477 T2: Okay, we'll start with Jordan then.
478 P: Staying at bottom and not dissolving.
479 T2: What was your substance?
480 P: Sugar.
481-482 T2: Sugar stays at bottom and not dissolving, are you sure? Now there's a little condensation at the bottom but apart from that Jordan, is there anything else?
483 P: There's still some sugar in it.
484 T2: Where?
485 P: Like when you put the spoon round it, it got stuck at some places.
486-488 T2: But that's just the shape of the cup, I think. I can't see any particles on the bottom. Right
489-490 let's see it's mostly dissolved, Jordan, hasn't it? Most dissolved. Okay, sugar mostly dissolved.

Further evidence that Student T2 had problems with the language of science arose in the deployment of inappropriate analogies, which could lead to misconceptions, with the student supporting a pupil in preparing their written findings; the student focussed the pupil on observable changes (*i.e.* there's nothing sitting at the bottom) in order to determine whether the substance had dissolved (see Extract 10.14). The pupil agreed that nothing could be seen at the bottom of the beaker. The student then introduced a completely different concept by stating, "*it's like it has melted*". The pupil had sufficient grasp of the investigative activity to interpret this as evidence that the substance had dissolved. Hopefully the pupil will not, at the same time, have set up a conceptual equivalence between dissolving and melting. The interaction suggests that this may be a possibility; however, working within a collaborative framework the pupils can consider the contributions from MKO's other than the student-teacher.

Extract 10.14

245-246 T2: Right you need to report that so you'd better get writing things down. Do you not think
247 that's dissolved? There's nothing sitting at the bottom, is there?
248 P: No.
249 T2: It's like it has melted.
250 P: So it's dissolved.

However, towards the end of the lesson (see Extract 10.15) Student T2 was able to neatly consolidated the investigative findings by introducing new scientific terms (*i.e.* soluble and insoluble) suggesting that her problems in using the language of science did not impede her otherwise effective pedagogic skills.

Extract 10.15

353-355	T2:	Yes, well done. Okay, who wants to read the next sentence out for me? Okay, who wants
356		to read the next sentence out for me? It's a hard one, Christopher?
357	P:	A substance that disappears in water is?
358	T2:	Who can help him with that word, Rachel?
359	P:	Soluble.
360-361	P:	Soluble. It makes a solution.
362-363	T2:	Okay, a substance that disappears in water is soluble. Okay, hands up if your group had a
364-367		soluble substance. A soluble substance. Did it dissolve? Did it disappear? Jane's group
368-369		and Rachel's group, okay. Sugar and coffee was soluble and made a solution. Okay, next sentence, who's going to read that out, Rachel?
370-371	P:	A substance that does not disappear isn't soluble. It does not make a solution.
372-374	T2:	Okay, a substance that does not disappear is insoluble. It does not make a solution. Okay,
375-376		hands up if you had an insoluble substance. Oil, flour and chalk. Okay, and what about
377		the sand? Was that soluble or insoluble?
378	T2:	Hands up, don't shout. Ryan, sand?
379	P:	Insoluble.
380	T2:	The sand was insoluble.

Student T3 engaged pupils in verbal interaction which sought to clarify her P1's understanding of how to determine whether a material was 'waterproof' (see Extract 10.16). There was some *linguistic looseness* in this interaction which could cause the pupils to become confused. Firstly the student indicated that cotton wool, which was one of the materials being investigated, had been selected as the little pig (he) might think it keeps him nice and warm. This is a different concept and it may cause P1 pupils to become confused as to what is being investigated. A P1 pupil may well think that keeping the pig warm is a very good reason for selecting cotton wool as the roofing material. Consequently it is important that the focus of the investigation is kept clear and unambiguous (*i.e.* is the material 'waterproof'?); with no extraneous thoughts or variables being introduced which could cause the pupils to lose their focus. This would have been a useful example for the student to explore the pupils' understanding of the activity. The delightfully surreal world that the young, at times, inhabit, which often leads to drift in their thinking, is shown by a subsequent discussion (see Extract 10.17). Clearly the loose use of language can cause confusion and misconceptions that need to be corrected rather than reinforced.

Extract 10.16

53	T3:	Wool. Now I've got cotton wool because he might think it keeps him nice and warm,
54		right? So we're going to change all of these in our experiment today, because what we're going to do is, I've built you a house with leggo and we're going to change the type of roof we have, so if it's a bread roof, if it's a plastic roof, but how I'm I going to know if
55		these keep me dry or not? Hands up.

Extract 10.17

98	P:	Pigs like mud.
99	T3:	The pig does like mud Bethany, but he's decided that he wants a new type of house this time.
100	P:	Does he not want mud?
101	T3:	No.
102	P:	But he eats mud.
103	T3:	That's right.

Student T4 appeared to have preconceived notions that affected the outcomes from the pupil-teacher discourse (see Extract 10.18 and Extract 10.19). In both these extracts the pupils correctly indicate that the roots take up water from the soil. The student accepted this but on both occasions she attempted to establish, wrongly, that the roots also take up food from the soil. The roots system does translocate nutrients which are used in the production of food through photosynthesis; however, they do not extract food from the soil. Perhaps I am being too harsh with respect to the second extract in that minerals (*e.g.* nitrogen, potassium and phosphorous) in the soil are used in the chemical reactions as part of photosynthesis to produce food and as such they can be said to 'feed' (verb) the plant. Consequently within horticulture it appears to be perfectly respectable to talk about plant feed (noun). However, this is not the same as food (noun), in the form of starch, which is produced in the plant to provide a source of energy. The student failed to make this distinction despite the fact that elsewhere in the lesson they clearly state that, "*the leaves are a special thing, they take in all this sunshine and they make food for the plant*". This interaction suggests that the student either had poor 'listening skills' or they had a preconceived outcome in mind, which in this case happened to be mistaken, that they sought pupil responses to confirm. However, the pupils' scientifically accurate responses presented the student with a problem. The student neatly resolved the problem by interpreting the pupils response in light of the student's preconceived outcome. In so doing they have exposed the pupils to a source of misconception with respect to the role of roots in plant development.

Extract 10.18

205	T4:	But what do roots do for the plant? (*Tape cutting out*) the roots hold the plant in place, they keep it in the spot it should be but what else, it's important?
206	P:	If it rains where water will go into the ground and they'll dry it all up.
207	T4:	So the roots take the water and the food to the plant (*Tape cutting out*) what's this here?

Extract 10.19

374-375	T4:	You water the plants and what's that do for the roots? What does the root do, Lucy?
376	P:	The water goes into the ground and the roots suck it up and give it to the plants.
377-379 380	T4:	A perfect answer. Who was listening? Now some girls are too busy talking and Lucy gave us a perfect answer. The root takes all the water and all the minerals and everything else that's in the ground and takes it up the plant to feed it.

Student T6, in a lesson on electricity and electrical circuits, was able to convey a sense of the flow of electricity (see Extract 10.20) using terms appropriate to young pupils (*e.g.* it passes through, it travels). It would only cause confusion to attempt, at this early stage, to examine the notion that electrical current is carried by electrons and ions. Best to save this confusion for their later years.

Extract 10.20

84-86	T6:	It conducts electricity. So the electricity what does it do? How does the electricity get from one place to another in this conductor, it?
87	P:	It passes through.
88-90	T6:	It passes through it, that's great. So an insulator, what does an insulator do then? Tell me what an insulator does, Connor?
91	P:	It travels.
92	T6:	No, it travels through a conductor, so if a conductor makes it go, what does an insulator
93		do? An insulator makes it?
94	P:	Stop.

Extract 10.21

141-142	T6:	A circuit, didn't she, and why was it a circuit? Because the?
143	P:	Because the electric can travel.
144	T6:	Because the electric can travel in a circle, can't it.

That an electric current travels in a circle (see Extract 10.21) is again an appropriate analogy for young people. It would have been useful to further develop their understanding of the flow of electricity in a circuit by reference to the direction of flow being from the positive to the negative terminal. However, it would be churlish to suggest that this is a weakness on the part of the student. Furthermore the analogy of electricity moving in a circle will be useful in later years when their science teachers will develop the notion that voltage is defined between two points.

These observations are significant as the language teachers use in "*explanation is central to developing children's thinking and understanding of the scientific vocabulary and concepts*" (Heywood and Roberts, 2002, p. 135). Consequently there is a clear need to sharpen up pre-service students use of language as there are a number of examples of 'linguistic looseness'. One possibility is that this should provide a major focus of lesson preparation, with specific and accurate vocabulary for defining scientific concepts being identified as part of the teaching plan. Students, unfamiliar with the language of science, should be encouraged to undertake small manageable steps in lesson planning, such that they may "*translate a science concept into appropriate and useful instructional representations to enable children to assimilate abstract ideas*" (Carré and Carter, 1990, p.339). Another possibility is to plan teaching in terms of a series of questions to be answered:

- ➢ What ideas and experiences do children have about this already? How are they likely to be thinking?
- ➢ What exactly do I want children to understand or be able to do as a result of teaching?

- What will happen ‘in the learner’s mind in responding to the first two questions?
- What teaching strategies might be used?
- What activities could be used? What would be the purpose of each? How could learning opportunities be exploited?
- How will this be managed in the classroom?

[Adapted from Asoko, 2002]

10.6 Knowledge of science

There are a range of misconceptions and straightforward errors that can be detected in the students’ teaching (see Figure 10.7) suggesting that their scientific thinking is at the same level as the children (Summers, 1994). There are a number of instances when the pupils’ contributions indicated that their thinking had moved beyond that of the pre-service student. For example Student T3 failed to realise the significance of the pupil’s observation that the tray being flooded has an impact upon the validity of the results obtained. In Extract 10.22 a pupil asked what would happen if, “the water goes all over the table?” This was not thought to be a problem as each group had been provided with a non-draining tray in which the investigative activity was to take place. However, herein there was significant problem, in terms of the methodological approach, which surfaced in a later student-pupil interaction (see Extract 10.23).

Extract 10.22

116-117 118	T3:	If the water doesn't go through then that makes a good roof. That means a bad roof would be when all the water goes inside. So what you're going to do is, you're going to draw the pictures of, there's a picture of bread and if that's good for the roof you would draw it under that one, and if it's cotton wool and it's terrible and it makes all the water go inside then you draw it in here.
119	P:	Miss, what if the water goes all over the table?
120-121	T3:	No that's what your tray's for. You're going to put you house into your tray and do it into your tray so that the water doesn't go all over your table.
122	P:	We've got wee holes in our trays.

Extract 10.23

215	P:	Miss, my table is flooded.
216-217 218-220	T3:	Right, will we try the slate then? Who's not had a shot, have you all had a shot? Right, I'll do it then. Right are you ready? What do you think?
221	P:	It didn’t work.
222-223 224-225	T3:	It hasn't, it's because your tray's full of water. Right, so have you done everything? Right, well fill in your tables now. Have you tried the slate?
226	P:	No it’s Matthew's turn.
227-228 229-230	T3:	Right Matthew, you pour it over then. Wait a minute, in a place there's no water, up there. Are you ready? Can you see inside?
231	P:	Yes.
232-234	T3:	No there's not, there was no water in the slate. Have you all had a shot? Sarah, you're the group leader so you can take the last shot.

During the investigative activity the student engaged in good practice by moving about the groups assessing the pupils’ performance through observation as they conducted the investigation as well as questioning the pupils about their findings. The problem of

Figure 10.7: Key problem areas in observed lessons

	Major problems	Minor problems
T1	• confusion between types and forms of energy; • water can produce energy.	• failure to establish notion of useful work; • potential energy is 'waiting'.
T2	• condensation forms under water; • varying several variables simultaneously.	• dissolves = disappears; • mostly dissolved = dissolved; • dissolved = melted.
T3	• materials are 'waterproof'; • pretend that one material can replace another; • flooded tray does not invalidate results; • introducing different variables at end of lesson (*e.g.* shape and strength of material).	• pupil's observation that cotton wool is warm is not discounted; • pupil's observation that wind blows the water away is not discounted; • pigs eat mud; • failure to establish control over variables at outset; • water in the slate.
T4	• every plant needs sunshine; • reproductive growth synonymous with growth linked to production of food; • roots take up food from soil.	• failure to establish role of oxygen in plant growth; • chlorophyll not linked to sunlight; • failure to distinguish between plants in terms of growth rates
T5	• Uranus and Neptune the same size; • Mercury is the smallest planet.	• Greenhouse Effect is gases trapped by carbon dioxide; • failure to control accuracy of measurements.
T6	*No major problems*	*No minor problems*
T7	• confusion between complete and incomplete circuit; • failure to identify nature of circuit needed in lesson.	• suggestion that all electrical currents are harmful; • unaware that holder will complete electrical circuit.

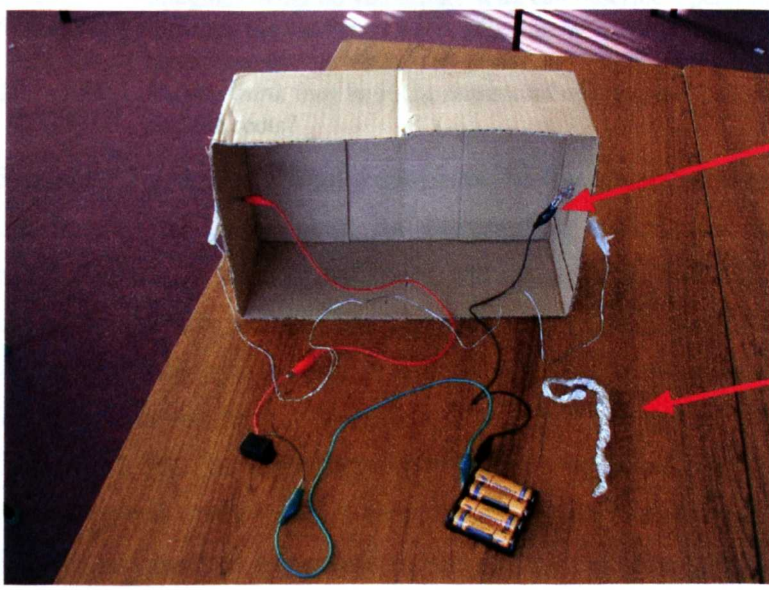
'flooding' was pointed out to the student only to be initially ignored (see Extract 10.23). However, the student was forced to rationalise an anomalous result, namely that slate 'doesn't work', with the observation that the tray was full of water. The problem here is that if the tray *was* full of water, and bearing in mind the pupils were using leggo houses which had no base, then *all* of the results are arguably invalid. The problem is how could the pupils determine if the leggo house was dry? The student failed to recognise the significance of this leaving at least one pupil in a state of confusion in that they have observed water in the tray and this, as far as they are concerned, is an indication that the material, 'didn't work'. The student had developed a methodological approach to investigative activity without fully thinking through how the practical activity would affect the methodological approach. In addition they did not have a pedagogic strategy for turning a problematic situation into a learning experience.

Student T7 repeatedly failed to distinguish between a complete and incomplete circuit despite being prompted, on several occasions, by a pupil's observation that the holder was 'not connected' (see Figure 10.8). The student misinterpreted this in terms of *attaching* the holder to the wire rather than *connecting* the holder (see Extract 10.24). The pupil continued to pursue the point until the student realised its significance. However, she did, when under pressure to account for the steady-hands apparatus failing to operate in the manner intended, exhibit constructivist traits when she asked, "*do you think you should have that connected up to something?*" This was a rare glimpse of a student prepared to shed the mantle of teacher-as-expert and engage in learning along with the pupils. Selly (1999) argues that constructivist teaching is evident when the teacher becomes an 'active listener' with teacher-pupil dialogue anchored on the observation of what is going on. Student T7 was prepared to take that step.

Extract 10.24

295	P:	You didn't say how you connect the handle thing to it, to make it when you touch it, it'll light up.
296-297	T7:	Well, how do you think you would attach it? Would you wind it round?

Figure 10.8: Problematic steady-hands test



Student T4 also has major problems in confusing reproductive growth with growth brought about in response to the production of food (energy) through the operation of photosynthesis, a major focus of the lesson (see Extract 10.25). The student in the first part of the extract established that there are seeds in the flower which produce other plants. Although not stated the student was describing how plants accomplish reproductive growth. Several incorrect pupil responses were ignored during this interaction, one of which attempted to establish a link between the flower and sunlight. This is a significant misconception which was likely to arise as the link between sunlight and green matter had not been explicitly stated. The pupil's response in the second part of the extract, uncorrected by the student, indicated that there is indeed a misconception which needs to be addressed. The pupil clearly confuses reproductive growth with that growth that comes about due to the production of sources of energy brought about by photosynthesis. This is a crucial distinction which the student failed to delineate. The student's also made the lesson overly complex by touching on subject matter which was essentially tangential to the stated outcomes, indeed the points raised were separate lessons in themselves.

Extract 10.25

299-302	T4:	A bud. A flower grows from the bud. And have a look at the sunflower. We talked about
303		petals but what else do you get in the flower that's important? Remember we talked about dandelions, how the flower turns from yellow to white and there's something important there, Alan?
304	P:	Miss, the root.
305	T4:	Paul?
306	P:	It helps bring in the sunshine.
307	T4:	Lucy?
308	P:	There's seeds in it.
309-310	T4:	Seeds to make other plants grow. So do we know that?
326	T4:	Well, do you know that's a good idea, I was going to bring some but it's too early in the year for them just now because it's good to bring them in and see how different they look
327		and then you get to blow them all as well and that's good fun isn't it? Oh could you
328-329		imagine? What do you think? Who can describe a petal to me, Nicole?
330-331	P:	It makes the sunflower head, Miss, grow. That means it'll all grow Miss, it makes it have more energy when it all grow.
332	T4:	Do you think they have the same kind of important role to play as the stem and the leaves and the roots?

Student T2 grappled for an explanation to the observation that there was some sugar at the bottom of the beaker, an observation which was not expected. The student suggested that it was not sediment, but rather condensation that was being observed at the bottom of the beaker. The suggestion that condensation can form *inside* a beaker of water is simply wrong. This will inevitably lead to misconceptions among the pupils as to what is meant by condensation. The student repeated this in a later interaction (see Extract 10.26). In reporting their findings on what happens when oil is mixed with water a pupil observed that there was a white sediment at the bottom of the beaker. This is an unusual observation suggesting that the group may have used a beaker contaminated with another substance when carrying out the experiment on oil. The student attempted to explain away this problematic observation by saying it's like condensation at the bottom of the beaker. It could be argued that, in this instance, the student had deployed an inappropriate analogy. However, this was the second occasion when the student suggested that condensation can be observed inside a beaker of water. This would suggest that the student had a faulty understanding of this concept.

Extract 10.26

504-505 P: Oil. A massive big bubble at the top, wee bubbles in the middle. A wee bit
506 cloudy. A white bit at the bottom.
507-508 T2: Okay, did you have the two layers again? Like Jordan's group had, was there two layers?
509 P: Didn't see them, just a big bubble.
510-511 T2: Okay, it's like condensation on the bottom Jane.

In Student T3's lesson the P1 class were asked to determine, using experimental methods, whether selected materials were 'waterproof'. The Science Guidelines (2000b) does include reference to two attainment targets which the student appears to have targeted in her lesson. The first of these attainment targets looks at the uses of materials based on simple properties (*e.g.* twisting, stretching, *etc.*) whilst the second is concerned with the main uses of water. In combining these attainment targets the student appears to have come up with the concept of 'waterproof' materials. This is not part of the Science Guidelines (2000b) and although materials can be made waterproof (*e.g.* jackets) there is; however, no such concept as 'waterproof' materials.

Student T2 and Student T3, developed lessons which involved an investigative activity. Consequently the lessons provided the pupils with an experience of the process skills (*e.g.* observing, measuring, *etc.*) which were absent in most of the other lessons. However, the experience of engaging in investigative work may have provided fertile ground for the development of misconceptions amongst the pupils. Student T2 was able to effectively engage the pupils with the language of investigation. An early interaction encourages the pupils to predict what happens when specified substances are mixed with water (see Extract 10.27). The interesting feature of this interaction is that the student openly states that the pupils are not going to be given an answer. Again the student showed an awareness of an underlying principle of investigation; namely that prediction is not synonymous with the answer. The hypothesis is tested through investigation in the hope of obtaining a verifiable answer. This point may seem trivial to the science specialist. However, such an awareness, in a student in the early part of their ITE degree course, is the exception rather than the rule.

Extract 10.27

50 T2: Okay, now we've got a table on the worksheet and we've got six different things that we're
51-52 going to see whether or not they dissolve. John Paul, are you okay? Okay, we're going to
53 see if they dissolve. Now what we have to do first is, we're going to talk about, together,

54-55 whether or not we think it will dissolve. We're going to predict what will happen. Okay,
56 now the first item. Sand, where do we get sand?
57 P: At the beach.
58-59 T2: At the beach. Okay, now does that dissolve when it's mixed with water?
60 P: Yes / No.
61-63 T2: Hands up for yes. Hands up for no. Okay, now I'm not going to tell you whether you're
64 right or wrong. Okay, under the heading "Will it dissolve?", you write either yes or no.
65-67 Okay, whatever you think, yes or no. I'm not going to tell you if you're right. Okay has everybody done that?

However, Student T2's activity involved varying several variables simultaneously. The student engaged the pupils in discussion aimed at identifying the experimental variables which they intended to alter in subsequent experiments. Changing the variables formed part of the lesson plan (see Extract 10.28). The student-pupil interaction did identify a variety of changes that could be examined; however, the decision to alter two of the variables is methodologically suspect. Ultimately the lesson had the narrow focus of observing change, rather than an investigation of how varying the key variables affects that change. Despite this the student provided, in my view, a well-structured learning experience. However, she missed an opportunity to engage the pupils in deep thinking about an investigative approach which, although intimately linked with science, is applicable to a range of situations in which the pupils have to resolve problems.

Extract 10.28

419 P: Use less coffee and more water.
420-421 T2: Using less coffee and more water, we could do that. Or flour or chalk, whatever it was.
422 What else could we do in the class?
423 P: Make it smaller.
424-427 T2: Smash it up, Okay, make it smaller. And stirring it. Okay, we can do these three things.
428-429 We can make it smaller, more water, less substance and what was the third thing? Stirring
430-431 it. Okay. Hands up for more water less substance. I think that's probably the easiest
432 actually. We'll do that.

The investigative activity devised by Student T2 did incorporate good practice in terms of involving all of the pupils in a well-structured activity. This activity involved pupil representatives, drawn from each group, reporting their findings within a social context (McGuigan and Russell, 1997). The results and interpretations of each group were subjected to scrutiny by the whole class. The student also used these exchanges to engaged in assessing progress towards the learning objectives. This process of reflective practice was a powerful outcome of the lesson plan. However, did it fall within the constructivist paradigm? A critique of the approach developed by Student T2 could suggest that the reporting sessions were structured to achieve predetermined outcomes (Louden and Wallace, 1994) as the pupils worked through the clearly defined steps within the activity (Tobin, 1997). There was also a suggestion that the intellectual input was restrained with a much greater emphasis on the management of the experience (Summers, 1994). However, such a critique would, in my opinion, be overly harsh as there is no reason why the teacher should not set the agenda, as part of their planning, with respect to the pupils' knowledge base on a given topic. For a pragmatic constructivist this is a methodological approach which is 'fit-for-purpose' albeit a little weak in the assessment of the pupils' knowledge base. Indeed this appears to be a criticism which can be levelled at all of the lessons observed, namely that the students fail to vary the means by which they ascertain the views that the pupils possess on the topic being examined. The students' repertoire is limited to a few questions, with little or no attempt to probe.

Student T3 introduced variables, as answers to the activity, which had not been previously examined (*e.g.* shape, strength, *etc*). Furthermore, the investigative activity devised by Student T3 had predetermined outcomes developing a view of science experiments leading to a 'right' answer in that the student appeared to have selected materials which were designed to *fail* in order to provide a *single* correct answer. Science is usually much messier that this. However, this is a P1 class and the pupils, from their responses, were clearly unaware of this. Nevertheless, some of the pupils suggested materials which, in terms of this experiment, could have produced some interesting results (*i.e.* wood and tin foil). Including materials such as these would have made the investigative activity a much more open process with potentially multiple-learning outcomes. The student's also ignored legitimate contributions from several pupils which appeared to take the student beyond her 'comfort zone'.

During the reporting phase of the lesson one pupil indicated that bread would be good as a roofing material. This finding was disputed by another pupil. In order to reconcile this, and presumably not to demotivate the pupil articulating an anomalous result, the result was initially accepted. However, the student then attempted to pick up a piece of bread that has been lying in a 'flooded tray' to reinforce their position that bread is a bad material for a roof. At no point does the student invite the pupil with the anomalous result to explain what they did. Clearly there are a number of points which could have been usefully explored augmenting the learning experience of all of the pupils. Was the bread the first material to be examined (*i.e.* when the tray was dry)? Did the pupil pour all of the water from the cup onto the bread? Did the pupil leave the bread on the roof for any period of time? These are just some variables, none of which were stated as part of the methodological approach, which could have affected the outcome. This situation was compounded by the student picking up a piece of saturated bread; in so doing she changed the experimental approach as she never articulated time and the quantity of water as variables to be controlled. Unfortunately this investigative activity was closed down (Osborne and Simon, 1996) in that the experimental method had a predetermined outcome or 'right answer'. This tends to drive the lesson placing a constraint upon the student, the activity and the pupils' learning. Within a constructivist paradigm it is important to be more open to experiences and prepared to explore anomalous results as herein lies the potential for deep learning. This is an example of practical work which is 'hands-on' but not 'minds-on' (Harlen, 1992) in that the direction of any discussion was controlled as part of the planning process. This promotion of a view of science education as inevitably leading to explanation (Jenkins, 1999) is aligned to the objectivist paradigm. The constructivist position is much more tentative in its assertions on the power of science to explain. These lesson illustrate that although the students' knowledge base may require further development they are, nevertheless, able to develop lessons which articulate an internal or personal aspect to learning consistent with a constructivist paradigm.

Student T5 had simply failed to review basic facts about the size of the planets, a key focus of her lesson. Student T6 provided a lesson which was flawless in terms of the knowledge base and her ability to respond to the pupils' questions and observations was indeed impressive. The student was also able to provide detailed answers to potentially difficult questions (see Extract 10.29) displaying a sound grasp of the technical applications of the science under investigation.

Extract 10.29

595 P: Miss, are alarms battery or mains?
596 T6: It's mains, sorry you asked that, it's mains and it has a battery back-up because if the
mains electricity gets switched off, you're house alarm will still work because you have a
597 battery pack back-up. While your system is fed with mains electricity, it's continually
storing electricity in these batteries, so that if there is a failure, the batteries are always
598-599 topped up. Right come on, are you all right Walter? Are we finished yet?

Extract 10.30

165-166 T6: The circuit had been broken, hadn't it. Now, I know you're all desperate to get your
167-168 hands on this. Kayleigh, that's not very sensible is it? I know you're all desperate to get
169 your hands on these things so in your pairs, do we have .... Kevin could you go over
with Kayleigh please, no swap with Keiran, and can you rig up your circuit .... you and
170 Demi work together. You need two wires, a bulb and a battery, have you got two
171 batteries. It's a funny bulb, it should be enough.
172 P: We've done it

If the student had a weakness it relates to the task set failing to present an adequate challenge to the pupils (see Extract 10.30) who evidently had developed both their knowledge and understanding of electricity as a result of the programme of work produced by the student. The first practical activity required the pupils to construct a battery-powered electrical circuit; some of the pairs had completed this task before the student completed the instructions.

Student T1 did not appear to have had a firm grasp of the distinction between types and sources of energy. She also made sweeping statements such as solar energy can be transformed and converted into electricity. The concept involved in such a statement requires a monumental leap in the pupils' understanding; however, the student did not verify if the pupils understood the concept. It would appear that the student was not sufficiently aware that the notion of energy conversion requires considerable development. More serious was the casual way in which the notion that the wind "*can move other things*" was introduced. The significance of this statement, in terms of useful work (*i.e.* whereby the action of one body on another body leads to a transfer of energy), was not explored. Yet it is the rate at which this transfer of energy takes place which is critical in any attempt explain power, a key learning outcome of this lesson. The student's understanding of science was also faulty when she introduced the idea that the action of water can *produce* energy. The principle of the conservation of energy states that energy cannot be created or destroyed only converted from one form to another. The pupils are essentially passive in these latter lessons with the focus appearing to be on the instructional event. There appears to be little attempt to determine how this event impacts the learners' experience, understanding and conceptualisation of the world around them.

10.7 Concluding remarks

It was, and is not my intention to engage in a polemic on the primary science teaching of the pre-service student teachers observed. These students were identified in terms of their school science qualifications and their stated confidence with respect to teaching primary science. This confidence was expressed in terms of teaching:

- the attainment outcomes;
- the different age stages in the primary school;
- the investigative skills.

The primary purpose of the observed lessons was to determine the extent to which the students' stated intentions matched with the actuality of practice. It is important to articulate these fairly basic points in light of the evidence accumulated which suggests that there are *significant* problems, with respect to teaching primary science, amongst most of the sample of students observed. I make no claim that these findings are generalisable; however, I would suggest that, although drawn from a small sample, they are sufficiently alarming as to merit further investigation.

The students' stated intentions, in terms of teaching primary science, were generally framed within the constructivist paradigm. Constructivism is a term which is open to many interpretations, my own view in adopting constructivist thinking, with respect to teaching science, is that science education should be taken forward by whatever methodological approach is 'fit-for-purpose' (Miller, 1989; Bell and Gilbert, 1996). This position has been described by Matthews (1994a) as being one of pragmatic constructivism. Within such a perspective it is necessary to first examine the children's own learning rather than merely concentrating on the content of the curriculum. Indeed what the child knows and thinks about a particular aspect of science must be given priority, if subsequent learning is to be meaningful (Selley, 1999). Bruner (1994) describes this in terms of 'agency in learning' whereby learners do not passively receive knowledge, but actively make sense of experience (*i.e.* construct knowledge) in relation to pre-existing knowledge (Murphy, 1997). This view of teaching and learning in science education is informed by the following:

- knowledge is constructed, not transmitted;
- the prior experience of pupils leads them to develop their own view of the world;
- each pupil's scientific conceptions act as a filter on new experience which serves to interpret those experiences in accordance with their current thinking;
- the views that a pupil has of the world are resistant to change;
- developing accurate conceptions of reality requires purposeful activity.

The conditions for children's learning has provided a focus for much recent research effort (Louden and Wallace, 1994). However, this requires to be rethought by the research community as dealing with the misconceptions evident in the pre-service teachers' learning is critical if we hope to develop strategies to respond to children's misconceptions. Although developing the students' subject knowledge is important there is also a need for the students to examine the theories of learning (Galton *et al.*, 1999) in order that they know how to teach science effectively. The observed lessons within my study were, for the most part, steered by the students with clearly defined structural components which consisted of teacher exposition, dialogic interaction through questions and answer followed by a set exercise. The pre-service students controlled the focus of the questions, partly out of a fear of having their lack of subject knowledge exposed, as well as being unsure of the subject matter. Qualter (1999) argues that a heavy emphasis on subject knowledge focusses the teacher's attention on auditing and remediation of their own learning, leading to didactic modes of teaching. The pupils were generally steered towards the 'correct' answer, given little time to reflect and think on the nature of the question being asked. However, some of the students' pedagogy was aligned towards a social and collaborative paradigm. It is important that science tutors find ways of tapping into the pedagogical practices of such students. Lack of subject knowledge appears to inhibit some of the students causing them to adopt a 'teacher-as-expert' paradigm. Again it is important that science tutors find ways of alleviating this pressure to conform to 'past ways of doing' in order that the students adopt pedagogical practices, in teaching primary science, which are consistent with their emerging epistemological framework. Currently the pre-service students frame their intentions within the constructivist paradigm; however, the practice of some of the students appears aligned to an objectivist paradigm:

> *new ways of knowing can only emerge from reconstruction of old ways of knowing*
>
> [Louden and Wallace, 1994, p. 655]

The final chapter will focus on a discussion of the findings obtained from my research. These findings will then be examined in order to determine what recommendations can be made to advance the knowledge base within this field of research.

CHAPTER 11 DISCUSSION and RECOMMENDATIONS

11.1 Knowledge base

There is a body of research evidence which suggests that teachers with a sound knowledge of subject matter are more effective in their teaching (Osborne and Simon, 1996; OfSTED, 1999; Poulson, 2001). My research has shown that the students' educational qualifications in science is limited. If we accept that a good background in science is indeed important then this would suggest that the Faculty of Education should reconsider the entrance requirements to Initial Teacher Education (ITE) courses. Currently there is no requirement for a qualification in science for those wishing to train as primary teachers. However, the modal structure of the Scottish educational system has meant that most Scottish students, who have completed their secondary education since 1988, will have at least a Foundation level pass in Standard Grade Science or a General level pass in one of the discrete sciences. This may well change in the future as a result of the flexibility in the curriculum arrangements, currently being discussed within the secondary sector. These arrangements permit, depending upon local school circumstances, a relaxation in the:

- age and stage of pupil presentation for certificate courses;
- the replacement of Standard Grade with Access and Intermediate courses.

At present this has not extended to a relaxation in the modal structure although this has not been specifically prohibited. Indeed individual pupils currently have a right to request an adapted curriculum which does not conform to the modal structure. This is subject to obtaining parental permission followed by discussion with a representative of the school's Senior Management Team.

Although a specified level of pass in the discrete sciences (*i.e.* at least one Credit level pass in one of the discrete sciences) would be a welcomed inclusion as part of the entrance requirements, it is not an essential prerequisite. I would suggest that such a recommendation would be an overly simplistic solution to a much more complex problem. Furthermore recommendations which are outwith teacher educators' control to fulfil should not form the main plank of a strategy for improvement. This is not to say that teacher educators should not attempt to influence the Scottish Executive that a change is necessary. Indeed the Scottish Science Advisory Committee (2003, p.14) argues that more should be done to '*encourage science graduates to consider a career in primary teaching and to provide existing primary teachers with training in science*'. Additionally, if the problem was simply a lack of content knowledge then this could be rectified by producing CD Roms and published materials containing lesson plans geared to age/stage, supported by detailed specification of science objectives, content and outcomes, which science tutors could provide to the students. Teaching would then focus on the skills necessary to make effective use of these resources. However, although simplistic 'tell them; teach them' solutions have a logic they rarely work in practice. The development of a bank of such materials by science tutors (*i.e.* the vertical transfer of knowledge) would nevertheless be a useful contribution to the students' experience of science education courses. This would provide the students with a source of ideas, consistent with scientific thinking, which they could incorporate into their planning removing the 'reinventing the wheel' syndrome. Providing the students with such materials would enable them to 'adjust and pitch' the activities to the context in which they find themselves. These materials would act as 'boundary objects' (Star, 1989) providing a focus for collaborative activity within schools, thus facilitating horizontal transfer of knowledge, whereby cross-boundary perspectives (*i.e.* teaching institutes and schools) can be shared, mediated by dialogic interaction. However, teaching goes beyond such technical considerations. Consequently the provision of such materials would be ultimately meaningless if the students are uninformed with respect to the nature of pupils' learning in science and the implications of this on pedagogical practice. Science tutors have a key role to play in the development of knowledge appropriate for 'boundary-crossing' purposes (Lambert, 2003). Arguably the key developmental goal is to provide students with strategies which empower them to engage in the recontextualisation of knowledge (Tuomi-Gröhn, 2003).

The lack of background knowledge in science is significant in relation to one of the key insights offered by constructivism, namely that prior learning has an impact upon how students come to understand science. An absence of 'agency in learning' (Bruner, 1994) often results in the interpretations that students construct being different from scientific interpretations; students construct meaning which allows them to make sense of their environment. It is my contention that the experiences being provided, within science education methods courses, do not necessarily enable students to achieve scientific understanding as these experiences currently do not take account of the students' prior learning. Indeed it could be argued that science tutors reinforce the view that 'science is hard' by their failure to construct a curricular experience which matches with students' understandings that they bring with them to science education courses. In order that we may share our meanings of scientific phenomena it is essential that on entry to ITE science education courses, science tutors establish the 'baseline' of the students' understanding by conducting a 'prior learning audit'.

However, the students' knowledge of subject matter is but one component of science education courses which aim to promote effective teaching. Students also require an understanding of the ways in which children come to understand science and teaching strategies that enable children to learn science. Clearly this has implications for the teaching institutions in terms of the equity of their programmes. I would suggest that ITE programme coordinators need to review the balance of science teaching in relation to the other subject areas. I would also argue that they should examine the nature of the teaching programmes that the students provide whilst on the teaching placements, with students being required to submit evidence that they have participated in teaching science. The 'science portfolio' would provide a useful 'boundary object' (Star, 1989) to inform 'reflection-on-action' (Schön, 1983) whereby students could participate in discourse accompanied by reflective writing aimed at examining their experiences. My research indicates that the students have little experience of observing science teaching, or of delivering science lessons. This may well be, as some of the students suggest, a result of the primary curriculum being delivered in terms of topics. However, this is unlikely to be the case for all of the students, all of the time. It is my contention that many of the students are not proactive in this area of the curriculum as a consequence of the students' personal experience of science being at odds with how they believe young people should be taught. My research has shown that the students have a limited grasp of the ontology of science whilst experiencing a conflict between what they perceive to be the scientific methodology and their emerging epistemological framework.

11.2 Curriculum

What we teach primary pupils is less important than how we teach them (Solomon, 1997). A good knowledge of science by the student teacher is, in itself, not sufficient as they also need a knowledge of how pupils learn in science as well as how to manage this learning. Furthermore students should have some insight as to how they should handle pupils' questions, and how to plan and provide appropriate experiences. I would suggest that the specification of what we teach is flawed. Millar *et al.* (1998, p.19) assert that the science curriculum concerns itself with "*atomistic concepts to be taught, focussing on the bricks in the wall rather than the edifice of science itself*". The need to cover content along with a lack of time and resources combine to promote a transmissive style despite research evidence suggesting that direct information-giving behaviour in not very effective in ensuring pupil learning in science (Eagleston *et al.*, 1976). Unfortunately the science we teach is designed to be 'transmitted' and learned by rote as the underlying ideas have not been well enough specified as 'content' to be taught. Additionally the 5-14 curriculum is based on progression in complex recall with the pupils being given no choice other that to adopt rote-learning strategies.

Teaching science in a way that stresses the accumulation of facts with the locus of control retained by the teacher, allied to a dense instructional framework, is unlikely to promote an understanding of what science is about. It is important that student teachers are encouraged and supported in stepping away from the notion, partly borne out of their own experiences, that school science is about the accumulation of scientific knowledge and skills. Fensham and Harlen (1999, p.758) would argue that "*science is not a conceptual cathedral to be remembered, but a quarry to be raided for information to be put to use*". This is unlikely to happen if teacher educators are expected to place a heavy emphasis on subject knowledge involving them, and students, in extensive auditing and remediation of subject knowledge. This could promote a didactic method of teaching within the teacher education institutions which would merely serve to reinforce the students' experience of science.

The what to teach requires systematic and through research. The challenge we face is to develop scientific capability in young people, such that they emerge from their experience of school education with:

- an inquiring habit of mind: *scientific curiosity*;
- an ability to investigate scientifically: *scientific competence*;
- an understanding of scientific ideas and the way science works: *scientific understanding*;
- an ability to think and act creatively: *scientific creativity*;
- a critical awareness of the role of science in society combined with a caring and responsible disposition: *scientific sensitivity*.

[SCCC, 1996, p.15]

Many have argued that this requires a drastic reduction in content rather than dotting the i's and crossing the t's which typifies curricular development. This view was given official support by the Scottish Science Advisory Committee (SSAC) in their report entitled 'Why Science Education Matters' (2003) where they argued that the science curriculum was too content-dominated and required more selection and updating. This has been taken up by the Scottish Executive in the 'Curriculum for Excellence' (2004) which advocates a 'decluttering' and 'updating of the science curriculum'. The ministerial response to a 'Curriculum for Excellence' states that the 3-18 science curriculum needs to be reformed such that:

> *unnecessary or outdated content will be removed, gaps will be identified and filled, content will be updated and progression between stages and course will be smoothed out*

[SEED, 2004, p.7]

Research could inform this debate by determining whether it is possible to identify a smaller number of 'big ideas' (Qualter, 1999) each of which could be explained in more detail. Millar *et al.* (1998) advocate a curriculum based around 'explanatory stories' which require us to tell not only what is, but also how we come to this understanding, how useful it is and what a hard fought struggle it was to obtain such knowledge.

However, what is proposed does not appear to be in any way radical; furthermore it is doubtful whether the reform proposed will lead to 'decluttering'. Those charged with reviewing the science curriculum need to consider the evidence emerging from researchers in science education of the efficacy of constructing the primary science curriculum around a smaller number of 'science stories' (Tao, 2003).

11.3 Nature of science

My research suggests that at the point of initial contact with neophyte student teachers it is important to discern the students' experience and views of science as I have shown that pre-service students have a limited understanding of the nature of science. This lack of understanding is likely to adversely affect their teaching in the classroom (Murcia and Schibeci, 1999). It is my assertion, that in order to accomplish meaningful changes in teaching behaviours it is essential for science tutors to have an understanding of the students' implicit conceptions of teaching and learning in order that they may bring about fundamental changes in student teachers' conceptions of science. Science tutors should seek to elicit the students' 'idiosyncratic conceptions' (Wadsworth, 1997) or 'misconceptions' (Novak, 1977; Driver and Easley, 1978) by a few open-ended questions at the outset of each ITE experience in science to determine the nature of the students' school experience and views of science. Gott and Johnson (1999) suggest that there is a strong link between teachers' attitudes towards science and their understanding. The antipathy to science, detected amongst many of the students in my research, need not be a cause for despair in that it is possible to turn around these attitudes by showing the students that science can make sense, and that there are 'big ideas' (Qualter, 1999) to think about. Toa (2003) argues that science should be seen as a 'narrative human story'. The construction and reconstruction of scientific knowledge takes place within a human context suggesting an 'argument-based pedagogy' rather than an 'abstract context-free pedagogy' (Toa, 2003). The implications of this are twofold:

- science education courses should engage students in dialogic interaction which has been defined as a "*social activity of making meaning with language*" (Lemke, 1995, p.8);
- some background knowledge in the history of science could enrich the pre-service students understanding of the nature of science (Murcia and Schibeci, 1999).

As such science tutors should seek to provide pre-service students with the 'tools of inquiry rather than a package of facts' (Abell and Smith, 1994) through an examination of the 'big stories' (Millar *et al.*, 1998) or 'science stories' (Tao, 2003).

My research has shown that most students articulate an epistemological position which is consistent with a constructivist perspective. However, for some their rhetoric does not match with the observed practice. It is important to support the students through induction into the philosophy and practice of science; providing them with opportunities to explore different theories of learning in relation to science teaching. If we can provide them with a model of science teaching which 'fits' with the way they feel children ought to be taught, and articulate how this could promote high quality thinking in their pupils, then this would be more likely to motivate them as teachers to learn. Research is required in order to develop effective support strategies. Kinder and Harland (1991) have shown that single in-service events are insufficient to change the practice of qualified teachers. However, official pronouncements calling for reviews of ITE and continuing professional development, which will provide high quality professional updating (SEELLD, 2001; SSAC, 2003), tends to call for the provision of resources and content-based courses. The Scottish Science Advisory Committee (SSAC) in their report entitled 'Why Science Education Matters' (2003) is the most recent example of a well-intentioned initiative aimed at improving the pupils' experience of science education by advocating that:

- SEED continue to resource the Improving Science Education 5-14 Programme with Learning and Teaching Scotland coordinating the strategic development of resources;
- SEED and the Scottish Higher Education Funding Council (SHEFC) provide funding for the Institute for Science Education in Scotland (ISES) to promote the development of regional hubs linking schools and CPD provision, from which to disseminate good practice.

Whilst these capacity building initiatives, that seek to coordinate and connect developments in science education, are to be welcomed they are, nevertheless, unlikely to bring about the conceptual shifts necessary in student-teachers and teachers with a limited background in, and predisposition towards, teaching science. This is not surprising when one considers that these advisory committees tend to draw on the academic scientific community for their membership rather than primary science practitioners or academics with a background in educational research. The Scottish Executive needs to consider the balance of representatives on these bodies in order that they arrive at proposals which make sense in light of the available research evidence.

My research indicates that when students do engage with teaching primary science they appear to enjoy the experience. Teacher educators attempt to support this by assisting the students in the development of their repertoire of techniques by providing investigative workshops linked to the age-stage of the students' school placements during each year of the BEd course. The hope is that by getting student teachers involved in teaching science they will continue to deliver science in the curriculum, as well as search for new techniques. Consequently it is necessary to develop an on-going support strategy, which is an integral part of the teaching programmes of primary science courses, by focussing on the embedded notions of teaching and learning science which students bring with them to ITE courses, and often retain when they enter practice. It is essential that we persuade the students that their actions can, and do make a difference; however, current practice in science education courses is fundamentally flawed.

11.4 Developing pedagogical practice

Activity Theory provides an important insight in terms of the interaction between an individual and the environment as being mediated by cultural means such that people do not simply absorb, or react, but actively explore and transform their environment. Within such a context the role of science tutors would be to provide a focus on knowledge creation through participation in meaningful activities. Social engagement would provide the context for learning to take place with knowledge acquisition being inseparable from practice. Within such a context practice (*i.e.* participating in teaching), or '*artifact-mediated and object-orientated action*' (Vygotsky, 1978, p. 40), is fundamentally important in terms of learning and transfer.

Further research is required in order to determine how it is possible to make best use of teacher educators' time in preparing student teachers. How can we best support the development of the students' knowledge base or 'background science', given the limited amount of 'contact time' available? It has already been suggested that the 'technical' component (*i.e.* science content) can be easily overcome. Currently, science tutors attempt to provide a practical experience of science by modelling science lessons focussed on science knowledge outcomes -- learning by imitative practice (Bruner, 1999). This approach establishes 'hands-on' lesson routines which this research has shown results in practical activity being implemented in the science lessons observed. However, the students' lack of scientific understanding leaves them focussed on a narrow range of performance outcomes. It is evident that they are unable to anticipate the direction in which learning proceeds and tend to 'close down' situations when pupils raise questions which do not fit with the objectives set out in their lesson plans. In other words they have little real understanding of the ways in which children understand science or the teaching strategies that enable children to learn science. The practical activities serve to keep the pupils occupied whilst the student dispenses information -- learning by didactic exposure (Bruner, 1999). Thus the problem with modelling science lessons is that it does not engage the students in 'minds-on' activity that facilitates the development of what Schön (1983) refers to as 'reflection-in-action' whereby teachers engage in reflection during the practice of teaching, or 'reflection-on-action' whereby teachers engage in an analysis of teaching after the teaching event has taken place.

Shayer and Adey (2002) suggest that the way in which teachers 'come to know' is just as important as 'what they know' with teachers' learning involving an interpretative construction and reconstruction in thinking through processes by reflection on activity. In concentrating on the 'what' it is possible to lose sight of the 'how'. The work of Lave and Wenger (1991) gives an insight as to how students can be initiated into practice and can move them from the periphery towards the centre with respect to participation in the development of 'contextualised knowledge'. This movement can be achieved through the development of '*communities of science education practice*' (CoSEP). These communities would be rooted in an interpretation of experiential learning (*i.e.* we learn by doing) which stresses the importance of collaborative, problem-solving activity rather than imitative practice.

Another key difference of the CoSEP approach is that the relationships that exist between everyone involved in science education would be seen as central to the process of learning. Such an approach moves away from the view that learning is a process that happens to an individual, but rather is embedded in the various discourses that take place between people. These discourses would focus on the activity of science education enabling students to derive meaning from the information that is exchanged. The experiences and understandings of 'more knowledgeable others' (MKO's), including tutors as well as some of the students, would help to inform the discourse that takes place. Additionally such an approach would build upon the students' interests; these are likely to be functional in terms of the age/stage related teaching placements. Indeed, as part of collaborative working, groups of students could be given responsibility for planning learning experiences / activities. These experiences / activities would be expected to conform to the learning standards outlined in the 5-14 Guidelines.

Another significant implication of the CoSEP approach for ITE courses is that imitative practice (*i.e.* modelling science lessons) does not adequately engage in a critical enquiry of the embedded notions of teaching and learning science which students bring with them to ITE courses. It is my contention that although a practical dimension to learning to teach is desirable this does not, by itself, promote critical reflection, nor does it lead to deep thinking about practice in order to facilitate change. How then can science tutors support students in negotiating the complexities involved in making the transition from student-teacher to teacher? One possibility is to create a transitional space, prior to but not replacing teaching placements, between the university and the school through the use of microteaching (Allen, 1966).

Microteaching is a methodology introduced at Stanford University in the 1960's which would involve student participation and recording of science lessons, with small groups of pupils, as part of their university science education course. The aim of these lessons would be to simulate the classroom environment whilst removing the pressure of performance, which is intimately linked to the process of assessment, during teaching placements. Another significant feature of such an approach is that its location within the university enables us to tap into the culture of (pedagogical) critique which is a feature of the community of practice within university Faculties of Education. In addition universities are better placed to be at the 'cutting edge' with respect to new developments in primary science. The real strength of microteaching is that it provides a 'performative space' (I'Anson *et al.*, 2003) which provides the activity focus for the CoSEP through which to promote critical reflection. Students and science tutors would be encouraged to engage in a collaborative dialogic discourse which seeks to enable students:

> *to become aware of the nature of their inscribed values, attitudes and assumptions about learning which they have previously internalised*
>
> [I'Anson *et al.*, 2003, p.193]

The hope is that the quality of the attention that science tutors can give to the outcomes of microteaching would lead to reflective practice. This is more likely when compared with the current model of imitative practice as the students would be provided with an opportunity to consider the perspectives of others (*i.e.* peers and tutors), in relation to their practice through the exchange and interpretation of information, accompanied by self-reflective writing in order to achieve an understanding of the relationship between their thoughts and actions. Microteaching would provide the students with a framework to triangulate multiple perspectives within authentic contexts (*i.e.* realistic, meaningful and relevant to real-life situations). The CoSEP by remaining rooted in experiential learning allied to collaborative, problem-solving activity would provide a more appropriate model for boundary-crossing practice. Such an approach would also provide science tutors with a new insight and understanding of the capabilities of students. Another advantage of such an approach is that it could be used to provided a 'bridge' between the university and the school through the involvement of practising teachers in the process of reflective discourse. The sharing of perspectives across the boundaries of different CoP's could provide further 'scaffolding' for the students as they develop their professional identities which is a crucial aspect of learning in a dynamic forward-looking community of practice.

11.5 Teacher discourse

During the observation phase of the research I found that most of the students avoided dialogic interaction which incorporated any attempt to explain. The discourse of science tends to be descriptive and factual in nature concentrating on the procedural aspects of the activity. Furthermore there are serious deficiencies in the pre-service students' knowledge base evident in 'science talk'. Numerous errors, some of a serious nature, in the substance of what was said is evident in the case study material. That science is concerned with causes and reasons needs to be brought to the students attention in order that we may encourage them to seek advice as to how this can be achieved. Dialogic interaction can be shallow for a number of reasons:

- some students may see science as being about providing factual information borne out of their own apprenticeship in science;
- some may know that science involves a search for reasons but are unable to support this in their own teaching due to their limited educational qualifications in science;
- those students who know that their knowledge is limited may lack the confidence to make use of teaching styles which involve interaction. Rather than dealing with uncertainty they prefer a 'closed pedagogy';
- some may be inclined towards a less interactive role by nature;
- some may feel that causal understanding is beyond the capabilities of younger children;
- some may feel that the external demands and expectations with which they have to accommodate in their teaching programmes make a concern for causal understanding a luxury.

[Adapted from Newton and Newton, 2000]

Ogborn *et al.* (1996) assert that this is unlikely to change unless we provide the students with knowledge of the various forms of discourse which are effective in supporting understanding (*e.g.* focused questioning, using analogy and telling explanatory stories).

My research found that some of the students included practical activity in their lessons. However, Newton and Newton (2000) argue that an unqualified faith in the ability of practical activity to support scientific understanding may be misplaced. Many researchers have drawn a distinction between practical work which involves '*hands-on*' and that which involves '*minds-on*' (Harlen, 1992). The latter type of practical work is investigative in nature and commonly involves discussion and reflection. It is my assertion that without such a discourse practical work is little different from chalk and talk exercises.

My research also indicates that there is a gulf between the students' aspirational rhetoric of what should happen, and the actuality of practice when teaching primary science. This should not surprise us as our understanding of research evidence with respect to what actually happens in science classrooms remains limited. In order for us to achieve an understanding of what takes place in the classroom it is necessary to observe the 'folkways' (Olson, 1992) of teachers' teaching. Microteaching observational studies would focus on a variety of aspects of the classroom experience such as:

- the structural components of science lessons;
- the dynamics of the classroom (*e.g.* whole class, groups and individuals);
- classroom questioning;
- the nature of the interactions developed by successful teachers and student teachers.

These studies would engage the students in a discourse aimed at identifying how they can transform their developing knowledge of subject matter into a form that primary pupils can understand. The microteaching CoSEP framework, of experiential learning linked to collaborative, problem-solving activity, would provide students with an opportunity to engage in such a discourse through an analysis of a series of 'action moments' (Schön, 1987). These 'action moments' are currently not available to them in science courses based around imitative practice.

11.6 Reflection

Currently there is a low level of research attention in the primary school when compared to the post-primary sectors. That decisions on policy and practice, implemented in the primary school, are uninformed by research evidence and practitioners is bewildering as the primary puts in place the foundations for each individual's future learning. The lack of informed debate, or at best an injudicious use of language, is exemplified by the statement from 'A Science Strategy for Scotland' which states that:

> *most primary schools are in the process of introducing science education as part of their environmental studies curriculum, although provision varies considerably across schools*
>
> [SEELLD, 2001]

That this 'process' has been underway since the introduction of the 5-14 Guidelines in 1993, and that primary science formed part of the curriculum prior to this, does not appear to be recognised by 'the great and the good' of the academic science community. Such statements do little to encourage practitioners within the primary sector. However, it is important to acknowledge that there are indeed serious problems with regards to teaching primary science. Hopefully this will stimulate others to engage in more focussed research aimed at addressing the issues raised in this research.

The process of research periodically involves reflection. What did I do that was right or wrong? What worked or did not work? Obviously this must come with a health warning as the research experience is not one of unmitigated joy. Things do go wrong.

You will will identify smarter questions to ask; usually once the opportunity to ask them has passed. Therefore any interrogation of experience should not be debilitating preventing further progress with the research. The learning derived from reflection should be used to inform the future. There have been a number of things I would, on reflection, have done differently. These include:

- the questionnaire could have provided a tighter focus on the various levels of the pre-service students' qualifications by asking the grades / levels obtained. In processing the questionnaires it became apparent that some students were reporting a Level D as a pass at Higher Level. This could mean that the data for Higher Level passes was inflated;
- the students' qualifications were incorporated into the framework developed to identify students for the observation phase. A knowledge of the grades/ levels would have facilitated more accurate targeting of students;
- the administration of the questionnaire was carried out in the Faculty with some students completing the questionnaire in class whilst others completed it in their own time. This may explain, in part, the differential completion rate. It would have been better to have had a uniform protocol for the administration of the questionnaire;
- there was a differential response rate with respect to 'closed' and 'open-ended' questions. There was a significant number of students who did not complete the open-ended questions. This requires further research;
- the students reported a 'fragmented experience' of science in the curriculum both in terms of observing teaching and being given opportunities to teach science whilst on their school placements. It would have been interesting to identify those students who reported positive experiences, and compared them with those students who had either a limited experience or, worse still, negative experiences in order to ascertain whether there are any differences in their practice;
- the questionnaire was delivered towards the beginning of the PGCE's course. Self-rated confidence amongst this group was consistently low. It would have been interesting to repeat the process towards the end of the course in order to determine if there was an improvement;
- it would have been interesting to determine if there was any linkage between the pre-service students' self-rated confidence and self-rated confidence amongst the pupils they teach. Is there a teacher effect? This, however, is perhaps another area for research rather than something I could have improved in this research;
- most intriguing of all would be to determine the nature of the pre-service students' practice across other areas of the curriculum in order to determine if there is a generic pedagogy;
- clearly the research would have benefited from additional observations. Perhaps I was overly ambitious in the scope of the research which could have been undertaken on a part-time basis.

11.7 Summary of recommendations

Research can be a lonely pursuit if we attempt to work without drawing on the strengths and expertise of our colleagues. The real joy gained from undertaking a PhD has been the opportunity to work collaboratively with a range of colleagues; research can be immensely invigorating amongst like-minded professionals. I believe it is vital, within the Faculty of Education, that there should be cross-fertilisation of ideas and thinking between the Department of Curriculum Studies (Science) and the Centre for Science Education. Each can bring their own strengths in terms of curricular and research expertise which together should provide a powerful engine to drive forward research in a range of areas. It is only in coming together and sharing that we can hope to provide meaningful learning experiences to pre-service students and through them to the children in our schools.

In conclusion I would propose the following areas for future research:

- a longitudinal study of the students' science qualifications;
- a longitudinal study of the nature of the students' school experience and views of science;
- a longitudinal study of the students' confidence indices in teaching primary science;
- a study of the balance of science teaching in relation to the other subjects and how this relates to the teaching programmes that the students provide whilst on their teaching placements;
- an exploration of strategies to support the development the students' content and pedagogic knowledge through the use of ICT and curricular support groups;
- how best to develop investigative workshops, based on a social and collaborative model of experiential learning which utilises problem-solving activity, linked to the age-stage of the students' school placements during each year of the BEd course;
- how and when to gather information on pupils' ideas in a form that can be used to inform the students' teaching;
- how best to develop microteaching, observational studies focussing on a variety of aspects of the classroom experience, to facilitate conceptual change in student-teachers' teaching.

Primary science is poorly researched compared to the secondary and tertiary sectors. I have suggested some areas for further research with respect to classroom practice and the implementation of the curriculum. The development of a body of research evidence, with respect to primary science, may make it possible to consider the behaviours of primary teachers and pre-service student teachers in a structured and integrated way such that we can develop a strategy for progressive change.

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Appendices

Science

Science contributes to environmental studies by providing a context for stimulating and encouraging pupils' curiosity to explore and understand the world around them.

Through their experiences of science, pupils are helped to:

- broaden their understanding of themselves, the society in which they live and the world as a whole;
- sustain their natural curiosity, encouraging an enquiring mind and fostering an interest in lifelong learning;
- develop a scientific approach to problem solving, encouraging critical thinking about phenomena, events and issues;
- develop their ability to think and act creatively;
- adopt a disposition to act responsibly and in a balanced way in relation to scientific issues;
- develop positive attitudes to science and appreciate its contribution to and impact on society.

The knowledge and understanding for earth and space, energy and forces and living things and the processes of life, reflect the major areas of scientific investigation and relate directly to children's everyday experiences. It is through the study of these areas that the skills outlined in the skills strands can be applied and developed. Learning in science provides children with a context within which they can develop the skills associated with investigations. Through their application children will learn to deal with more complex concepts and scientific knowledge. The extent to which they can develop the skills will depend on their age, their stage of development and the types of practical investigations that they experience.

Science is a human endeavour that depends on creativity and imagination. It is important that learning activities encourage and develop these important characteristics and at the same time sustain and promote curiosity and enjoyment, so that a lasting interest in science is established.

Health and safety

Safety should permeate all aspects of the teaching of science. It can be used as a context to consider working in a safe and hygienic manner in a variety of situations across environmental studies. It can also be used as a focus for teaching about science by using health and safety issues as starting points. Teachers should always be aware of the safety implications of any exploratory or investigatory work and children should be encouraged to observe safe and hygienic ways of working during all practical activities.

An overview of science

	Earth and space	Energy and forces	Living things and the processes of life
Knowledge and understanding	Earth in space	Properties and uses of energy	Variety and characteristic features
	Materials from Earth	Conversion and transfer of energy	The processes of life
	Changing materials	Forces and their effects	Interaction of living things with their environment
Skills	Preparing for tasks	Considering and understanding the nature of the task and planning what will be done including fair testing.	
	Carrying out tasks	Making and using appropriate observations and measurements then recording findings in a variety of ways appropriate to the task.	
	Reviewing and reporting on tasks	Describing and presenting the findings in appropriate forms and thinking critically about the significance of findings.	
Developing informed attitudes	A commitment to learning	Through their developing knowledge and understanding and ways of working in science, appreciate the impact of, and think about solutions in relation to social, environmental, moral and ethical issues.	
	Respect and care for self and others	Taking responsibility for their own, and others' health and safety and considering and responding sensitively to different beliefs and values.	
	Social and environmental responsibility.	Appreciating the need for conservation and the sustainable use of the earth's resources.	

Knowledge and understanding: Earth and space

Earth in space

At the earliest stages of primary, pupils will develop their experiences and observations of the effects of the movement of the Earth and Moon by exploring day and night and the seasons. At the later stages of primary, familiar planets of the solar system are introduced and aspects of space exploration are considered. Pupils should be encouraged to make connections between the observable patterns of the movement of the Earth and the Moon and the measurement of time. By S1 / S2 phenomena such as the phases of the Moon and seasonal change should be explained in terms of the effects of the motion of the Earth and the Moon. The distinguishing features of familiar components of the Universe are established and its origins are explored.

Materials from Earth

At the earliest stages of primary, a range of common materials, living and non-living. should be introduced and their properties explored in simple terms. Pupils should be encouraged to make connections between the properties and uses of these materials. The uses of water and the need for conservation are considered. At the later stages the differences between solids, liquids and gases are considered and applied to a simple consideration of the water cycle. By S1 / S2 examination of materials is expanded through a consideration of materials we obtain from the Earth's crust and atmosphere. The connections between properties of solids, liquids and gases and their particulate structure are explored and exemplified through study of the water cycle.

Changing materials

At the earliest stages of primary, pupils should be encouraged to observe changes in materials that can be brought about by various physical forces. The effect of heating,cooling and mixing is exemplified through simple studies of water. The idea of solubility is introduced through experimentation with water. At the later stages of primary more depth is added to the study through the perspective of solubility of materials, pollution and purification. By S1 / S2 chemical reactions should be explored, establishing the relationship between elements and compounds. These explorations can be extended through the study of chemical reaction and changes, and the effect of varying conditions.

Earth and space

Strand	Level A	Level B	Level C	Level D	Level E
Earth in space	identify the Sun, the Moon and the stars link the pattern of day and night to the position of the Sun	associate the seasons with differences in observed temperature describe how day and night are related to the spin of the Earth	describe the Solar System in terms of the Earth, sun and planets link the temperature of the planets to their relative positions and atmospheres	relate the movement of planets around the Sun to gravitational forces give some examples of the approaches taken to space exploration	explain day, month and year in terms of the relative motion of the Sun, the Earth and the Moon describe the Universe in terms of stars, galaxies and black holes
Materials from Earth	recognise and name some common materials from living and non-living sources give examples of uses of some materials based on simple properties give the main uses of water	make observations of differences in the properties of common materials relate uses of everyday materials to properties explain why water conservation is important	describe the differences between solids, liquids and gases give some everyday uses of solids, liquids and gases	describe the internal structure of the Earth describe the processes that led to the formation of the three main types of rock give examples of useful materials that we obtain from the Earth's crust describe how soils are formed name the gases of the atmosphere and describe some of their uses	describe the particulate nature of solids, liquids and gases and use this to explain their known properties describe what is meant by an element describe how physical properties of elements are used to classify them as metals or non-metals

Earth and space (continued)

Strand	Level A	Level B	Level C	Level D	Level E
Changing materials	make observations of the ways in which some materials can be changed by processes such as squashing, bending, twisting and stretching	describe how everyday materials can be changed by heating or cooling	describe changes when materials are mixed	describe what happens when materials are burned	give examples of simple chemical reactions, explaining them in terms of elements and compounds
		give examples of everyday materials that dissolve in water	describe how solids of different sizes can be separated	explain how evaporation and filtration can be used in the separation of solids from liquids	describe the effect of temperature on solubility
		give examples of common causes of water pollution	distinguish between soluble and insoluble materials	describe the effect of burning fossil fuels	describe the use of pH to measure acidity
			describe in simple terms the changes that occur when water is heated or cooled		describe the process of neutralisation and give some everyday applications
					describe what happens when metals react with oxygen, water and acids
					describe how metal elements can be extracted from compounds in the Earth's crust

Knowledge and understanding: Energy and forces

Properties and uses of energy

At the earliest stages, pupils should be introduced to energy through recognition and detection by the senses, for example, the Sun as the main source of heat and light. Pupils should be encouraged to consider safe everyday uses of energy. Light should be explored from the perspectives of shadows and reflections, and vibration identified and explored as the source of sound. At the later stages of primary, simple electrical circuits should be introduced and the relationship between conductors, insulators and safety established. Light and sound can be explored further, through lenses and by distinguishing between 'pitch' and 'volume'. By S1 / S2 electrical circuits should be explained in terms of voltage, current, resistance and power, leading to a consideration of electromagnets and safety. The differences between flow of heat by conduction, convection and radiation should be considered. The study of sound and light should be extended and the study of microelectronics introduced.

Conversion and transfer of energy

At the earlier stages, pupils should be introduced to the idea that energy from food supplies us with the energy to move about. At the later stages of primary, this idea should be developed further to show that one form of energy can be converted to another. The various chains of energy conversion involved in the generation of electricity should be the starting point for this key idea. By S1 / S2 this strand should be extended by exploring the distinctions between potential and kinetic energy. Chemical energy should be considered and the connection between this and renewable and non-renewable energy resources explored.

Forces and their effects

At the earlier stages, pupils should be introduced to the idea of a force through familiar examples of pushing and pulling, floating and sinking. The nature of a force should be established and friction explored in simple terms. The forces of attraction and repulsion relating to magnetism should lead to an introduction to the Earth's magnetic field. At the later stages of primary the force of gravity is introduced and linked to weight. The relationship between streamlining and air resistance is established. By S1 / S2 the distinction between mass and weight is established and the operation of forces in opposing pairs is explained.

Energy and forces

Strand	Level A	Level B	Level C	Level D	Level E
Properties and uses of energy	give examples of sources of heat, light and sound	identify the sun as the main source of heat and light	link light to shadow formation	distinguish between heat and temperature	describe the differences between the flow of heat by conduction and convection
	give examples of everyday uses heat, light and sound	link light and sound to seeing and hearing	give examples of light being reflected from surfaces	describe in simple terms how lenses work	give examples of everyday uses of good and poor conductors of heat
	give examples of everyday appliances that use electricity		link sound to sources of vibration	give examples of simple applications of lenses	explain the effect of a prism on white light
	identify some of the common dangers associated with the use of electricity		construct simple battery operated circuits, identifying the main components	use the terms 'pitch' and 'volume' to describe sound	describe what happens when white light passes through different materials
			classify materials as electrical conductors or insulators and describe how these are related to the safe use of electricity	construct a series circuit following diagrams using conventional symbols	explain what happens when sound passes through different materials
				describe the effect of changing the number of components in a series circuit	construct a parallel circuit following diagrams
					use the terms 'voltage', 'current' and 'resistance' in the context of simple circuits

Energy and forces (continued)

Strand	Level A	Level B	Level C	Level D	Level E
Conversion and transfer of energy		give examples of being 'energetic' link the intake of food to the movement of their body	give examples of energy being converted from one form to another describe the energy conversions in the components of an electrical circuit	give some examples of energy conversions involved in the generation of electricity describe how electrical energy is distributed to our homes name some energy resources	describe some examples of the inter-conversion of potential and kinetic energy give some examples of chemical energy changes explain the difference between renewable and non-renewable energy resources
Forces and their effects	give examples of pushing and pulling, floating and sinking	describe the effect that a push and pull can have on the direction, speed or shape of an object give examples of magnets in everyday use describe the interaction of magnets in terms of the forces of attraction and repulsion	give some examples of friction explain friction in simple terms describe air resistance in terms of friction	give examples of streamlining and explain how this lowers resistance describe the relationship between the Earth's gravity and the weight of an object	describe the effects of balanced and unbalanced forces explain how gravity on other planets and the Moon affects the weight of an object

Knowledge and understanding: Living things and the processes of life

Variety and characteristic features

At the earliest stages of primary, pupils are encouraged to make simple observations of self and others and to name and sort familiar living things. At later stages of primary, the range of living things studied is extended to include major flowering and non-flowering plants. The naming of common plants and animals is done using simple keys. By S1 / S2 the subject of microorganisms is introduced and their impact on life explored. Pupils are expected to be able to create and use classification keys to identify living things. Genetic links between generations should be explored and related to reproduction and the physical basis of inheritance. The principles and scope of modern biotechnology should be introduced.

The processes of life

At the earliest stages of primary, the human life cycle should be examined and pupils encouraged to observe features of growth in themselves and others. The use of the senses as a means of keeping safe should be explored. Pupils should be encouraged to examine the basic structure of flowering plants and the features of growth and development in familiar plants and animals in order to understand their life cycles. At the later stages of primary, the focus should move to a broad study of the human body systems and related life processes. The life cycle of flowering plants should be studied in greater detail and should include germination, growth, pollination and seed dispersal. By S1 / S2 attention should be given to structure at a cellular level through examination of typical plant and animal cells. The process of photosynthesis and its significance should be introduced. The role of enzymes in cellular reactions should be explored.

Interaction of living things with their environment

At the earliest stages of primary, pupils should be encouraged to care for living things in the classroom and at home and to discuss how they go about this. Studies of the local environment will allow children to collect evidence of how living things depend upon each other and will lead to the recognition of simple food chains. The effect of the seasons on the appearance and activity of living things should be observed and discussed. At the later stages of primary, the interaction between humans and their environment should be examined in relation to local industries and the impact of humans on the environment should be explored through local examples. The importance of conservation and recycling should be introduced and living things that are very rare or are extinct should be considered. By S1 / S2, the investigation of food webs and pyramids and the extension of this to consider competition for food and space should develop an understanding of birth and death rates and factors controlling population size.

Living things and the processes of life

Strand	Level A	Level B	Level C	Level D	Level E
Variety and characteristic features	recognise similarities and differences between themselves and others sort living things into broad groups according to easily observable characteristics	give some of the more obvious distinguishing features of the major invertebrate groups name some common members of the invertebrate groups	give some of the more obvious distinguishing features of the five vertebrate groups name some common members of the vertebrate groups name some common animals and plants using simple keys	give the main distinguishing features of the major groups of flowering and non-flowering plants	give the main distinguishing features of microorganisms create and use keys to identify living things give examples of inherited and environmental causes of variation
The processes of life	name and identify the main external parts of the bodies of humans and other animals describe some ways in which humans keep themselves safe give the conditions needed by animals and plants in order to remain healthy	give examples of how the senses are used to detect information recognise the stages of the human life cycle recognise stages in the life cycles of familiar plants and animals identify the main parts of flowering plants	name the life processes common to humans and other animals identify the main organs of the human body describe the broad functions of the main parts of flowering plants	describe the role of lungs in breathing outline the process of digestion describe the main changes that occur during puberty describe the main stages in human reproduction describe the main stages in flowering plant reproduction	identify and give the functions of the main structures found in plant and animal cells identify, name and give the functions of the main organs of the human reproductive system identify the raw materials, conditions and products of photosynthesis

Living things and the processes of life (continued)

Strand	Level A	Level B	Level C	Level D	Level E
Interaction of living things with their environment	recognise and name some common plants and animals found in the local environment	give examples of feeding relationships found in the local environment	give examples of living things that are rare or extinct	describe examples of human impact on the environment that have brought about beneficial changes and examples that have detrimental effects	construct and interpret simple food webs and make predictions of the consequences of change
	give examples of how to care for living things and the environment	construct simple food chains	explain how living things and the environment can be protected and give examples	give examples of how plants and animals are suited to their environment	describe examples of competition between plants and between animals
	give some examples of seasonal changes in the appearance of plants			explain how responses to changes in the environment might increase the chances of survival	give examples of physical factors that affect the distribution of living things

Skills in science

Although investigating is an activity that crosses the curriculum, it has special significance for science. First-hand investigations are central to the way in which young children learn science, providing opportunities to plan fair tests, make observations, hypothesise, predict, collect evidence, research, survey and discuss. Through such means, opportunities arise to infer, deduce, calculate, draw conclusions from evidence, make judgements and debate important issues. Characteristics such as curiosity, responsibility, perseverance, cooperation, attention to detail and divergent thinking are also encouraged.

Skills in science - investigating

Strand	Level A	Level B	Level C	Level D	Level E
Preparing for tasks Understanding the task and planning a practical activity	make suggestions and contribute to the planning of simple practical explorations	plan simple approaches by asking questions and making suggestions	suggest a question for exploration and decide how they might find an answer	identify two or three questions to investigate provide reasons for planning decisions	identify a number of questions to investigate plan a valid and reliable test for a given hypothesis
Predicting		make suggestions about what might happen	make reasoned predictions about a possible outcome		
Undertaking fair testing		recognise when a test or comparison is unfair	suggest some ways of making a test fair	include fair testing in planning by changing one factor show awareness of the significance of variables	
Carrying out tasks Observing and measuring	carry out simple observations and measurements	use simple equipment and techniques to make observations and measurements	select and use appropriate measurement devices or make appropriate observations	make an appropriate series of accurate measurements	
Recording findings in a variety of ways	record observations in a simple form	record findings in a range of ways	record findings in a greater range of ways	select an appropriate way of recording findings	select and use appropriate forms of graphical presentation

Skills in science - investigating (continued)

Strand	Level A	Level B	Level C	Level D	Level E
Reviewing and reporting tasks					
Reporting and presenting	participate in the presentation of the findings through visual displays and oral reports	make a short report of an investigation	make a short report of an investigation, communicating key points clearly	make an organised report of an investigation using appropriate illustrations	write a structured report of an investigation using appropriate illustrations and vocabulary
Interpreting and evaluating results and processes	answer simple questions about what happened	answer questions on the meaning of the findings	explain what happened, drawing on their scientific knowledge	provide explanations related to scientific knowledge	
		recognise simple relationships and draw conclusions	make links to original predictions	draw conclusions consistent with their findings	establish links between the results and the original hypothesis
				identify limitations of the approach used	suggest improvements to the approach used

Dr Hirek Kwiatkowski
Dean of the Faculty of Education
University of Glasgow

Mike Carroll
10 MacNeill Drive
Kittoch Glen
East Kilbride
G74 4TR
22nd October 2001
Tele: 013552 63790

Dear

As you are no doubt aware I am currently engaged on study towards a PhD in the field of science education with Dr Norman Reid of the Centre for Science Education acting as my supervisor. The focus of my thesis is on the experience of B.Ed students engaged on ITE science courses within the Faculty and the science teaching they undertake during their primary school placements.

The focus of the thesis was borne out of discussions with Mr Derek Fraser who, aware of the nature of my M.Ed thesis on confidence levels amongst P5 to P7 teachers in the teaching of primary science, was keen for me to continue my work in this field. It was agreed that I should work collaboratively with a member of the science team. This it was hoped would both inform the work of the science team as well as providing them with the opportunity to engage in school based research.

During session 2000-2001 my contact with the the science team, under the close scrutiny of Mr Derek Fraser, continued as we worked through the nature of the research instruments to be delivered. The draft version of these instruments was introduced to all the staff members involved in the study. Suggested amendments have been incorporated into the final version of these instruments.

The thesis has now reached the stage of data collection. As such I am writing to request your formal approval to approach the BEd students. If your approval is granted I would intend the following course of action:

- circulating a questionnaire survey to all BEd students. This will consist largely of closed-style questions, in order to minimise the amount of time needed for completion, on a range of issues related to 5-14 Primary Science.

- seeking the agreement of selected students to participate in the observation of science lessons during their primary school placements. These lessons would be ones which they would intend delivering in the normal course of their placements and not lessons suggested by myself.

I am aware that should your permission be forthcoming there is no guarantee that students would be willing to participate as they may see such a study as a diversion from their first priority, namely the successful pursuit of their studies. Their right of refusal to participate is freely acknowledged and will be respected.

I am also aware that there is a further protocol to be undertaken in seeking approval from the respective Education Authorities and the primary schools involved. Indeed it may also be necessary to seek approval from parents as we would intend using video recordings as part of the research. Seeking such approval would be my responsibility. Furthermore I would take great care to ensure that the Faculty representatives responsible for both the BEd students and for school placements are aware of all actions I undertake.

Needless to say any information gathered would be treated in the strictest confidence and at no point would individual schools, staff or students be identified. Additionally you and your representatives would be granted access to a summary of the findings.

I would appreciate your approval of this request as I believe that the study proposed holds potential for gaining insights into the nature of BEd students experience of 5-14 Primary Science.

Your sincerely,

UNIVERSITY
of
GLASGOW

Mike Carroll
5-14 Primary Science

This questionnaire is being issued to all B.Ed students at the University of Glasgow with the permission of the Dean of the Faculty of Education. Whilst I fully realise how busy you are, I would be most grateful if you would take the time to complete the questionnaire.

Your responses will be treated in the **strictest confidence** and as such you will not be identified in the study. I have asked for your name to be given as I would like to follow up the questionnaire and talk to a sample of the students involved in order for me to explore some issues in more depth.

When going through the questionnaire, please put a **tick** in the box corresponding to your response, like this:

Yes [✓] No [ ]

On a small number of occasions you will be asked to provide more detail to a response. A space will be provided in those instances.

B.Ed year : [ ]

Section 1 : Personal Background

1. Name ______________________

2. Gender   Male ☐   Female ☐

3. At what stage did you last study science in the secondary school?

S1	S2	S3	S4	S5	S6
☐	☐	☐	☐	☐	☐

4. Please indicate your secondary school science qualifications by inserting your grades in the appropriate boxes.

		Physics	Chemistry	Biology	Science
Scotland	O Grade	☐	☐	☐	☐
	S Grade	☐	☐	☐	☐
	H Grade	☐	☐	☐	☐
	CSYS	☐	☐	☐	☐
	Scotvec	☐	☐	☐	☐
England / Wales	O Level	☐	☐	☐	☐
	A Level	☐	☐	☐	☐

Other (Please specify) ______________________

5. Please indicate how you felt about your own school experience of the sciences

	Physics	Chemistry	Biology	Science
Enjoyed	☐	☐	☐	☐
Mostly enjoyed	☐	☐	☐	☐
Neither	☐	☐	☐	☐
Mostly disliked	☐	☐	☐	☐
Disliked	☐	☐	☐	☐

6. What is the present level of your science education during teacher education?   Generalist ☐   Specialist ☐

End of Section 1

Page 1

Section 2 : Attainment Outcomes and Key Features

Questions 7 and 8 use the 5 point scale given below. Please tick the box that best represents your own confidence levels within the science attainment outcomes.

1 = Very confident
2 = Confident
3 = Confident with support
4 = Not very confident
5 = Not confident even with support

7. How confident are you that you have the knowledge and skills necessary to teach the science attainment outcomes?

   [A **SUPPORT SHEET** has been supplied to remind you of the content of each of the knowledge and understanding strands].

Living things and the processes of life :	**1**	**2**	**3**	**4**	**5**
variety and characteristic features	☐	☐	☐	☐	☐
the processes of life	☐	☐	☐	☐	☐
the interaction of living things with their environment	☐	☐	☐	☐	☐

Energy and forces :	**1**	**2**	**3**	**4**	**5**
properties and uses of of energy	☐	☐	☐	☐	☐
conversion and transfer of energy	☐	☐	☐	☐	☐
forces and their effects	☐	☐	☐	☐	☐

Earth and Space :	**1**	**2**	**3**	**4**	**5**
the Earth in space	☐	☐	☐	☐	☐
materials from Earth	☐	☐	☐	☐	☐
changing materials	☐	☐	☐	☐	☐

		1	2	3	4	5
8. How confident are you in teaching science at the different stages?	P1 to P3	☐	☐	☐	☐	☐
	P4 to P5	☐	☐	☐	☐	☐
	P6 to P7	☐	☐	☐	☐	☐

9. How confident are you that you have the knowledge and skills necessary to develop pupils' abilities to engage in investigative work?

[A **SUPPORT SHEET** has been supplied to remind you of the content of each of the skill strands]

	1	2	3	4	5
Preparing for tasks	☐	☐	☐	☐	☐
Carrying out tasks	☐	☐	☐	☐	☐
Reviewing and reporting on tasks	☐	☐	☐	☐	☐

End of Section 2

[Please continue]

Page 3

Section 3 : Teaching and Learning in Science

10. The following statements relate to the process of teaching and learning within the three science attainment outcomes. Please use the 5 point scale to record your response to each statement :

1 = Strongly agree
2 = Agree
3 = Uncertain
4 = Disagree
5 = Strongly disagree

	1	2	3	4	5
Science lessons are largely about the development of factual knowledge	☐	☐	☐	☐	☐
Teachers should supply notes for pupils to copy	☐	☐	☐	☐	☐
Pupils should be taught to concentrate during science lessons and not to talk	☐	☐	☐	☐	☐
Science lessons are an ideal opportunity for pupils to work collaboratively in groups	☐	☐	☐	☐	☐
Pupils should observe experiments which are demonstrated by the teacher	☐	☐	☐	☐	☐
Science should start with pupils talking about and exploring their ideas on scientific issues	☐	☐	☐	☐	☐
Pupils should gain direct experience of science through practical activity	☐	☐	☐	☐	☐
Pupils should develop their own notes through observation and practical activity	☐	☐	☐	☐	☐
Science lessons should mostly involve pupils in working by themselves	☐	☐	☐	☐	☐
The most important aspect of science is that pupils follow the procedures given	☐	☐	☐	☐	☐

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	1	2	3	4	5
Science lessons are more about the development of skills rather than facts	☐	☐	☐	☐	☐
Science can take place using everyday materials	☐	☐	☐	☐	☐
Science is made easier by the fact that there is little need for discussion and debate	☐	☐	☐	☐	☐
Science lessons require the teacher to devise experiments using available resources	☐	☐	☐	☐	☐
Handling equipment safely is an important aspect of science lessons	☐	☐	☐	☐	☐
Lessons should engage pupils in investigative approaches	☐	☐	☐	☐	☐
Lessons should involve pupils in exploring, observing and ordering	☐	☐	☐	☐	☐
It is too dangerous to give pupils access to scientific equipment	☐	☐	☐	☐	☐
Pupils should be given opportunities to devise methods of testing ideas	☐	☐	☐	☐	☐
Whole class lessons should be the norm in science	☐	☐	☐	☐	☐
Investigative work is inappropriate in science	☐	☐	☐	☐	☐
To be effective, science needs to be related to other areas of the curriculum	☐	☐	☐	☐	☐
Science lessons should be based around textbooks and worksheets	☐	☐	☐	☐	☐
Science lessons should be relevant to the everyday experience of the pupils	☐	☐	☐	☐	☐
The teacher must identify the focus of science lessons	☐	☐	☐	☐	☐

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	1	2	3	4	5
Science lessons should consist mostly of group activity with only some whole class work	☐	☐	☐	☐	☐
Science should be taught as separate lessons	☐	☐	☐	☐	☐
Pupils should choose the way to examine scientific problems	☐	☐	☐	☐	☐
Pupils should be given responsibility for identifying resources to carry out experiments	☐	☐	☐	☐	☐
It is not necessary to engage in practical activity in science lessons	☐	☐	☐	☐	☐
The teacher should plan investigative activities for the pupils	☐	☐	☐	☐	☐
The basic purpose of investigative work is to illustrate scientific theories	☐	☐	☐	☐	☐
Pupils should engage in evaluation of the outcomes of science lessons for themselves	☐	☐	☐	☐	☐
Scientific knowledge is not in any way different from other forms of knowledge	☐	☐	☐	☐	☐
Pupils should be allowed to use resources to discover scientific principles for themselves	☐	☐	☐	☐	☐
Pupils should be encouraged to identify the questions to ask during science activities	☐	☐	☐	☐	☐
The teachers should direct pupils towards the correct scientific answer to problems	☐	☐	☐	☐	☐

End of Section 3

[Please continue]

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Section 4 : Professional Skills

11. To take forward pupils' learning in science requires teachers to possess certain professional skills. Please use the 5 point scale to record your level of confidence in response to each statement :

1 = Very confident
2 = Confident
3 = Confident with support
4 = Not very confident
5 = Not confident even with support

	1	2	3	4	5
Focusing the teaching of science on knowledge and understanding of science	☐	☐	☐	☐	☐
Focusing the teaching of science on the skills of science	☐	☐	☐	☐	☐
Using the assessment process to plan group learning in science	☐	☐	☐	☐	☐
Reporting on pupils' attainment in knowledge and understanding	☐	☐	☐	☐	☐
Reporting on pupils' attainment in practical investigative skills	☐	☐	☐	☐	☐
Using whole class teaching to introduce and consolidate work in science	☐	☐	☐	☐	☐
Organising pupils into science ability (attainment) groups	☐	☐	☐	☐	☐
Using interactive (e.g. engaging in discussion, questioning etc) teaching methods with ability groups in science	☐	☐	☐	☐	☐
Developing homework linked to science topics	☐	☐	☐	☐	☐
Organising resources for science topics	☐	☐	☐	☐	☐

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	1	2	3	4	5
Defining attainment targets in science	☐	☐	☐	☐	☐
Anticipating likely areas of confusion in relation to scientific concepts	☐	☐	☐	☐	☐
Developing 'thinking skills' (e.g. problem solving, drawing conclusions etc)	☐	☐	☐	☐	☐
Assisting pupils in carrying out science investigations	☐	☐	☐	☐	☐
Assessing the discrete investigative skills (e.g. planning an activity)	☐	☐	☐	☐	☐
Managing practical science learning activities in different ways (e.g. groups, rotating between work stations etc)	☐	☐	☐	☐	☐
Differentiating science lessons to meet the needs of pupils	☐	☐	☐	☐	☐
Encouraging and responding to pupils' questions in science topics	☐	☐	☐	☐	☐

End of Section 4

[Please continue]

Section 5 : Personal Views

Thanks for your patience and perseverance so far. In this last section to the questionnaire
I am interested in **your personal views** on science.

12. How would you define science?

13. What is the purpose of science?

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14. Could you please supply a brief outline of **your** experience of science (e.g. positive and negative experiences, how science was taught, degree of difficulty etc).
(Please do not mention the names of schools or teachers)

End of Section 5

[A sincere thank you for your help]

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Scottish Wider Access Programme - SWAP

A SWAP Programme aims to prepare adults who lack traditional qualifications, for entry to higher education. Particular emphasis is placed on engaging adults from disadvantaged backgrounds. Programmes can be full-time, part-time, flexible, based on accreditation of prior experiential learning, or tailored combinations of these.

Since its inception in 1988, the Scottish Wider Access Programme has made significant progress towards its aim of establishing routes into higher education for mature students with few, if any, conventional qualifications. The success of the initiative may be attributed in no small part to the adoption of a consortium approach, which brought together further and higher education institutions to work collaboratively on the development of Access Programmes which addressed the needs of those from backgrounds which had previously been under-represented in higher education for example disabled, ethnic minorities, lone parents, women returners and those socially, economically or educationally disadvantage.

The aims of SWAP are:
- to raise awareness of Access and HE opportunities amongst the target groups;
- to support and facilitate entry to HE by individuals from the target groups;
- to promote a range of opportunities for study to include diversity in level, type and mode of study;
- to offer guaranteed progression of students to an appropriate programme;
- to facilitate collaboration between a range of sectors including community education, the voluntary sector, FE and HE;
- to provide high quality impartial information to students preparing for return to study;
- to provide a quality service to meet the needs of its users.

Courses are designed to build on the experience of adults and to prepare them, not just for entry to higher education, but also success there. Among the critical elements that distinguish SWAP programmes as a suitable route for adult returners are:
- the need for adequate preparation for Higher Education;
- the need for minimum entry points and maximum progression routes;
- the need for introductory units which build confidence;
- the need for rapid progression;
- the need to take account of previous experience;
- the need to provide opportunities for students to experience a wide range of subject areas to enable them to make realistic choices about career paths;
- the need for a national strategy for revised Scottish Wider Access Programmes which allows local flexibility, both in terms of progression routes and of geography.

Source: http://www.abdn.ac.uk/~com168/snap/seswap.hti

❖ **Terminal point in the participants' school science education**

Year	S1	S2	S3	S4	S5	S6
B.Ed1	1 (1)	3 (3)	1 (1)	40 (33)	38 (31)	37 (31)
B.Ed2	0 (0)	4 (4)	1 (1)	28 (31)	33 (36)	25 (28)
B.Ed3	0 (0)	3 (5)	0 (0)	21 (31)	22 (32)	22 (32
B.Ed4	0 (0)	0 (0)	1 (1)	29 (35)	28 (34)	25 (30)
PGCE	2 (2)	6 (5)	1 (1)	35 (31)	42 (37)	28 (24)
All	3 (1)	16 (3)	4 (1)	153 (32)	163 (34)	137 (29)

❖ **Number of participants with qualifications in Physics and Chemistry**

Year	1 SG	2 SG	O + H	1 H	2 Hs	H/AH	2AHs
B.Ed1	19	8	6	3	4	0	0
B.Ed2	12	8	4	6	5	0	0
B.Ed3	8	5	7	6	5	0	0
B.Ed4	14	9	12	4	2	0	0
PGCE	7	5	9	8	16	3	2
All	60	35	38	27	32	3	2

❖ **Number of participants with qualifications in Chemistry and Biology**

Year	1 SG	2 SG	O + H	1 H	2 Hs	H/AH	2AHs
B.Ed1	18	4	20	18	8	3	0
B.Ed2	15	3	17	9	2	1	0
B.Ed3	11	2	7	7	5	2	0
B.Ed4	5	7	16	3	7	2	0
PGCE	13	10	7	10	8	2	1
All	62	26	67	47	30	10	1

❖ **Summary of participants with dual qualifications in school science**

	1 SG	2 SG	O + H	1 H	2 Hs	H/AH	2AHs	None
N = 479	122	61	105	74	62	13	3	39
%	25	13	22	15	13	3	1	7

❖ Number of participants with qualifications in Physics and Biology

YEAR	Physics	Chemistry	Biology
BEd 1	SG		H
	SG	H	H
BEd2	SG	SG	H
	SG	SG	H
	H	SG	H
	H		SG
BEd3	SG	SG	SG
	H	H	SG
BEd4	H	SG	H
	H	SG	H
	SG		SG
PGCE	H		H
	H		H
	SG	H	H
	SG	H	H
	H	SG	H
	H	SG	H
	H	H	H
	H	H	SG
	SG	SG	H
	SG		H

Key:	1 = Enjoyed			4 = Mostly disliked	
	2 = Mostly enjoyed			5 = Disliked	
	3 = Neither				

❖ Participants' experience of Physics

Year	1	2	3	4	5	Missing
B.Ed1	15 (19)	14 (18)	19 (24)	18 (23)	13 (16)	42
B.Ed2	7 (10)	14 (21)	14 (21)	14 (21)	19 (28)	23
B.Ed3	10 (20)	12 (23)	7 (14)	6 (12)	16 (31)	17
B.Ed4	11 (20)	17 (31)	4 (7)	9 (16)	14 (26)	28
PGCE	13 (15)	19 (21)	12 (13)	22 (25)	23 (26)	27
All	56 (16)	76 (22)	56 (16)	69 (20)	85 (25)	137

Note: The figures in brackets are valid percentages calculated from each year cohorts sample.

❖ Participants' experience of Chemistry

Year	1	2	3	4	5	Missing
B.Ed1	14 (15)	32 (34)	18 (19)	16 (17)	15 (16)	26
B.Ed2	8 (11)	26 (35)	19 (25)	7 (9)	15 (20)	16
B.Ed3	8 (15)	13 (24)	11 (21)	12 (23)	9 (17)	15
B.Ed4	10 (13)	28 (38)	16 (22)	13 (18)	7 (9)	9
PGCE	19 (20)	37 (38)	10 (10)	19 (20)	11 (12)	20
All	59(15)	136 (35)	74 (19)	67 (17)	57 (14)	86

Note: The figures in brackets are valid percentages calculated from each year cohorts sample.

❖ Participants' experience of Biology

Year	1	2	3	4	5	Missing
B.Ed1	41 (41)	31 (31)	15 (15)	9 (9)	5 (5)	20
B.Ed2	12 (16)	36 (49)	13 (18)	3 (4)	9 (12)	18
B.Ed3	19 (48)	9 (23)	5 (12)	5 (12)	2 (5)	28
B.Ed4	14 (23)	22 (35)	15 (24)	3 (5)	8 (13)	21
PGCE	31 (37)	33 (39)	12 (14)	4 (5)	4 (5)	32
All	117 (32)	131 (36)	60 (17)	24 (7)	28 (8)	119

Note: The figures in brackets are valid percentages calculated from each year cohorts sample.

Kendall's tau-b

In most statistical packages, correlational analysis is a technique use to measure the association between two variables. A correlation coefficient is a statistic used for measuring the strength of a supposed linear association between two variables. Although it may be possible to detect an association between two variables using correlational analysis this does not necessarily mean that change in one variable causes another to change. It merely means that as one changes the other changes also. The cause of this change may be due to a third variable.

Kendall's tau is a measure of correlation, and so measure the strength of the relationship between two variables. We require that the two variables, X and Y, are paired observations, for example, level of confidence in teaching the knowledge strand 'the Earth in space' at the 'P4 to P5' primary stage, for each student in the sample. As both of these variables are ordinal, it is possible to calculate the correlation between them.

Kendall's tau, like Spearman's rank correlation, is carried out on the ranks of the data. That is, for each variable separately the values are put in order and numbered, 1 for the lowest value, 2 for the next lowest and so on. In common with other measures of correlation Kendall's tau will take values between -1 and +1, with a positive correlation indicating that the ranks of both variables increase together whilst a negative correlation indicates that as the rank of one variable increases the other one decreases.

Spearman's rank correlation is a more widely used measure of rank correlation because it is much easier to compute than Kendall's tau. However, this can be overcome using statistical software packages such as SPSS (v.11). This is important as the Kendall tau statistic is more useful in that it does not make a strong assumption of a linear trend in the data. Furthermore the Kendall's tau statistical properties provides for a direct interpretation of the statistic in terms of probabilities of observing concordant and discordant pairs.

Kendall's tau-b is a non-parametric measure of association based on the number of concordances and discordances in paired observations. Concordance occurs when paired observations vary together, and discordance occurs when paired observations vary differently. Essentially this means that all pairs of points are connected or tied and then counted in order to determine how many of the segments have negative slope and how many have positive slope. The formula for Kendall's tau-b is:

$$\frac{\sum_{i<j} \operatorname{sgn}(x_i - x_j)\operatorname{sgn}(y_i - y_j)}{\sqrt{(T_0 - T_1)(T_0 - T_2)}}$$

where:

$T_0 = n(n - 1) \div 2$

$T_1 = \Sigma\, t_i(t_i - 1) \div 2$

$T_2 = \Sigma\, u_i(u_i - 1) \div 2$

and where t_i is the number of tied x values in the ith group of tied x values, u_i is the number of tied y values in the ith group of tied y values, f is the number of observations, and sgn (z) is defined as:

$$\operatorname{sgn}(z) = \begin{cases} 1 & \text{if } z > 0 \\ 0 & \text{if } z = 0 \\ -1 & \text{if } z < 0 \end{cases}$$

Bibliography:

Crichton N.J. (2001) Information point: Kendall's Tau. *Journal of Clinical Nursing*, Vol 10, pps 707-715

University of Newcastle-upon-Tyne Computing Service (2003) Correlational Analysis. *http://www.ncl.ac.uk/ucs/statistics/docs/correlationanalysis.html*

❖ **Associations between participants' qualifications: Physics and Chemistry**

Disciplines	**Chemistry**					
Physics	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	NS					
B.Ed2		0.24*				
B.Ed3			.50**			
B.Ed4				NS		
PGCE					.41**	
ALL						.22**

❖ **Associations between participants' qualifications: Chemistry and Biology**

Disciplines	**Biology**					
Chemistry	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	-.2*					
B.Ed2		NS				
B.Ed3			NS			
B.Ed4				NS		
PGCE					NS	
ALL						NS

❖ **Associations between participants' qualifications: Biology and Chemistry**

Disciplines	**Physics**					
Biology	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	-.48**					
B.Ed2		-.32**				
B.Ed3			NS			
B.Ed4				-.39**		
PGCE					NS	
ALL						-.34**

Appendix 4.9: Kendall tau-b -- Participants' qualifications and science disciplines

❖ **Associations between participants' qualifications and experience of science disciplines**

Discipline	Experience of Physics						Experience of Chemistry						Experience of Biology					
Physics	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.45**						NS						-.22*					
B.Ed2		.4**						NS						-.33**				
B.Ed3			NS						NS						NS			
B.Ed4				NS						NS						NS		
PGCE					.21*						NS						NS	
ALL						.32**						.12*						-.19**
Chemistry	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	NS						.23**						NS					
B.Ed2		NS						NS						NS				
B.Ed3			NS						NS						NS			
B.Ed4				NS						-.26*						NS		
PGCE					NS						.27**						NS	
ALL						NS						.09*						NS
Biology	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	-.21*						NS						.23**					
B.Ed2		-.38**						-.23*						NS				
B.Ed3			-.28*						NS						NS			
B.Ed4				NS						-.29*						NS		
PGCE					-.24*						NS						.21*	
ALL						-.28**						-.10*						NS

❖ **Associations between participants' qualifications and experience: Physics and Science**

Disciplines	Experience of Science					
Physics	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.34**					
B.Ed2		NS				
B.Ed3			NS			
B.Ed4				0.39*		
PGCE					NS	
ALL						.15*

❖ **Associations between participants' qualifications and experience: Chemistry and Science**

Disciplines	Experience of Science					
Chemistry	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.31**					
B.Ed2		NS				
B.Ed3			NS			
B.Ed4				NS		
PGCE					NS	
ALL						.17**

❖ **Associations between participants' qualifications and experience: Biology and Science**

Disciplines	Experience of Science					
Biology	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	-.24*					
B.Ed2		NS				
B.Ed3			NS			
B.Ed4				NS		
PGCE					NS	
ALL						NS

❖ **Associations between participants' experience: Physics and Chemistry**

Experience	**Chemistry**					
Physics	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.26**					
B.Ed2		.32**				
B.Ed3			.47**			
B.Ed4				NS		
PGCE					.34**	
ALL						.27**

❖ **Associations between participants' experience: Chemistry and Biology**

Experience	**Biology**					
Chemistry	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	NS					
B.Ed2		NS				
B.Ed3			NS			
B.Ed4				NS		
PGCE					.29**	
ALL						.16**

❖ **Associations between participants' experience: Biology and Chemistry**

Experience	**Physics**					
Biology	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	NS					
B.Ed2		NS				
B.Ed3			NS			
B.Ed4				NS		
PGCE					NS	
ALL						NS

❖ **Associations between participants' experience: Physics and Science**

Experience	**Science**					
Physics	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	NS					
B.Ed2		.27*				
B.Ed3			NS			
B.Ed4				NS		
PGCE					.28*	
ALL						.27**

❖ **Associations between participants' experience: Chemistry and Science**

Experience	**Science**					
Chemistry	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.33**					
B.Ed2		.33**				
B.Ed3			0.6**			
B.Ed4				.49**		
PGCE					.58**	
ALL						.43**

❖ **Associations between participants' experience: Biology and Science**

Experience	**Science**					
Biology	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.32**					
B.Ed2		.41**				
B.Ed3			.6**			
B.Ed4				NS		
PGCE					.47**	
ALL						.36**

Section 5 of questionnaire : Personal Views

A small number of open-ended questions were asked to elicit the students' personal views on science. These included:

- How would you define science?
- What is the purpose of science?
- Could you please supply a brief outline of your experience of science (*e.g.* positive and negative experiences, how science was taught, degree of difficulty, *etc.*). Please do not mention the names of schools or teachers.

Analytic induction

The data was analysed by the technique of analytic induction (Abell and Smith, 1994; Murcia and Schibeci, 1999). This is a method based on the constant comparative method developed by Glaser and Strauss (1967) as part of the 'grounded theory' approach. The basic aim of such an approach is to generate theoretical constructs from the data rather than to impose a theoretical construct on the data.This technique involves the researcher reading and re-reading the students responses in order to identify patterns. A coding or category system is developed on the basis of the emerging patterns.

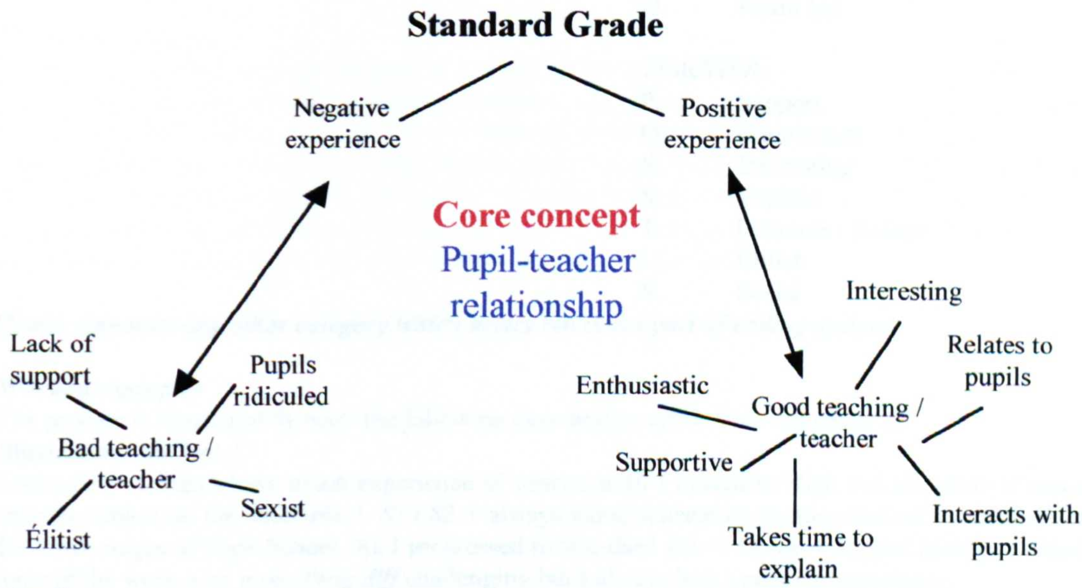
Step 1
All of the questionnaires had been coded using a student year and sequential numbering system as part of the earlier SPSS analysis of demographic characteristics, teaching and learning, *etc*. Thus 5 / 65 = PGCE number 65.

Step 2
The students' responses were copied using a rank xerox. The questionnaire coding system was transferred onto the copies beside the response *for each* of the open-ended questions. The copies were then cut up and the individual questions were bundled together.

Step 3
The process of reading and re-reading the individual bundles commenced. I worked on one bundle (*i.e.* question) at a time. Initially I made pencil annotations onto the copies as patterns emerged (*e.g.* SG (Standard Grade), PS (primary school), + (positive experience), PA (practical activities), *etc*). I kept a separate record of these codings for later reference.

Step 4
Once I had read and re-read the bundle of responses and felt comfortable that I had identified the main patterns within the students' responses I began to construct a data analysis concept map. I used A3 paper and worked on fragments of the concept map making connections between them over time so constructing a map which incorporated all of the patterns identified in the students' responses for the question being examined.

Three fragment section from concept map



Step 5
Part of this process involved identifying similarities and differences in the respondents' answers. By comparing similar responses it becomes possible to define each concept through identification of synonyms. Thus the students will describe 'good teachers' and 'bad teachers' in a variety of ways. There could be a concern that you will become immersed in a morass of detail, however, within this detail there is a *core concept*, namely that good and bad teaching is defined in terms of the 'pupil-teacher relationship'.

Step 6
Once the concept map was produced an alpha-numeric, or more correctly a numeric-alpha, coding system was laid onto the map. I then re-read the responses and began to red pen them with the coding system. The alpha-numeric coding system quickly proved to be inadequate as there was a clear loss of detail in terms of the specific descriptors of the key ideas identified. Consequently an numeric-alpha-alpha was developed to incorporate these detailed descriptors. This system was a little cumbersome to use but it did appear to work. The error also established the importance of not working with the originals.

Step 7
The frequency of the various coding categories were determined.

CODING SYSTEM

Key idea		First level descriptor		Second level descriptor	
1.	Primary school	a.	Limited experience	*SUBJECT*	
		b.	Some experience	A.	Standard Grade
				B.	Higher Level
2.	S1 / S2	a.	Positive experience	C.	Progressively difficult
		b.	Negative experience	D.	Theoretical / Mathematical
3.	Biology	c.	Good teacher	E.	Relevant
		d.	Bad Teacher	F.	Not relevant
4.	Chemistry				
				METHODOLOGY	
5.	Physics			G.	Practical work
				H.	Investigative work
6.	Science			I.	Fact based
				J.	Textbooks / Worksheets
				K.	Directive
				L.	Discussion
				M.	Whole class
				N.	Group work
				O.	Exam led
				TEACHER	
				P.	Support
				Q.	Enthusiasm
				R.	Interesting
				S.	Explain
				T.	Interacts / Relates
				U.	Élitist
				V.	Sexist

[Note: ***Annotate any other category which arises but is not part of coding system***]

Worked examples
The process is illustrated through the following case studies taken from the research.
Illustration: Student 1[1]
Limited PS I didn't have much experience of science until I moved to High School where it was a separate subject on the timetable. I *S1 / S2* + always found science interesting and not too difficult in the lower stages of High School. As I progressed to Standard *Bio* + Grade + Higher Biology I found some of the work a lot more *Prog diff* challenging but I always had a positive experience.

Coding: 1a; 6a; 2a; 3aA/B; 3aC

[1] I have made no attempt to correct the spelling, punctuation or grammar of these citations. Nor have I made any attempt to indicate that they are linguistically incorrect.

Illustration: Student 2
Limited PS At primary school, I feel I had very little experience of any kind *S1 / S2 +* of science. In S1 + S2, Science was interesting as it was a relatively new subject for me. For S Grade, I then chose *Bio +ve / SG* Chemistry and Biology. Biology was interesting, and the *PA/relevant* experiments more linked to the world around us, so they were relevant. I enjoyed the subject, and chose to do it at higher level. *Bio +ve / Higher /* Because of the direct link with Biology and our surrounding *relevant* environment, it was easier to make sense of and was more *teacher +ve* relevant. My teacher, who was the same for both S Grade and *support / explain* Higher, was also very supportive and took time to explain *theory / difficult* theories which were more difficult to understand.

Chem -ve / Chemistry, on the other hand, was of no relevance to me *no relevance* whatsoever. The experiments were fiddly and boring, and it was hard at times to see the point of mixing 2 substances together just to see a colour change!

Coding: 1a; 2a; 3aG - E, 3cP/S - D(difficult), 4bF, 4bG.

Illustration: Student 3
Chem -ve i didn't really enjoy chemistry as my teacher wasn't very good *poor teacher /* at explaining the meaning of thinks i didn't like the formula - *explain / formula* equations either
Bio +ve i really enjoyed Biology all through school

Coding: 4b; 4dS; 4bD; 3a.

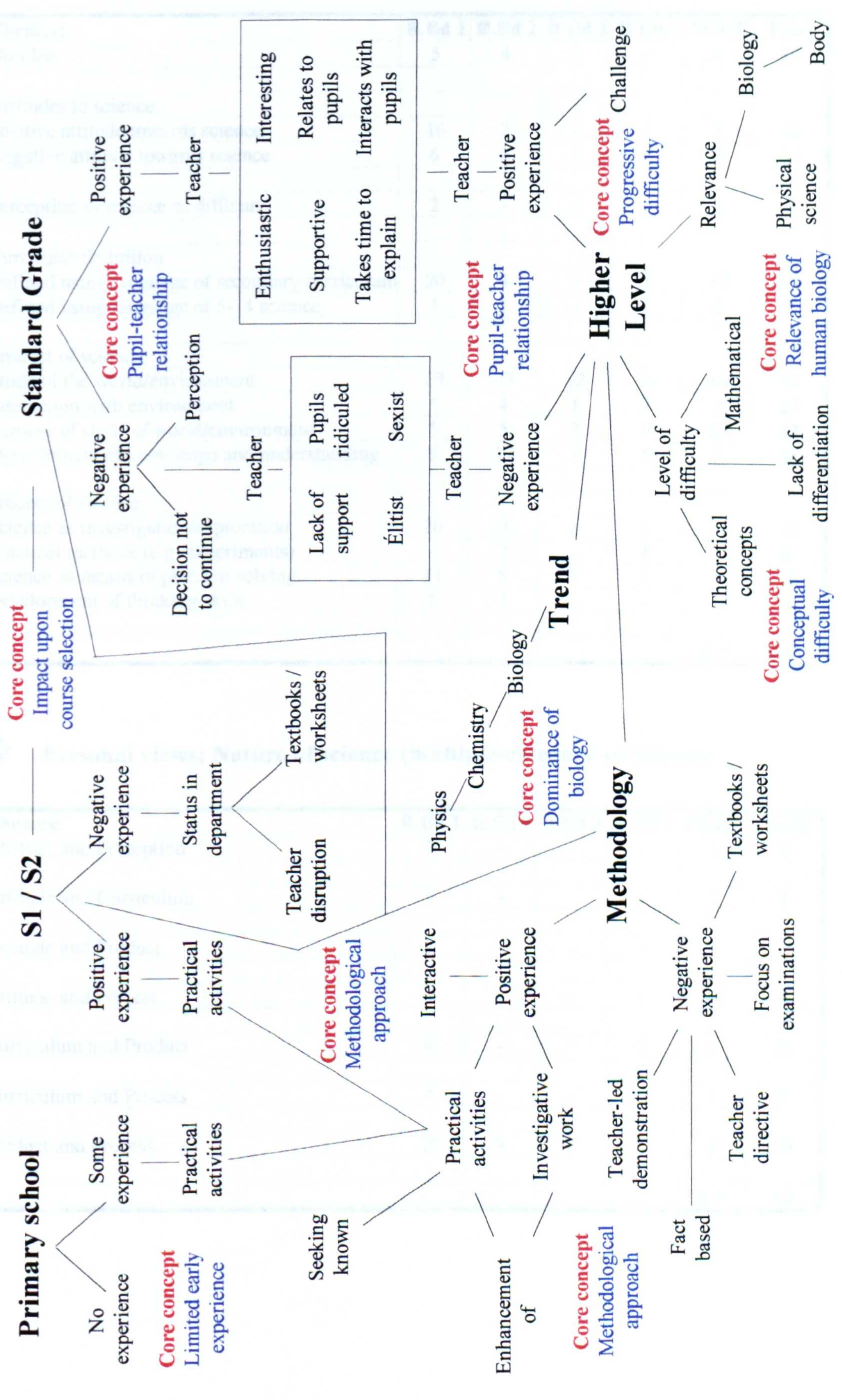
Illustration: Student 4
Science +ve My experience of Science was both enjoyable and unenjoyable. *PA +ve* Times it was enjoyable as there was practical activities to do *Discussion +ve* and there were also whole class discussions on a certain part of the work being done. *Whole class &* Science was always taught in the whole class, the only time we *groups - PA* were split into groups was for practical work. The reason that sometimes I did not like Science was *Higher / difficult* because as I progressed through to higher levels it became harder. Although Science was sometimes hard, on the whole I enjoyed my years of learning science.

Coding: 6aG - N, 6aL - M, 6bC.

Illustration: Student 5
S1 / S2 +ve In first and second year at school I quite enjoyed science, although in second year physics and chemistry I had a lot of *Supply teachers* supply teachers and so quite a lot of course work was not covered. In third and fourth year I chose to do 'S' grade *Bio / SG / +ve* Biology. I enjoyed biology mainly and I had an interesting and *Teacher / support* enthusiastic teacher who was always very supportive. */ enthusiastic* In fifth year, I struggled with the work and I often felt that I *Higher / difficult* was being left behind. Although the teacher tried to support me. *Teacher / support* I didn't really enjoy the classes and I didn't feel positive about *Exam -ve* sitting the exam.

Coding: 2a + 2b - supply; 3aA; 3cP/Q/R; 3bB - C; 3cP; 3bO.

❖ Data analysis concept map -- experience of science as pupil



❖ Personal views: Nature of science

Themes:	B.Ed 1	B.Ed 2	B.Ed 3	B.Ed 4	PGCE	Total
No idea	5	4	4	-	6	19
Attitudes to science:						
Positive attitude towards science	16	2	-	1	3	22
Negative attitude towards science	6	3	-	-	3	34
Perception of science as difficult	2	-	-	-	2	4
Curricular definition						
Defined using language of secondary curriculum	20	4	-	3	10	37
Defined using language of 5-14 science	4	1	-	1	2	8
Product of science:						
Study of the world/environment	29	23	12	16	16	96
Interaction with environment	5	4	1	2	2	14
Purpose of study of world/environment	5	5	2	9	12	33
Development of knowledge and understanding	9	12	7	5	5	38
Process of science:						
Science as investigation/exploration	20	10	2	6	4	42
Practical methods (e.g. experiments)	-	7	-	1	-	8
Science as means of problem solving	11	8	3	1	3	26
Development of thinking skills	1	2	-	-	1	4
					n =	363

❖ Personal views: Nature of science (multiple-category responses)

Themes:	B.Ed 1	B.Ed 2	B.Ed 3	B.Ed 4	PGCE	Total
Attitude and Perception	2	-	-	-	1	3
Attitude and Curriculum	-	-	-	-	1	1
Attitude and Product	1	-	-	-	-	1
Attitude and Process	3	-	-	1	-	4
Curriculum and Product	6	-	-	2	2	10
Curriculum and Process	4	-	-	-	1	5
Product and Process	10	9	2	5	2	28
					n =	52

❖ Personal views: Purpose of science

Themes:	B.Ed 1	B.Ed 2	B.Ed 3	B.Ed 4	PGCE	Total
Focus on teaching:						
Introduction of theories and facts	13	1	3	1	3	21
To give knowledge	18	6	5	7	4	40
Product of science:						
Development of knowledge and understanding	39	17	9	11	27	101
Knowledge of how things work	28	23	4	5	14	74
Improvement of environment	1	1	-	2	1	5
Environmental sustainability	-	-	1	3	-	4
Process of science:						
Science as investigation/exploration	24	26	6	13	12	81
Questioning aspects of experience	4	2	-	-	1	7
Experimental approach	4	3	1	1	-	9
Hands-on / practical experience	5	2	3	-	-	10
Skill development:						
Thinking skills	2	4	-	-	1	7
Problem solving	1	9	2	-	2	14
Working collaboratively	4	4	-	1	1	10
Technological orientation	2	1	1	1	1	6
					n =	389

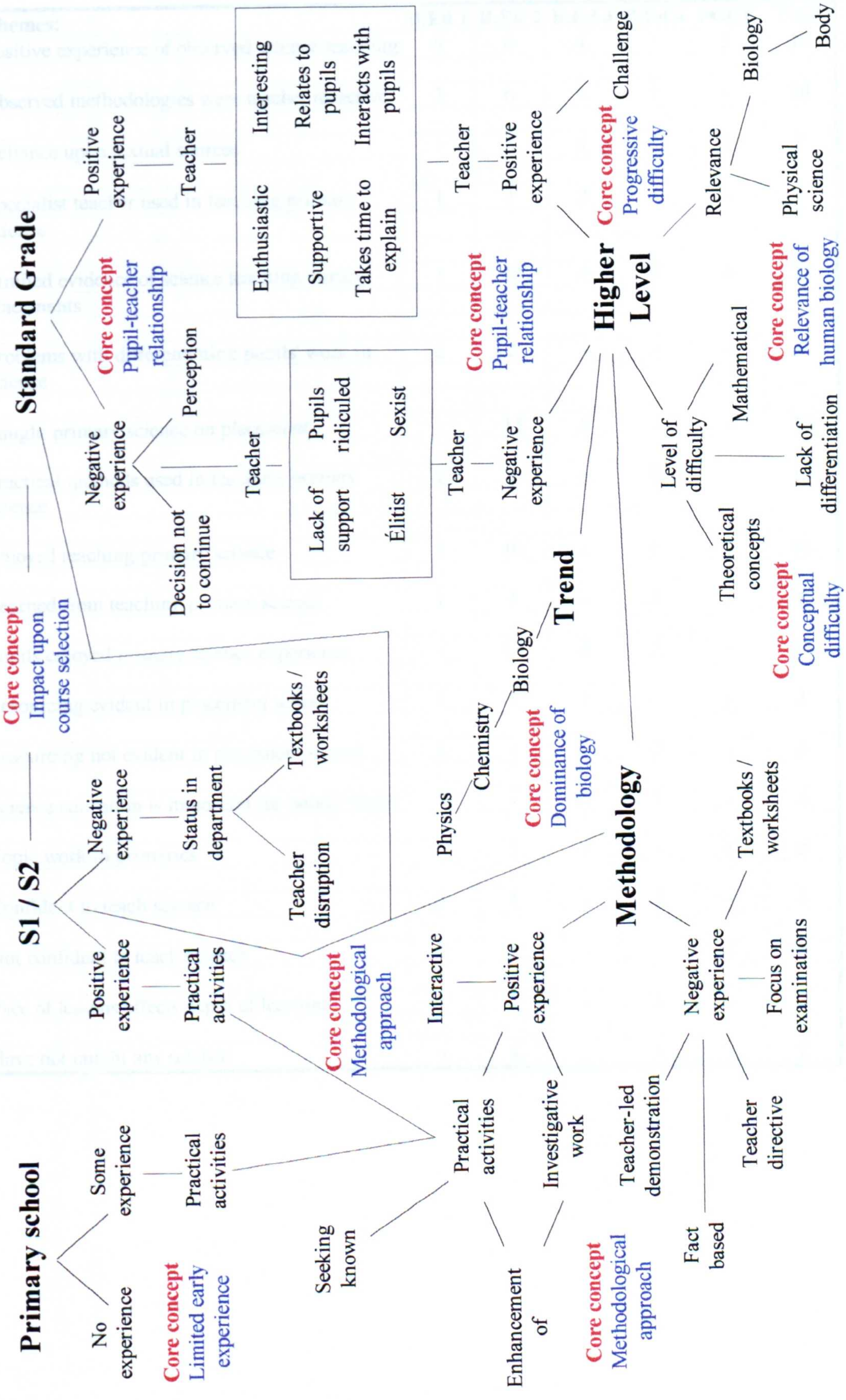
❖ Personal views: Purpose of science (multiple-category responses)

Themes:	B.Ed 1	B.Ed 2	B.Ed 3	B.Ed 4	PGCE	Total
Focus on teaching and:						
Product of science	2	1	-	-	-	3
Process of science	3	1	-	-	-	4
Skill development	-	1	-	-	-	1
Product of science and:						
Process of science	16	9	4	6	4	39
Skill development	2	-	-	-	-	2
Technological orientation	1	-	-	-	1	2
Process of science and:						
Skill development	2	7	-	-	1	10
Technological orientation	1	-	1	-	-	2
					n =	63

❖ Personal views: Experience of science as a pupil

Themes:	B.Ed 1	B.Ed 2	B.Ed 3	B.Ed 4	PGCE	Total
No experience of science during primary years	13	8	5	9	5	40
Some experience of science during primary years	3	-	-	4	1	8
Positive experience of science during S1/S2 years	16	3	4	5	5	33
Negative experience of science during S1/S2 years	2	1	-	-	3	6
Selected certificate course on the basis of a positive experience in S1/S2	15	1	1	7	4	28
Positive experience of science post-S2	32	7	7	10	17	73
Negative experience of science post-S2	19	18	3	2	14	56
Biology:						
Positive experience of certificate courses	25	10	3	7	18	63
Negative experience of certificate courses	5	2	-	2	3	12
Chemistry:						
Positive experience of certificate courses	8	5	3	4	9	29
Negative experience of certificate courses	13	4	7	10	7	41
Physics:						
Positive experience of certificate courses	8	2	4	3	6	23
Negative experience of certificate courses	13	4	4	2	16	39
Found science increasingly difficult between Standard Grade and Higher	23	8	5	8	7	51
Found physical sciences too theoretical	3	2	1	4	1	11
Found physical sciences too mathematical	6	1	1	2	4	14
Found physical sciences too élitist	3	2	3	1	6	15
Liked practical activities / experiments	18	8	6	9	15	56
Insufficient practical activities / experiments	7	3	-	1	1	12
Did not like practical activities / experiments	3	-	-	1	1	5
Liked investigative work	5	2	2	1	2	12
Practical methodologies experienced as pupil have relevance to students as teachers	3	2	-	5	3	13
Positive interaction with science teacher	21	8	7	8	12	56
Negative interaction with science teacher	23	9	9	6	22	69
Positive experience due to involvement in practical activities	10	-	2	-	2	14
Negative experience due to lack of involvement in practical activities	1	5	1	1	-	8
Teaching methodologies were directive	3	4	2	3	6	18
Course work relied heavily on textbooks and worksheets	4	7	2	2	-	15
Subject was relevant –						
Biology	8	3	1	1	5	18
Chemistry	-	-	-	-	-	-
Physics	1	-	-	-	1	2
Subject was not relevant –						
Biology	1	1	1	-	-	3
Chemistry	-	-	-	1	2	3
Physics	1	-	-	-	2	3
Science course was too rushed	2	4	-	-	3	9
Science course was boring	12	8	2	4	5	31
Science teachers had negative views of females' ability to do science	4	-	-	-	-	4

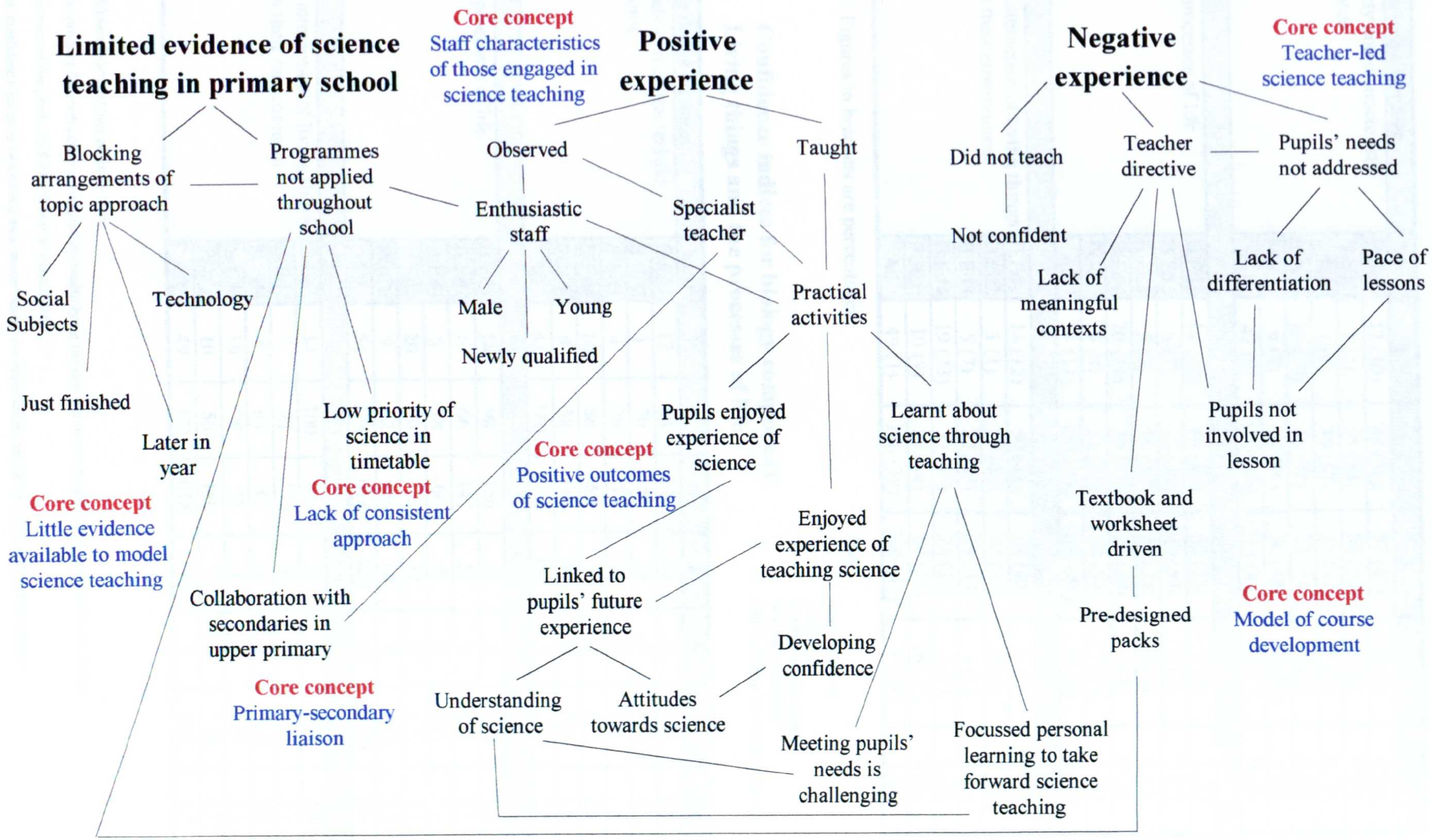
❖ **Data analysis concept map – experience of science as pupil**



❖ Personal views: Experience of science as student teacher

Themes:	B.Ed 1	B.Ed 2	B.Ed 3	B.Ed 4	PGCE	Total
Positive experience of observed science teaching	6	6	4	1	2	19
Observed methodologies were teacher directive	2	6	1	1	-	10
Reliance upon textual sources	-	3	1	2	1	7
Specialist teacher used in teaching primary science	1	1	2	-	-	4
Limited evidence of science teaching during placements	1	13	4	4	5	27
Problems with differentiating pupils' work in science	2	2	-	-	-	4
Taught primary science on placement	-	15	5	4	-	24
Practical methods used in teaching primary science	1	8	-	4	-	13
Enjoyed teaching primary science	2	10	-	1	-	13
Learned from teaching primary science	1	4	-	1	1	7
Pupils enjoyed primary science experience	-	11	4	5	-	20
Resourcing evident in placement school	1	1	1	-	-	3
Resourcing not evident in placement school	1	-	-	2	-	3
Science education is important for pupils' future	3	-	-	1	-	4
Topic work in primaries	-	2	-	-	1	3
Confident to teach science	1	1	-	2	-	4
Not confident to teach science	1	3	-	-	1	5
Pace of lessons affects depth of learning	-	1	-	1	-	2
Have not taught any science	-	1	-	1	-	2

❖ **Data analysis concept map -- experience of teaching primary science**



❖ Knowledge strands for biology component: Living things and the processes of life

Knowledge strands:	Year	1	2	3	4	5
variety and characteristic features	B.Ed1	12 (10)	44 (36)	57 (47)	8 (7)	0 (0)
	B.Ed2	1 (1)	35 (38)	50 (55)	5 (6)	0 (0)
	B.Ed3	4 (6)	39 (57)	25 (37)	0 (0)	0 (0)
	B.Ed4	16 (19)	43 (52)	23 (28)	1 (1)	0 (0)
	PGCE	9 (8)	29 (25)	56 (48)	22 (19)	0 (0)
	All	42 (9)	190 (40)	211 (44)	36 (7)	0 (0)
the processes of life	B.Ed1	14 (12)	49 (40)	52 (43)	5 (4)	1 (1)
	B.Ed2	6 (7)	33 (36)	49 (54)	3 (3)	0 (0)
	B.Ed3	5 (7)	39 (57)	22 (33)	2 (3)	0 (0)
	B.Ed4	20 (24)	35 (42)	25 (30)	3 (4)	0 (0)
	PGCE	9 (8)	31 (27)	58 (50)	17 (14)	1 (1)
	All	54 (11)	187 (39)	206 (43)	30 (6)	2 (1)
the interaction of living things with their environment	B.Ed1	14 (12)	50 (41)	48 (40)	9 (7)	0 (0)
	B.Ed2	1 (1)	37 (41)	45 (49)	8 (9)	0 (0)
	B.Ed3	5 (7)	32 (47)	29 (43)	1 (1)	1 (1)
	B.Ed4	19 (23)	39 (47)	24 (29)	1 (1)	0 (0)
	PGCE	10 (9)	28 (24)	60 (52)	18 (15)	0 (0)
	All	49 (1)	186 (39)	206 (43)	37 (8)	1 (0)

Note: Figures in brackets are percentages

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

❖ Confidence indices for biology component: Living things and the processes of life

Knowledge strands:	Year	1	2	3	4	5	Σ	CI
variety and characteristic features	B.Ed1	12	88	171	32	0	303	2.5
	B.Ed2	1	70	150	20	0	241	2.6
	B.Ed3	4	78	75	0	0	157	2.3
	B.Ed4	16	86	69	4	0	175	2.1
	PGCE	9	58	168	88	0	323	2.8
	All	42	380	633	144	0	1199	2.5
the processes of life	B.Ed1	14	98	156	20	5	293	2.4
	B.Ed2	6	66	147	12	0	231	2.5
	B.Ed3	5	78	66	8	0	157	2.3
	B.Ed4	20	70	75	12	0	177	2.1
	PGCE	9	62	174	68	5	318	2.7
	All	54	374	618	120	10	1176	2.5
the interaction of living things with their environment	B.Ed1	14	100	144	36	0	294	2.4
	B.Ed2	1	74	135	32	0	242	2.7
	B.Ed3	5	64	87	4	5	165	2.4
	B.Ed4	19	78	72	4	0	173	2.1
	PGCE	10	56	180	72	0	318	2.7
	All	49	372	618	148	5	1192	2.5

Confidence index calculated as follows:

- the product for each cell is calculated by multiplying the row number with the value assigned to its column
- the sum of the products for each row is calculated;
- the confidence index is calculated as a'*mean*' using the population sample for each of the year cohorts.

❖ Knowledge strands for physics component: Energy and forces

Knowledge strands:	Year	1	2	3	4	5
properties and uses of energy	B.Ed1	9 (7)	35 (29)	50 (41)	26 (22)	1 (1)
	B.Ed2	7 (8)	24 (26)	49 (54)	11 (120	0 (0)
	B.Ed3	7 (10)	28 (41)	21 (31)	12 (18)	0 (0)
	B.Ed4	18 (22)	38 (46)	20 (24)	6 (7)	1 (1)
	PGCE	10 (9)	22 (19)	39 (33)	44 (38)	1 (1)
	All	51 (10)	147 (31)	179 (37)	99 (21)	3 (1)
conversion and transfer of energy	B.Ed1	6 (5)	33 (27)	51 (42)	30 (25)	1 (1)
	B.Ed2	6 (7)	25 (27)	46 (51)	14 (15)	0 (0)
	B.Ed3	7 (10)	29 (43)	21 (31)	11 (16)	0 (0)
	B.Ed4	14 (17)	32 (39)	30 (36)	7 (8)	0 (0)
	PGCE	10 (8)	22 (19)	38 (33)	44 (38)	2 (2)
	All	43 (9)	141 (29)	186 (39)	106 (22)	3 (1)
forces and their effects	B.Ed1	13 (11)	34 (28)	49 (40)	24 (20)	1 (1)
	B.Ed2	8 (9)	20 (22)	46 (50)	17 (19)	0 (0)
	B.Ed3	4 (6)	35 (51)	17 (25)	12 (18)	0 (0)
	B.Ed4	14 (17)	39 (47)	24 (29)	6 (7)	0 (0)
	PGCE	10 (8)	24 (21)	38 (33)	44 (38)	0 (0)
	All	49 (10)	152 (32)	174 (36)	103 (22)	1 (0)

Note: Figures in brackets are percentages

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

❖ Confidence indices for physics component: Energy and forces

Knowledge strands:	Year	1	2	3	4	5	Σ	CI
properties and uses of energy	B.Ed1	9	70	150	104	5	338	2.8
	B.Ed2	7	48	147	44	0	246	2.7
	B.Ed3	7	56	63	48	0	174	2.6
	B.Ed4	18	76	60	24	5	183	2.2
	PGCE	10	44	117	176	5	352	3
	All	51	294	537	396	15	1293	2.7
conversion and transfer of energy	B.Ed1	6	66	153	120	5	350	2.9
	B.Ed2	6	50	138	56	0	250	2.7
	B.Ed3	7	58	63	44	0	172	2.5
	B.Ed4	14	64	90	28	0	196	2.4
	PGCE	10	44	114	176	10	354	3.1
	All	43	282	558	424	15	1322	2.8
forces and their effects with their environment	B.Ed1	13	68	147	96	5	329	2.7
	B.Ed2	8	40	138	68	0	254	2.8
	B.Ed3	4	70	51	48	0	173	2.5
	B.Ed4	14	78	72	24	0	188	2.3
	PGCE	10	48	114	176	0	348	3
	All	49	304	522	412	5	1292	2.7

Confidence index calculated as follows:

- the product for each cell is calculated by multiplying the row number with the value assigned to its column
- the sum of the products for each row is calculated;
- the confidence index is calculated as a '*mean*' using the population sample for each of the year cohorts.

❖ Knowledge strands for chemistry component: Earth and space

Knowledge strands:	Year	1	2	3	4	5
the Earth in space	B.Ed1	4 (3)	47 (39)	55 (45)	14 (12)	1 (1)
	B.Ed2	5 (5)	29 (32)	48 (53)	9 (10)	0 (0)
	B.Ed3	3 (4)	42 (62)	23 (34)	0 (0)	0 (0)
	B.Ed4	29 (35)	40 (48)	14 (17)	0 (0)	0 (0)
	PGCE	11 (9)	33 (28)	40 (35)	32 (28)	0 (0)
	All	52 (11)	191 (40)	180 (38)	55 (11)	1 (0)
materials from Earth	B.Ed1	7 (6)	48 (40)	51 (42)	12 (10)	3 (2)
	B.Ed2	3 (3)	28 (31)	53 (58)	7 (8)	0 (0)
	B.Ed3	8 (12)	33 (48)	26 (38)	1 (2)	0 (0)
	B.Ed4	27 (32)	38 (46)	17 (21)	1 (1)	0 (0)
	PGCE	13 (11)	27 (23)	43 (37)	33 (29)	0 (0)
	All	58 (12)	174 (36)	190 (40)	54 (11)	3 (1)
changing materials	B.Ed1	6 (5)	50 (41)	52 (43)	10 (8)	3 (3)
	B.Ed2	3 (3)	28 (31)	49 (54)	11 (12)	0 (0)
	B.Ed3	6 (9)	31 (46)	26 (38)	5 (7)	0 (0)
	B.Ed4	23 (28)	39 (47)	19 (23)	2 92)	0 (0)
	PGCE	13 (11)	29 (25)	39 (34)	35 (30)	0 (0)
	All	51 (11)	177 (37)	185 (39)	63 (13)	3 (0)

Note: Figures in brackets are percentages

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

❖ Confidence indices for chemistry component: Earth and space

Knowledge strands:	Year	1	2	3	4	5	Σ	CI
the Earth in space	B.Ed1	4	94	165	56	5	324	2.7
	B.Ed2	5	58	144	36	0	243	2.7
	B.Ed3	3	84	69	0	0	156	2.3
	B.Ed4	29	80	42	0	0	151	1.8
	PGCE	11	66	120	128	0	325	2.8
	All	52	382	540	220	5	1199	2.5
materials from Earth	B.Ed1	7	96	153	48	15	319	2.6
	B.Ed2	3	56	159	28	0	246	2.7
	B.Ed3	8	66	78	4	0	156	2.3
	B.Ed4	27	76	51	4	0	158	1.9
	PGCE	13	54	129	132	0	328	2.8
	All	58	348	570	216	15	1207	2.5
changing materials	B.Ed1	6	100	156	40	15	317	2.6
	B.Ed2	3	56	147	44	0	250	2.7
	B.Ed3	6	62	78	20	0	166	2.4
	B.Ed4	23	78	57	8	0	166	2
	PGCE	13	58	117	140	0	328	2.8
	All	51	354	555	252	15	1227	2.6

Confidence index calculated as follows:

- the product for each cell is calculated by multiplying the row number with the value assigned to its column
- the sum of the products for each row is calculated;
- the confidence index is calculated as a'*mean*' using the population sample for each of the year cohorts.

❖ Teaching science at the different stages

Teaching stages:	Year	1	2	3	4	5
P1 to P3	B.Ed1	33 (27)	58 (48)	21 (17)	9 (8)	0 (0)
	B.Ed2	17 (19)	44 (48)	23 (25)	7 (8)	0 (0)
	B.Ed3	17 (25)	38 (56)	13 (19)	0 (0)	0 (0)
	B.Ed4	31 (37)	35 (42)	16 (19)	1 (2)	0 (0)
	PGCE	23 (20)	37 (32)	42 (36)	14 (12)	0 (0)
	All	121 (25)	212 (44)	115 (24)	31 (7)	0 (0)
P4 to P5	B.Ed1	14 (12)	46 (38)	44 (36)	17 (14)	0 (0)
	B.Ed2	12 (13)	41 (45)	34 (37)	3 (5)	0 (0)
	B.Ed3	7 (10)	49 (72)	12 (18)	0 (0)	0 (0)
	B.Ed4	22 (26)	47 (57)	10 (12)	3 (4)	1 (1)
	PGCE	16 (14)	35 (30)	44 (38)	21 (18)	0 (0)
	All	71 (15)	218 (46)	144 (30)	44 (9)	1 (0)
P6 to P7	B.Ed1	6 (5)	23 (19)	55 (45)	30 (25)	7 (6)
	B.Ed2	10 (11)	32 (35)	39 (43)	10 (11)	0 (0)
	B.Ed3	6 (9)	34 (50)	25 (37)	3 (4)	0 (0)
	B.Ed4	16 (19)	42 (51)	21 (25)	4 (5)	0 (0)
	PGCE	10 (8)	24 (21)	47 (40)	32 (28)	3 (3)
	All	48 (10)	155 (32)	187 (39)	79 (17)	10 (2)

Note: Figures in brackets are percentages

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

❖ Confidence indices for teaching science at the different stages

Knowledge strands:	Year	1	2	3	4	5	Σ	CI
P1 to P3	B.Ed1	33	116	63	36	0	248	2
	B.Ed2	17	88	69	28	0	202	2.2
	B.Ed3	17	76	39	0	0	132	1.9
	B.Ed4	31	70	48	4	0	153	1.8
	PGCE	23	74	126	56	0	279	2.4
	All	121	424	345	124	0	1014	2.1
P4 to P5	B.Ed1	14	92	132	68	0	306	2.5
	B.Ed2	12	82	102	12	0	208	2.3
	B.Ed3	7	98	36	0	0	141	2.1
	B.Ed4	22	94	30	12	5	163	2
	PGCE	16	70	132	84	0	302	2.6
	All	71	436	432	176	5	1120	2.3
P6 to P7	B.Ed1	6	46	165	120	35	372	3.1
	B.Ed2	10	64	117	40	0	231	2.5
	B.Ed3	6	68	75	12	0	161	2.4
	B.Ed4	16	84	63	16	0	179	2.2
	PGCE	10	48	141	128	15	342	2.9
	All	48	310	561	316	50	1285	2.7

Confidence index calculated as follows:

- the product for each cell is calculated by multiplying the row number with the value assigned to its column
- the sum of the products for each row is calculated;
- the confidence index is calculated as a '*mean*' using the population sample for each of the year cohorts.

❖ Developing the pupils' abilities in investigative work

Investigative skill strands:	Year	1	2	3	4	5
Preparing for tasks	B.Ed1	15 (12)	58 (48)	40 (33)	8 (7)	0 (0)
	B.Ed2	8 (9)	51 (56)	30 (33)	2 (2)	0 (0)
	B.Ed3	11 (16)	50 (74)	5 (7)	2 (3)	0 (0)
	B.Ed4	29 (35)	43 (52)	11 (13)	0 (0)	0 (0)
	PGCE	10 (8)	46 (40)	43 (37)	17 (15)	0 (0)
	All	73 (15)	248 (52)	129 (27)	29 (6)	0 (0)
Carrying out tasks	B.Ed1	14 (12)	57 (47)	39 (32)	11 (9)	0 (0)
	B.Ed2	6 (7)	44 (48)	40 (44)	1 (1)	0 (0)
	B.Ed3	6 (9)	52 (76)	8 (12)	2 (3)	0 (0)
	B.Ed4	25 (30)	49 (59)	9 (11)	0 (0)	0 (0)
	PGCE	10 (9)	47 (40)	43 (37)	16 (14)	0 (0)
	All	61 (13)	249 (52)	139 (29)	30 (6)	0 (0)
Reviewing and reporting on tasks	B.Ed1	14 (12)	60 (50)	38 (31)	9 (7)	0 (0)
	B.Ed2	5 (6)	50 (55)	33 (36)	3 (3)	0 (0)
	B.Ed3	6 (9)	53 (78)	7 (10)	2 (3)	0 (0)
	B.Ed4	24 (29)	47 (57)	12 (14)	0 (0)	0 (0)
	PGCE	9 (8)	47 (40)	40 (35)	20 (17)	0 (0)
	All	58 (12)	257 (54)	130 (27)	34 (7)	0 (0)

Note: Figures in brackets are percentages

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

❖ Confidence indices for developing the pupils' abilities in investigative work

Investigative skill strands:	Year	1	2	3	4	5	Σ	CI
Preparing for tasks	B.Ed1	15	116	120	32	0	283	2.3
	B.Ed2	8	102	90	8	0	208	2.3
	B.Ed3	11	100	15	8	0	134	2
	B.Ed4	29	86	33	0	0	148	1.8
	PGCE	10	92	129	68	0	299	2.6
	All	73	496	387	116	0	1072	2.2
Carrying out tasks	B.Ed1	14	114	117	44	0	289	2.4
	B.Ed2	6	88	120	4	0	218	2.4
	B.Ed3	6	104	24	8	0	142	2.1
	B.Ed4	25	98	27	0	0	150	1.8
	PGCE	10	94	129	64	0	297	2.6
	All	61	498	417	120	0	1096	2.3
Reviewing and reporting on tasks	B.Ed1	14	120	114	36	0	284	2.3
	B.Ed2	5	100	99	12	0	216	2.4
	B.Ed3	6	106	21	8	0	141	2.1
	B.Ed4	24	94	36	0	0	154	1.9
	PGCE	9	94	120	80	0	303	2.6
	All	58	514	390	136	0	1098	2.3

Confidence index calculated as follows:

- the product for each cell is calculated by multiplying the row number with the value assigned to its column
- the sum of the products for each row is calculated;
- the confidence index is calculated as a '*mean*' using the population sample for each of the year cohorts.

Appendix 6.6: *Kendall tau-b -- Attainment outcomes and knowledge strands*

❖ **Associations within and between knowledge strands (1)**

	Biology 1 + Biology 2						Biology 2 + Biology 3						Biology 3 + Biology 1					
Biology	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.76**						.86**						.83**					
B.Ed2		.88**						.75**						.79**				
B.Ed3			.83**						.86**						.69**			
B.Ed4				.81**						.87**						.76**		
PGCE					.92**						.9**						.86**	
ALL						.85**						.85**						.81**

	Chemistry 1						Chemistry 2						Chemistry 3					
Biology 1	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.26**						.28**						.3**					
B.Ed2		NS						.27**						.32**				
B.Ed3			.35**						.41**						.49**			
B.Ed4				.36**						.4**						.37**		
PGCE					.49**						.56**						.51**	
ALL						.41**						.45**						.45**

	Physics 1						Physics 2						Physics 3					
Biology 1	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	NS						NS						NS					
B.Ed2		.34**						.27**						.25**				
B.Ed3			NS						NS						NS			
B.Ed4				.29**						.23*						.3**		
PGCE					.42**						.38**						.41**	
ALL						.31**						.26**						.28**

❖ **Associations within and between knowledge strands (2)**

	Chemistry 1						Chemistry 2						Chemistry 3					
Biology 2	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.29**						.33**						.30**					
B.Ed2		.21*						.27**						.30**				
B.Ed3			.51**						.51**						.52**			
B.Ed4				.33**						.38**						.39**		
PGCE					.46**						.52**						.47**	
ALL						.40**						.46**						.43**

	Physics 1						Physics 2						Physics 3					
Biology 2	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	NS						NS						NS					
B.Ed2		.33**						.331**						.3**				
B.Ed3			NS						NS						NS			
B.Ed4				.34**						.28**						.34**		
PGCE					.36**						.34**						.38**	
ALL						.29**						.27**						.28**

	Chemistry 1						Chemistry 2						Chemistry 3					
Biology 3	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.25**						.3**						.27**					
B.Ed2		.22*						.27**						.31**				
B.Ed3			.53**						.42**						.41**			
B.Ed4				.35**						.39**						.39**		
PGCE					.52**						.6**						.53**	
ALL						.42**						.46**						.43**

❖ **Associations within and between knowledge strands (3)**

	Physics 1						Physics 2						Physics 3					
Biology 3	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	NS						NS						NS					
B.Ed2		.38**						.25*						.31**				
B.Ed3			NS						NS						NS			
B.Ed4				.35**						.26**						.37**		
PGCE					.42**						.41**						.4**	
ALL						.30**						.24**						.27**

	Chemistry 1 + Chemistry 2						Chemistry 2 + Chemistry 3						Chemistry 3 + Chemistry 1					
Chemistry	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.82**						.86**						.76**					
B.Ed2		.66**						.73**						.76**				
B.Ed3			.66**						.76**						.61**			
B.Ed4				.86**						.88**						.78**		
PGCE					.93**						.88**						.85**	
ALL						.84**						.85**						.79**

	Physics 1						Physics 2						Physics 3					
Chemistry 1	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.51**						.48**						.47**					
B.Ed2		.41**						.42**						.42**				
B.Ed3			NS						NS						NS			
B.Ed4				.47**						.46**						.51**		
PGCE					.57**						.53**						.51**	
ALL						.51**						.48**						.49**

❖ **Associations within and between knowledge strands (4)**

	Physics 1						Physics 2						Physics 3					
Chemistry 2	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.49**						.51**						.422**					
B.Ed2		.44**						.46**						.489**				
B.Ed3			.39**						.38**						.396**			
B.Ed4				.55**						.53**						.528**		
PGCE					.6**						.55**						.521**	
ALL						.55**						.53**						.514**

	Physics 1						Physics 2						Physics 3					
Chemistry 3	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.54**						.58**						.49**					
B.Ed2		.45**						.54**						.47**				
B.Ed3			.39**						.43**						.38**			
B.Ed4				.43**						.41**						.42**		
PGCE					.6**						.54**						.49**	
ALL						.55**						.55**						0.50**

	Physics 1 + Physics 2						Physics 2 + Physics 3						Physics 3 + Physics 1					
Physics	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.84**						.82**						.83**					
B.Ed2		.68**						.76**						.82**				
B.Ed3			.93**						.88**						.87**			
B.Ed4				.8**						.85**						.86**		
PGCE					.96**						.92**						.89**	
ALL						.85**						.85**						.86**

❖ **Associations between knowledge strands and primary age stages (1)**

	P1 to P3						**P4 to P5**						**P6 to P7**					
Biology 1	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.17*						.26**						.25**					
B.Ed2		NS						.31**						.38**				
B.Ed3			NS						NS						.34**			
B.Ed4				.43**						.54**						.46**		
PGCE					.44**						.51**						.47**	
ALL						.31**						.42**						.42**
Biology 2	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	NS						.16*						NS					
B.Ed2		NS						.29**						.41**				
B.Ed3			NS						.3**						.3**			
B.Ed4				.51**						.56**						.45**		
PGCE					.46**						.51**						.43**	
ALL						.35**						.4**						.37**
Biology 3	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.23**						.24**						.22**					
B.Ed2		NS						.33**						.27**				
B.Ed3			NS						NS						NS			
B.Ed4				.54**						.50**						.51**		
PGCE					.41**						.52**						.5**	
ALL						.35**						.4**						.36**

❖ **Associations between knowledge strands and primary age stages (2)**

	P1 to P3						P4 to P5						P6 to P7					
Chemistry 1	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.30**						.37**						.29**					
B.Ed2		.25**						.34**						.42**				
B.Ed3			.27*						NS						NS			
B.Ed4				.45**						.30**						.43**		
PGCE					.44**						.53**						.55**	
ALL						.39**						.45**						.45**
Chemistry 2	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.32**						.36**						.29**					
B.Ed2		.25**						.36**						.49**				
B.Ed3			NS						NS						NS			
B.Ed4				.49**						.37**						.51**		
PGCE					.44**						.56**						.56**	
ALL						.39**						.46**						.47**
Chemistry 3	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.34**						.41**						.3**					
B.Ed2		.21*						.34**						.42**				
B.Ed3			NS						NS						.29**			
B.Ed4				.48**						.34**						.42**		
PGCE					.39**						.51**						.58**	
ALL						.38**						.45**						.45**

❖ **Associations between knowledge strands and primary age stages (3)**

	P1 to P3						P4 to P5						P6 to P7					
Physics 1	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.22**						.35**						.26**					
B.Ed2		NS						.31**						.43**				
B.Ed3			NS						.23*						.50**			
B.Ed4				.32**						.38**						.46**		
PGCE					.4**						.58**						.66**	
ALL						.29**						.45**						.5**
Physics 2	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.25**						.34**						.26**					
B.Ed2		.19*						.32**						.44**				
B.Ed3			NS						.24*						.51**			
B.Ed4				.26**						.35**						.49**		
PGCE					.38**						.54**						.64**	
ALL						.28**						.43**						.5**
Physics 3	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.24**						.37**						.27**					
B.Ed2		NS						.26**						.41**				
B.Ed3			NS						NS						.42**			
B.Ed4				.35**						.38**						.47**		
PGCE					.41**						.56**						.56**	
ALL						.3**						.43**						.46**

❖ **Associations between knowledge strands and investigative skill strands (1)**

	Preparing for tasks						Carrying out tasks						Reviewing and reporting on tasks					
Biology 1	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.25**						.25**						.22**					
B.Ed2		.39**						.42**						.43**				
B.Ed3			NS						NS						NS			
B.Ed4				.4**						.51**						.35**		
PGCE					.54**						.51**						.53**	
ALL						.42**						.44**						.4**
Biology 2	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.28**						.33**						.23**					
B.Ed2		.39**						.41**						.39**				
B.Ed3			NS						NS						NS			
B.Ed4				.44**						.55**						.33**		
PGCE					.55**						.52**						.53**	
ALL						.43**						.45**						.4**
Biology 3	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.28**						.35**						.28**					
B.Ed2		.31**						.37**						.32**				
B.Ed3			NS						NS						NS			
B.Ed4				.44**						.5**						.41**		
PGCE					.54**						.54**						.54**	
ALL						.4**						.45**						.41**

Appendix 6.8: *Kendall tau-b -- Knowledge strands and investigative skill strands*

❖ **Associations between knowledge strands and investigative skill strands (2)**

	Preparing for tasks						Carrying out tasks						Reviewing and reporting on tasks					
Chemistry 1	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.47**						.43**						.43**					
B.Ed2		.24*						.31**						.29**				
B.Ed3			NS						NS						.36**			
B.Ed4				.51**						.46**						.55**		
PGCE					.49**						.47**						.48**	
ALL						.49**						.48**						.5**
Chemistry 2	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.47**						.46**						.43**					
B.Ed2		.26**						.38**						.34**				
B.Ed3			NS						NS						NS			
B.Ed4				.54**						.51**						.63**		
PGCE					.48**						.45**						.47**	
ALL						.48**						.48**						.49**
Chemistry 3	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.55**						.5**						.48**					
B.Ed2		.23*						.39**						.27**				
B.Ed3			.24*						NS						NS			
B.Ed4				.46**						.49**						.52**		
PGCE					.44**						.47**						.43**	
ALL						.48**						.49**						.47**

❖ **Associations between knowledge strands and investigative skill strands (3)**

	Preparing for tasks						Carrying out tasks						Reviewing and reporting on tasks					
Physics 1	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.4**						.27**						.31**					
B.Ed2		.29**						.38**						.29**				
B.Ed3			NS						NS						NS			
B.Ed4				.34**						.33**						.36**		
PGCE					.41**						.38**						.38**	
ALL						.4**						.37**						.37**
Physics 2	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.39**						.31**						.29**					
B.Ed2		.28**						.33**						.33**				
B.Ed3			NS						NS						NS			
B.Ed4				.41**						.36**						.36**		
PGCE					.38**						.37**						.36**	
ALL						.39**						.37**						.35**
Physics 3	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL	B.Ed1	B.Ed2	B.Ed3	B.Ed4	PGCE	ALL
B.Ed1	.39**						.26**						.35**					
B.Ed2		.2*						.29**						.23*				
B.Ed3			NS						NS						NS			
B.Ed4				.41**						.36**						.35**		
PGCE					.42**						.37**						.38**	
ALL						.4**						.35**						.37**

Teaching and Learning in Science

1. Science lessons are largely about the development of factual knowledge
2. Teachers should supply notes for pupils to copy
3. Pupils should be taught to concentrate during science lessons and not to talk
4. Science lessons are an ideal opportunity for pupils to work collaboratively in groups
5. Pupils should observe experiments which are demonstrated by the teacher
6. Science should start with pupils talking about and exploring their ideas on scientific issues
7. Pupils should gain direct experience of science through practical activity
8. Pupils should develop their own notes through observation and practical activity
9. Science lessons should mostly involve pupils in working by themselves
10. The most important aspect of science is that pupils follow the procedures given
11. Science lessons are more about the development of skills rather than fact
12. Science can take place using everyday materials
13. Science is made easier by the fact that there is little need for discussion and debate
14. Science lessons require the teacher to devise experiments using available resources
15. Handling equipment safely is an important aspect of science lessons
16. Lessons should engage pupils in investigative approaches
17. Lessons should involve pupils in exploring, observing and ordering
18. It is too dangerous to give pupils access to scientific equipment
19. Pupils should be given opportunities to devise methods of testing ideas
20. Whole class lessons should be the norm in science
21. Investigative work is inappropriate in science
22. To be effective, science needs to be related to other areas of the curriculum
23. Science lessons should be based around textbooks and worksheets
24. Science lessons should be relevant to the everyday experience of the pupils
25. The teacher must identify the focus of science lessons
26. Science lessons should consist mostly of group activity with only some whole class work
27. Science should be taught as separate lessons
28. Pupils should choose the way to examine scientific problems
29. Pupils should be given responsibility for identifying resources to carry out experiments
30. It is not necessary to engage in practical activity in science lessons
31. The teacher should plan investigative activities for the pupils
32. The basic purpose of investigative work is to illustrate scientific theories
33. Pupils should engage in evaluation of the outcomes of science lessons for themselves
34. Scientific knowledge is not in any way different from other forms of knowledge
35. Pupils should be allowed to use resources to discover scientific principles for themselves
36. Pupils should be encouraged to identify the questions to ask during science activities
37. The teachers should direct pupils towards the correct scientific answer to problems

TEACHING and LEARNING in SCIENCE:
STRUCTURE of QUESTIONNAIRE STATEMENTS

METHODOLOGY:

Statement (1) - Science lessons are largely about factual knowledge [NEGATIVELY FRAMED]

Statement (3) - Pupils should be taught to concentrate during science lessons and not to talk [NEGATIVELY FRAMED]

Statement (6) - Science should start with pupils talking about and exploring their ideas on scientific issues [POSITIVELY FRAMED]

Statement (10) - The most important aspect of science is that pupils follow the procedures given [NEGATIVELY FRAMED]

Statement (11) - Science lessons are more about the development of skills rather than facts [POSITIVELY FRAMED]

Statement (13) - Science is made easier by the fact that there is little need for discussion and debate [NEGATIVELY FRAMED]

Statement (24) - Science lessons should be relevant to the everyday experience of the pupils [POSITIVELY FRAMED]

Statement (25) - The teacher must identify the focus of science lessons [NEGATIVELY FRAMED]

Statement (28) - Pupils should choose the way to examine scientific problems [POSITIVELY FRAMED]

Statement (34) - Scientific knowledge is not in any way different from other forms of knowledge [POSITIVELY FRAMED]

Statement (36) - Pupils should be encouraged to identify the questions to ask during science activities [POSITIVELY FRAMED]

RESOURCING LESSONS:

Statement (2) - Teachers should supply notes for pupils to copy [NEGATIVELY FRAMED]

Statement (8) - Pupils should develop their own notes through observation and practical activity [POSITIVELY FRAMED]

Statement (12) - Science can take place using everyday materials [POSITIVELY FRAMED]

Statement (14) - Science lessons requires the teacher to devise experiments using available resources [NEGATIVELY FRAMED]

Statement (15) - Handling equipment safely is an important outcome of science lessons [POSITIVELY FRAMED]

Statement (18) - It is too dangerous to give pupils access to scientific equipment [NEGATIVELY FRAMED]

Statement (23) - Science lessons should be based around textbooks and worksheets [NEGATIVELY FRAMED]

Statement (29) - Pupils should be given responsibility for identifying resources to carry out experiments [POSITIVELY FRAMED]

Statement (35) - Pupils should be allowed to use resources to discover scientific principles for themselves [POSITIVELY FRAMED]

INVESTIGATIVE APPROACHES:

Statement (5) - Pupils should observe experiments which are always demonstrated by the teacher [NEGATIVELY FRAMED]

Statement (7) - Pupils should gain direct experience of science through experiments [POSITIVELY FRAMED]

Statement (16) - Lessons should engage pupils in investigative approaches [POSITIVELY FRAMED]

Statement (17) - Lessons should involve pupils in exploring, observing and ordering [POSITIVELY FRAMED]

Statement (19) - Pupils should be given opportunities to devise methods of testing ideas [POSITIVELY FRAMED]

Statement (21) - Investigative work is inappropriate in science [NEGATIVELY FRAMED]

Statement (30) - It is not necessary to engage in practical activity in science lessons [NEGATIVELY FRAMED]

Statement (31) - The teacher should plan investigative activities for the pupils [NEGATIVELY FRAMED]

Statement (32) - The basic purpose of investigative work is to illustrate scientific theories [NEGATIVELY FRAMED]

ORGANISATION OF LESSONS:

Statement (4) - Science lessons are an ideal opportunity for pupils to work collaboratively in groups [POSITIVELY FRAMED]

Statement (9) - Science lessons should mostly involve pupils in working by themselves [NEGATIVELY FRAMED]

Statement (20) - Whole class lessons are the norm in science [NEGATIVELY FRAMED]

Statement (22) - To be effective science needs to be related to other areas of the curriculum [POSITIVELY FRAMED]

Statement (26) - Science lessons should consist mostly of group activity with only some whole class work [POSITIVELY FRAMED]

Statement (27) - Science should be taught as separate lessons [NEGATIVELY FRAMED]

Statement (33) - Pupils should engage in evaluation of the outcomes of science lessons for themselves [POSITIVELY FRAMED]

Statement (37) - The teachers should direct pupils toward the correct scientific answer to problems [NEGATIVELY FRAMED]

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

❖ Teaching and learning in science (1)

Statements:	Year	1	2	3	4	5
Science lessons are largely about the development of factual knowledge	B.Ed1	8 (7)	44 (37)	39 (32)	28 (23)	1 (1)
	B.Ed2	4 (4)	41 (47)	23 (25)	21 (23)	1 (1)
	B.Ed3	11 (16)	28 (42)	14 (21)	14 (21)	0 (0)
	B.Ed4	12 (15)	36 (43)	18 (22)	15 (18)	2 (2)
	PGCE	4 (3)	69 (61)	18 (16)	21 (19)	1 (1)
[Methodology]	All	36 (9)	170 (43)	101 (25)	88 (22)	4 (1)
Teachers should supply notes for pupils to copy	B.Ed1	8 (7)	43 (36)	36 (30)	29 (24)	4 (3)
	B.Ed2	2 (2)	23 (26)	30 (33)	30 (33)	5 (6)
	B.Ed3	0 (0)	6 (9)	14 (20)	38 (56)	10 (15)
	B.Ed4	1 (1)	9 (11)	22 (27)	38 (46)	12 (15)
	PGCE	2 (2)	22 (19)	39 (34)	47 (41)	5 (4)
[Resources]	All	12 (3)	89 (22)	114 (28)	154 (39)	32 (8)
Pupils should be taught to concentrate during science lessons and not to talk	B.Ed1	6 (5)	25 (21)	21 (17)	53 (44)	16 (13)
	B.Ed2	0 (0)	8 (9)	22 (24)	50 (55)	11 (12)
	B.Ed3	0 (0)	1 (1)	9 (13)	44 (65)	14 (21)
	B.Ed4	1 (1)	9 (11)	6 (7)	40 (49)	26 (32)
	PGCE	8 (7)	11 (10)	12 (10)	64 (55)	21 (18)
[Methodology]	All	10 (3)	44 (11)	61 (15)	215 (53)	74 (18)
Science lessons are an ideal opportunity for pupils to work collaboratively in groups	B.Ed1	61 (50)	55 (49)	4 (3)	1 (1)	0 (0)
	B.Ed2	42 (46)	48 (53)	1 (1)	0 (0)	0 (0)
	B.Ed3	36 (53)	32 (47)	0 (0)	0 (0)	0 (0)
	B.Ed4	51 (62)	31 (37)	1 (1)	0 (0)	0 (0)
	PGCE	47 (41)	62 (53)	2 (2)	5 (4)	0 (0)
[Organisation]	All	205 (50)	190 (47)	7 (3)	3 (1)	0 (0)
Pupils should observe experiments which are demonstrated by the teacher	B.Ed1	34 (28)	47 (39)	21 (17)	12 (10)	7 (6)
	B.Ed2	8 (9)	36 (39)	23 (25)	17 (19)	7 (8)
	B.Ed3	6 (9)	24 (37)	8 (12)	20 (30)	8 (12)
	B.Ed4	4 (5)	28 (33)	23 (28)	18 (22)	10 (12)
	PGCE	23 (20)	52 (45)	17 (15)	18 (16)	5 (4)
[Investigation]	All	58 (14)	155 (39)	82 (20)	73 (18)	34 (9)
Science should start with pupils talking about and exploring their ideas on scientific issues	B.Ed1	37 (31)	55 (45)	25 (21)	4 (3)	0 (0)
	B.Ed2	24 (27)	52 (57)	12 (13)	3 (3)	0 (0)
	B.Ed3	13 (19)	34 (50)	18 (27)	2 (3)	1 (1)
	B.Ed4	21 (25)	42 (51)	15 (18)	5 (6)	0 (0)
	PGCE	32 (28)	64 (55)	18 (15)	2 (2)	0 (0)
[Methodology]	All	104 (26)	210 (52)	75 (18)	15 (4)	1 (-)

Note: Figures in brackets are percentages.

❖ Teaching and learning in science (2)

Statements:	Year	1	2	3	4	5
Pupils should gain direct experience of science through practical activity	B.Ed1	70 (58)	47 (39)	4 (3)	0 (0)	0 (0)
	B.Ed2	55 (60)	32 (35)	4 (5)	0 (0)	0 (0)
	B.Ed3	50 (74)	18 (26)	0 (0)	0 (0)	0 (0)
	B.Ed4	54 (65)	27 (33)	2 (2)	0 (0)	0 (0)
	PGCE	56 (48)	56 (48)	1 (1)	3 (3)	0 (0)
[Investigation]	All	245 (60)	148 (36)	10 (3)	2 (1)	0 (0)
Pupils should develop their ow notes through observation and practical activity	B.Ed1	34 (28)	63 (52)	19 (16)	5 (4)	0 (0)
	B.Ed2	27 (30)	49 (55)	9 (10)	4 (4)	1 (1)
	B.Ed3	25 (37)	28 (41)	15 (22)	0 (0)	0 (0)
	B.Ed4	25 (30)	34 (41)	21 (25)	3 (4)	0 (0)
	PGCE	29 (25)	71 (61)	12 (10)	4 (4)	0 (0)
[Resources]	All	119 (30)	202 (50)	69 (17)	13 (3)	1 (-)
Science lessons should mostly involve pupils in working by themselves	B.Ed1	1 (1)	11 (9)	35 (29)	55 (45)	19 (16)
	B.Ed2	2 (2)	9 (10)	29 (32)	38 (42)	13 (14)
	B.Ed3	0 (0)	0 (0)	15 (22)	44 (65)	9 (13)
	B.Ed4	0 (0)	6 (7)	15 (18)	46 (56)	16 (19)
	PGCE	3 (3)	7 (6)	21 (18)	74 (64)	11 (9)
[Organisation]	All	3 (1)	29 (7)	101 (25)	213 (53)	59 (14)
The most important aspect of science is that pupils follow the procedures given	B.Ed1	21 (17)	45 (37)	33 (27)	20 (17)	2 (2)
	B.Ed2	1 (1)	31 (34)	41 (45)	16 (18)	2 (2)
	B.Ed3	3 (5)	7 (10)	24 (35)	30 (44)	4 (6)
	B.Ed4	3 (4)	20 (24)	27 (33)	26 (31)	7 (8)
	PGCE	25 (22)	33 (29)	35 (31)	21 (18)	0 (0)
[Methodology]	All	35 (9)	111 (27)	139 (34)	103 (26)	15 (4)
Science lessons are more about the development of skills rather than facts	B.Ed1	4 (3)	29 (24)	61 (50)	24 (20)	3 (3)
	B.Ed2	4 (4)	24 (27)	53 (58)	9 (10)	1 (1)
	B.Ed3	2 (3)	29 (43)	30 (44)	5 (7)	2 (3)
	B.Ed4	4 (5)	23 (28)	38 (46)	16 (19)	2 (2)
	PGCE	2 (2)	26 (22)	54 (47)	31 (27)	3 (2)
[Methodology]	All	16 (3)	131 (28)	236 (49)	85 (18)	11 (2)
Science can take place using everyday materials	B.Ed1	58 (48)	57 (47)	5 (4)	1 (1)	0 (0)
	B.Ed2	36 (40)	52 (57)	3 (3)	0 (0)	0 (0)
	B.Ed3	29 (43)	37 (54)	2 (3)	0 (0)	0 (0)
	B.Ed4	39 (47)	36 (43)	8 (10)	0 (0)	0 (0)
	PGCE	30 (26)	75 (65)	6 (5)	5 (4)	0 (0)
[Resources]	All	192 (40)	257 (54)	24 (5)	6 (1)	0 (0)

Note: Figures in brackets are percentages.

❖ Teaching and learning in science (3)

Statements:	Year	1	2	3	4	5
Science is made easier by the fact that there is little need for discussion and debate	B.Ed1	0 (0)	11 (9)	38 (31)	58 (48)	14 (12)
	B.Ed2	1 (1)	9 (10)	26 (28)	48 (53)	7 (8)
	B.Ed3	0 (0)	1 (2)	20 (29)	38 (56)	9 (13)
	B.Ed4	0 (0)	1 (1)	22 (27)	48 (58)	12 (14)
	PGCE	2 (2)	12 (10)	16 (14)	76 (65)	10 (9)
[Methodology]	All	3 (1)	34 (7)	122 (25)	268 (56)	52 (11)
Science lessons require the teacher to devises experiments using available resources	B.Ed1	7 (6)	83 (70)	17 (14)	11 (9)	1 (1)
	B.Ed2	12 (13)	50 (55)	19 (21)	10 (11)	0 (0)
	B.Ed3	2 (3)	33 (48)	22 (32)	10 (15)	1 (2)
	B.Ed4	9 (11)	34 (41)	28 (34)	12 (14)	0 (0)
	PGCE	10 (8)	65 (56)	25 (22)	14 (12)	2 (2)
[Resources]	All	40 (8)	265 (56)	111 (23)	57 (12)	4 (1)
Handling equipment safely is an important aspect of science lessons	B.Ed1	101 (84)	16 (13)	2 (2)	1 (1)	0 (0)
	B.Ed2	57 (63)	28 (31)	4 (4)	2 (2)	0 (0)
	B.Ed3	53 (78)	15 (22)	0 (0)	0 (0)	0 (0)
	B.Ed4	51 (62)	31 (37)	1 (1)	0 (0)	0 (0)
	PGCE	96 (83)	17 (15)	0 (0)	0 (0)	3 (2)
[Resources]	All	358 (75)	107 (22)	7 (1)	3 (1)	3 (1)
Lessons should engage pupils in investigative approaches	B.Ed1	47 (39)	68 (57)	5 (4)	0 (0)	0 (0)
	B.Ed2	29 (32)	59 (65)	2 (2)	0 (0)	1 (1)
	B.Ed3	32 (48)	35 (52)	0 (0)	0 (0)	0 (0)
	B.Ed4	29 (35)	49 (59)	5 (6)	0 (0)	0 (0)
	PGCE	49 (42)	64 (55)	0 (0)	1 (1)	2 (2)
[Investigation]	All	186 (39)	275 (58)	12 (2)	1 (-)	3 (1)
Lessons should involve pupils in exploring, observing and ordering	B.Ed1	48 (40)	67 (55)	6 (5)	0 (0)	0 (0)
	B.Ed2	27 (30)	56 (61)	8 (9)	0 (0)	0 (0)
	B.Ed3	38 (56)	30 (44)	0 (0)	0 (0)	0 (0)
	B.Ed4	39 (47)	35 (42)	7 (9)	1 (1)	1 (1)
	PGCE	51 (44)	63 (54)	0 (0)	0 (0)	2 (2)
[Investigation]	All	203 (42)	251 (53)	21 (4)	1 (-)	3 (1)
It is too dangerous to give pupils access to scientific equipment	B.Ed1	2 (2)	6 (5)	30 (25)	69 (57)	14 (11)
	B.Ed2	0 (0)	3 (3)	18 (20)	47 (52)	23 (25)
	B.Ed3	0 (0)	0 (0)	5 (8)	41 (60)	22 (32)
	B.Ed4	1 (1)	1 (1)	13 (16)	48 (58)	20 (24)
	PGCE	4 (3)	6 (5)	22 (19)	69 (60)	15 (13)
[Resources]	All	7 (2)	16 (3)	88 (18)	274 (57)	94 (20)

Note: Figures in brackets are percentages.

❖ Teaching and learning in science (4)

Statements:	Year	1	2	3	4	5
Pupils should be given opportunities to devise methods of testing ideas	B.Ed1	29 (24)	77 (63)	13 (11)	2 (2)	0 (0)
	B.Ed2	20 (22)	60 (66)	9 (10)	0 (0)	2 (2)
	B.Ed3	21 (31)	44 (65)	3 (4)	0 (0)	0 (0)
	B.Ed4	22 (26)	47 (57)	14 (17)	0 (0)	0 (0)
	PGCE	25 (22)	74 (64)	15 (13)	2 (1)	0 (0)
[Investigation]	All	117 (25)	302 (63)	54 (11)	4 (1)	2 (-)
Whole class lessons should be the norm in science	B.Ed1	6 (5)	18 (15)	56 (46)	36 (30)	5 (4)
	B.Ed2	5 (6)	11 (12)	32 (35)	39 (43)	4 (4)
	B.Ed3	6 (9)	15 (22)	32 (47)	10 (15)	5 (7)
	B.Ed4	1 (1)	14 (17)	34 (41)	32 (39)	2 (2)
	PGCE	6 (5)	26 (22)	36 (31)	40 (35)	8 (7)
[Organisation]	All	24 (5)	84 (17)	190 (40)	157 (33)	24 (5)
Investigative work is inappropriate in science	B.Ed1	3 (3)	10 (8)	7 (6)	52 (43)	49 (40)
	B.Ed2	0 (0)	8 (9)	4 (4)	43 (48)	35 (39)
	B.Ed3	4 (6)	1 (1)	0 (0)	27 (40)	36 (53)
	B.Ed4	0 (0)	4 (5)	5 (6)	40 (48)	34 (41)
	PGCE	3 (3)	6 (5)	0 (0)	62 (53)	45 (39)
[Investigation]	All	10 (2)	29 (6)	16 (3)	224 (47)	199 (42)
To be effective, science needs to be related to other areas of the curriculum	B.Ed1	3 (2)	31 (26)	55 (45)	26 (22)	6 (5)
	B.Ed2	9 (10)	24 (26)	41 (45)	17 (19)	0 (0)
	B.Ed3	3 (4)	20 (29)	23 (34)	22 (33)	0 (0)
	B.Ed4	6 (7)	32 (39)	27 (32)	17 (21)	1 (1)
	PGCE	5 (4)	47 (41)	40 (34)	22 (19)	2 (2)
[Organisation]	All	26 (5)	154 (32)	186 (39)	104 (22)	9 (2)
Science lessons should be based around textbooks and worksheets	B.Ed1	0 (0)	12 (10)	34 (28)	59 (49)	16 (13)
	B.Ed2	0 (0)	3 (3)	15 (17)	45 (49)	28 (31)
	B.Ed3	0 (0)	1 (2)	9 (13)	47 (69)	11 (16)
	B.Ed4	0 (0)	5 (6)	13 (16)	57 (69)	8 (9)
	PGCE	1 (1)	14 (12)	19 (16)	64 (55)	18 (16)
[Resources]	All	1 (-)	35 (7)	90 (19)	272 (57)	81 (17)
Science lessons should be relevant to everyday experience of the pupils	B.Ed1	9 (7)	71 (59)	30 (25)	9 (7)	2 (2)
	B.Ed2	29 (32)	54 (59)	5 (6)	3 (3)	0 (0)
	B.Ed3	17 (25)	43 (63)	7 (10)	1 (2)	0 (0)
	B.Ed4	11 (13)	53 (64)	14 (17)	5 (6)	0 (0)
	PGCE	16 (14)	77 (66)	14 (12)	6 (5)	3 (3)
[Methodology]	All	82 (17)	298 (62)	70 (15)	24 (5)	5 (1)

Note: Figures in brackets are percentages.

❖ Teaching and learning in science (5)

Statements:	Year	1	2	3	4	5
The teacher must identify the focus of science lessons	B.Ed1	12 (10)	75 (62)	29 (24)	4 (3)	1 (1)
	B.Ed2	24 (27)	55 (60)	11 (12)	1 (1)	0 (0)
	B.Ed3	16 (24)	40 (59)	9 (13)	3 (4)	0 (0)
	B.Ed4	24 (29)	47 (57)	10 (12)	2 (2)	0 (0)
	PGCE	40 (34)	64 (55)	9 (8)	2 (2)	1 (1)
[Methodology]	All	116 (24)	281 (59)	68 (14)	12 (3)	2 (-)
Science lessons should consist mostly of group activity with only some whole class work	B.Ed1	14 (12)	50 (41)	35 (29)	21 (17)	1 (1)
	B.Ed2	7 (8)	40 (44)	35 (38)	9 (10)	0 (0)
	B.Ed3	2 (3)	25 (37)	39 (57)	2 (3)	0 (0)
	B.Ed4	5 (6)	36 (44)	26 (32)	13 (16)	2 (2)
	PGCE	6 (5)	57 (49)	39 (34)	14 (12)	0 (0)
[Organisation]	All	34 (7)	208 (44)	174 (36)	59 (12)	3 (1)
Science should be taught as separate lessons	B.Ed1	5 (4)	33 (27)	57 (48)	24 (20)	1 (1)
	B.Ed2	4 (4)	17 (19)	48 (53)	19 (21)	3 (3)
	B.Ed3	2 (3)	17 (25)	12 (18)	30 (44)	7 (10)
	B.Ed4	2 (2)	11 (13)	37 (45)	30 (36)	3 (4)
	PGCE	6 (5)	29 (25)	38 (33)	40 (34)	3 (3)
[Organisation]	All	19 (4)	107 (22)	192 (40)	143 (30)	17 (4)
Pupils should choose the way to examine scientific problems	B.Ed1	4 (3)	50 (41)	52 (43)	14 (12)	1 (1)
	B.Ed2	6 (7)	52 (57)	31 (34)	1 (1)	1 (1)
	B.Ed3	1 (1)	42 (62)	19 (28)	5 (8)	1 (1)
	B.Ed4	7 (9)	37 (45)	25 (30)	13 (16)	0 (0)
	PGCE	3 (3)	33 (28)	59 (51)	21 (18)	0 (0)
[Methodology]	All	21 (4)	214 (45)	186 (39)	54 (11)	3 (1)
Pupils should be given responsibility for identifying resources to carry out experiments	B.Ed1	7 (6)	71 (59)	24 (20)	16 (13)	2 (2)
	B.Ed2	10 (11)	66 (73)	11 (12)	3 (3)	1 (1)
	B.Ed3	0 (0)	48 (71)	19 (28)	1 (1)	0 (0)
	B.Ed4	8 (10)	50 (60)	14 (17)	9 (11)	2 (2)
	PGCE	8 (7)	54 (47)	26 (22)	26 (22)	2 (2)
[Resources]	All	33 (7)	289 (60)	94 (20)	55 (11)	7 (2)
It is not necessary to engage in practical activity in science lessons	B.Ed1	1 (1)	11 (9)	16 (13)	48 (40)	45 (37)
	B.Ed2	0 (0)	6 (6)	17 (19)	37 (41)	31 (34)
	B.Ed3	4 (6)	16 (23)	5 (7)	14 (21)	29 (43)
	B.Ed4	5 (6)	10 (12)	2 (2)	37 (45)	29 (35)
	PGCE	5 (4)	12 (10)	3 (3)	55 (48)	41 (35)
[Investigation]	All	15 (3)	55 (11)	43 (9)	191 (40)	175 (37)

Note: Figures in brackets are percentages.

❖ Teaching and learning in science (6)

Statements:	Year	1	2	3	4	5
The teacher should plan investigative activities for the pupils	B.Ed1	14 (11)	60 (50)	37 (31)	9 (7)	1 (1)
	B.Ed2	10 (11)	56 (62)	16 (17)	6 (7)	3 (3)
	B.Ed3	12 (18)	39 (57)	7 (10)	9 (13)	1 (2)
	B.Ed4	19 (23)	46 (55)	12 (14)	3 (4)	3 (4)
	PGCE	25 (21)	56 (48)	17 (15)	17 (15)	1 (1)
[Investigation]	All	80 (17)	257 (54)	89 (18)	44 (9)	9 (2)
The basic purpose of investigative work is to illustrate scientific theories	B.Ed1	8 (6)	54 (45)	45 (37)	13 (11)	1 (1)
	B.Ed2	4 (4)	23 (25)	46 (51)	15 (17)	3 93)
	B.Ed3	1 (1)	8 (12)	28 (41)	27 (40)	4 (6)
	B.Ed4	6 (7)	32 (39)	31 (37)	12 (15)	2 (2)
	PGCE	7 (6)	44 (38)	45 (39)	19 (16)	1 (1)
[Investigation]	All	26 (5)	161 (34)	195 (41)	86 (18)	11 (2)
Pupils should engage in evaluation of the outcomes of science lessons for themselves	B.Ed1	13 (11)	70 (58)	23 (19)	13 (11)	1 (1)
	B.Ed2	8 (9)	60 (66)	20 (22)	3 (3)	0 (0)
	B.Ed3	8 (12)	53 (79)	5 (8)	1 (1)	0 (0)
	B.Ed4	12 (15)	43 (52)	21 (25)	6 (7)	1 (1)
	PGCE	12 (10)	85 (73)	15 (13)	4 (4)	0 (0)
[Organisation]	All	53 (11)	311 (65)	84 (18)	27 (6)	2 (-)
Scientific knowledge is not in any way different from other forms of knowledge	B.Ed1	7 (6)	61 (50)	33 (27)	19 (16)	1 (1)
	B.Ed2	4 (4)	46 (51)	32 (35)	9 (10)	0 (0)
	B.Ed3	4 (6)	17 (25)	31 (46)	16 (23)	0 (0)
	B.Ed4	3 (4)	36 (44)	26 (31)	16 (19)	2 (2)
	PGCE	8 (7)	51 (44)	39 (33)	16 (14)	2 (2)
[Methodology]	All	26 (5)	211 (44)	161 (34)	76 (16)	5 (1)
Pupils should be allowed to use resources to discover scientific principles for themselves	B.Ed1	14 (12)	82 (68)	19 (15)	6 (5)	0 (0)
	B.Ed2	17 (19)	59 (66)	9 (10)	5 (5)	0 (0)
	B.Ed3	15 (22)	43 (63)	8 (12)	2 (3)	0 (0)
	B.Ed4	21 (26)	50 (61)	9 (11)	2 (2)	0 (0)
	PGCE	20 (17)	61 (53)	25 (21)	9 (8)	1 (1)
[Resources]	All	87 (18)	295 (62)	70 (15)	24 (5)	1 (-)
Pupils should be encouraged to identify the questions to ask during science activities	B.Ed1	32 (27)	80 (67)	8 (6)	0 (0)	0 (0)
	B.Ed2	25 (28)	63 (69)	1 (1)	1 (1)	1 (1)
	B.Ed3	15 (22)	51 (75)	2 (3)	0 (0)	0 (0)
	B.Ed4	23 (28)	49 (59)	11 (13)	0 (0)	0 (0)
	PGCE	28 (24)	84 (72)	2 (2)	2 (2)	0 (0)
[Methodology]	All	123 (26)	327 (68)	24 (5)	3 (1)	1 (-)

Note: Figures in brackets are percentages.

❖ Teaching and learning in science (7)

Statements:	Year	1	2	3	4	5
The teachers should direct pupils towards the correct scientific answer to problems	B.Ed1	12 (10)	39 (32)	45 (37)	21 (18)	4 (3)
	B.Ed2	6 (7)	27 (30)	32 (35)	23 (25)	3 93)
	B.Ed3	0 (0)	19 (28)	24 (35)	20 (29)	5 (8)
	B.Ed4	5 (6)	24 (29)	26 (31)	27 (33)	1 (1)
	PGCE	4 (3)	49 (42)	39 (34)	23 (20)	1 91)
[Organisation]	All	27 (5)	158 (33)	166 (35)	114 (24)	14 (3)

Note: Figures in brackets are percentages.

❖ Teaching and learning in science: Classroom management

Key:
1 — Strongly agree
2 — Agree
3 — Uncertain
4 — Disagree
5 — Strongly disagree.

Statements:	Year	1	2	3	4	5
Science lessons are largely about the development of factual knowledge	B.Ed1	8 (7)	44 (37)	39 (32)	28 (23)	1 (1)
	B.Ed2	4 (4)	41 (47)	23 (25)	21 (23)	1 (1)
	B.Ed3	11 (16)	28 (42)	14 (21)	14 (21)	0 (0)
	B.Ed4	12 (15)	36 (43)	18 (22)	15 (18)	2 (2)
	PGCE	4 (3)	69 (61)	18 (16)	21 (19)	1 (1)
[Methodology]	All	36 (9)	170 (43)	101 (25)	88 (22)	4 (1)
Pupils should be taught to concentrate during science lessons and not to talk	B.Ed1	6 (5)	25 (21)	21 (17)	53 (44)	16 (13)
	B.Ed2	0 (0)	8 (9)	22 (24)	50 (55)	11 (12)
	B.Ed3	0 (0)	1 (1)	9 (13)	44 (65)	14 (21)
	B.Ed4	1 (1)	9 (11)	6 (7)	40 (49)	26 (32)
	PGCE	8 (7)	11 (10)	12 (10)	64 (55)	21 (18)
[Methodology]	All	10 (3)	44 (11)	61 (15)	215 (53)	74 (18)
Science should start with pupils talking about and exploring their ideas on scientific issues	B.Ed1	37 (31)	55 (45)	25 (21)	4 (3)	0 (0)
	B.Ed2	24 (27)	52 (57)	12 (13)	3 (3)	0 (0)
	B.Ed3	13 (19)	34 (50)	18 (27)	2 (3)	1 (1)
	B.Ed4	21 (25)	42 (51)	15 (18)	5 (6)	0 (0)
	PGCE	32 (28)	64 (55)	18 (15)	2 (2)	0 (0)
[Methodology]	All	104 (26)	210 (52)	75 (18)	15 (4)	1 (-)
The most important aspect of science is that pupils follow the procedures given	B.Ed1	21 (17)	45 (37)	33 (27)	20 (17)	2 (2)
	B.Ed2	1 (1)	31 (34)	41 (45)	16 (18)	2 (2)
	B.Ed3	3 (5)	7 (10)	24 (35)	30 (44)	4 (6)
	B.Ed4	3 (4)	20 (24)	27 (33)	26 (31)	7 (8)
	PGCE	25 (22)	33 (29)	35 (31)	21 (18)	0 (0)
[Methodology]	All	35 (9)	111 (27)	139 (34)	103 (26)	15 (4)
Science lessons are more about the development of skills rather than facts	B.Ed1	4 (3)	29 (24)	61 (50)	24 (20)	3 (3)
	B.Ed2	4 (4)	24 (27)	53 (58)	9 (10)	1 (1)
	B.Ed3	2 (3)	29 (43)	30 (44)	5 (7)	2 (3)
	B.Ed4	4 (5)	23 (28)	38 (46)	16 (19)	2 (2)
	PGCE	2 (2)	26 (22)	54 (47)	31 (27)	3 (2)
[Methodology]	All	16 (3)	131 (28)	236 (49)	85 (18)	11 (2)
Science is made easier by the fact that there is little need for discussion and debate	B.Ed1	0 (0)	11 (9)	38 (31)	58 (48)	14 (12)
	B.Ed2	1 (1)	9 (10)	26 (28)	48 (53)	7 (8)
	B.Ed3	0 (0)	1 (2)	20 (29)	38 (56)	9 (13)
	B.Ed4	0 (0)	1 (1)	22 (27)	48 (58)	12 (14)
	PGCE	2 (2)	12 (10)	16 (14)	76 (65)	10 (9)
[Methodology]	All	3 (1)	34 (7)	122 (25)	268 (56)	52 (11)

Note: Figures in brackets are percentages.

❖ Teaching and learning in science: Classroom management (2)

Statements:	Year	1	2	3	4	5
Science lessons should be relevant to everyday experience of the pupils	B.Ed1	9 (7)	71 (59)	30 (25)	9 (7)	2 (2)
	B.Ed2	29 (32)	54 (59)	5 (6)	3 (3)	0 (0)
	B.Ed3	17 (25)	43 (63)	7 (10)	1 (2)	0 (0)
	B.Ed4	11 (13)	53 (64)	14 (17)	5 (6)	0 (0)
	PGCE	16 (14)	77 (66)	14 (12)	6 (5)	3 (3)
[Methodology]	All	82 (17)	298 (62)	70 (15)	24 (5)	5 (1)
The teacher must identify the focus of science lessons	B.Ed1	12 (10)	75 (62)	29 (24)	4 (3)	1 (1)
	B.Ed2	24 (27)	55 (60)	11 (12)	1 (1)	0 (0)
	B.Ed3	16 (24)	40 (59)	9 (13)	3 (4)	0 (0)
	B.Ed4	24 (29)	47 (57)	10 (12)	2 (2)	0 (0)
	PGCE	40 (34)	64 (55)	9 (8)	2 (2)	1 (1)
[Methodology]	All	116 (24)	281 (59)	68 (14)	12 (3)	2 (-)
Pupils should choose the way to examine scientific problems	B.Ed1	4 (3)	50 (41)	52 (43)	14 (12)	1 (1)
	B.Ed2	6 (7)	52 (57)	31 (34)	1 (1)	1 (1)
	B.Ed3	1 (1)	42 (62)	19 (28)	5 (8)	1 (1)
	B.Ed4	7 (9)	37 (45)	25 (30)	13 (16)	0 (0)
	PGCE	3 (3)	33 (28)	59 (51)	21 (18)	0 (0)
[Methodology]	All	21 (4)	214 (45)	186 (39)	54 (11)	3 (1)
Scientific knowledge is not in any way different from other forms of knowledge	B.Ed1	7 (6)	61 (50)	33 (27)	19 (16)	1 (1)
	B.Ed2	4 (4)	46 (51)	32 (35)	9 (10)	0 (0)
	B.Ed3	4 (6)	17 (25)	31 (46)	16 (23)	0 (0)
	B.Ed4	3 (4)	36 (44)	26 (31)	16 (19)	2 (2)
	PGCE	8 (7)	51 (44)	39 (33)	16 (14)	2 (2)
[Methodology]	All	26 (5)	211 (44)	161 (34)	76 (16)	5 (1)
Pupils should be encouraged to identify the questions to ask during science activities	B.Ed1	32 (27)	80 (67)	8 (6)	0 (0)	0 (0)
	B.Ed2	25 (28)	63 (69)	1 (1)	1 (1)	1 (1)
	B.Ed3	15 (22)	51 (75)	2 (3)	0 (0)	0 (0)
	B.Ed4	23 (28)	49 (59)	11 (13)	0 (0)	0 (0)
	PGCE	28 (24)	84 (72)	2 (2)	2 (2)	0 (0)
[Methodology]	All	123 (26)	327 (68)	24 (5)	3 (1)	1 (-)

Note: Figures in brackets are percentages.

Key:
1 — Strongly agree
2 — Agree
3 — Uncertain
4 — Disagree
5 — Strongly disagree.

❖ Teaching and learning in science: Resourcing lessons

Statements:	Year	1	2	3	4	5
Teachers should supply notes for pupils to copy	B.Ed1	8 (7)	43 (36)	36 (30)	29 (24)	4 (3)
	B.Ed2	2 (2)	23 (26)	30 (33)	30 (33)	5 (6)
	B.Ed3	0 (0)	6 (9)	14 (20)	38 (56)	10 (15)
	B.Ed4	1 (1)	9 (11)	22 (27)	38 (46)	12 (15)
	PGCE	2 (2)	22 (19)	39 (34)	47 (41)	5 (4)
[Resources]	All	12 (3)	89 (22)	114 (28)	154 (39)	32 (8)
Pupils should develop their own notes through observation and practical activity	B.Ed1	34 (28)	63 (52)	19 (16)	5 (4)	0 (0)
	B.Ed2	27 (30)	49 (55)	9 (10)	4 (4)	1 (1)
	B.Ed3	25 (37)	28 (41)	15 (22)	0 (0)	0 (0)
	B.Ed4	25 (30)	34 (41)	21 (25)	3 (4)	0 (0)
	PGCE	29 (25)	71 (61)	12 (10)	4 (4)	0 (0)
[Resources]	All	119 (30)	202 (50)	69 (17)	13 (3)	1 (-)
Science can take place using everyday materials	B.Ed1	58 (48)	57 (47)	5 (4)	1 (1)	0 (0)
	B.Ed2	36 (40)	52 (57)	3 (3)	0 (0)	0 (0)
	B.Ed3	29 (43)	37 (54)	2 (3)	0 (0)	0 (0)
	B.Ed4	39 (47)	36 (43)	8 (10)	0 (0)	0 (0)
	PGCE	30 (26)	75 (65)	6 (5)	5 (4)	0 (0)
[Resources]	All	192 (40)	257 (54)	24 (5)	6 (1)	0 (0)
Science lessons require the teacher to devises experiments using available resources	B.Ed1	7 (6)	83 (70)	17 (14)	11 (9)	1 (1)
	B.Ed2	12 (13)	50 (55)	19 (21)	10 (11)	0 (0)
	B.Ed3	2 (3)	33 (48)	22 (32)	10 (15)	1 (2)
	B.Ed4	9 (11)	34 (41)	28 (34)	12 (14)	0 (0)
	PGCE	10 (8)	65 (56)	25 (22)	14 (12)	2 (2)
[Resources]	All	40 (8)	265 (56)	111 (23)	57 (12)	4 (1)
Handling equipment safely is an important aspect of science lessons	B.Ed1	101 (84)	16 (13)	2 (2)	1 (1)	0 (0)
	B.Ed2	57 (63)	28 (31)	4 (4)	2 (2)	0 (0)
	B.Ed3	53 (78)	15 (22)	0 (0)	0 (0)	0 (0)
	B.Ed4	51 (62)	31 (37)	1 (1)	0 (0)	0 (0)
	PGCE	96 (83)	17 (15)	0 (0)	0 (0)	3 (2)
[Resources]	All	358 (75)	107 (22)	7 (1)	3 (1)	3 (1)

Note: Figures in brackets are percentages.

❖ Teaching and learning in science: Resourcing lessons (2)

Statements:	Year	1	2	3	4	5
It is too dangerous to give pupils access to scientific equipment	B.Ed1	2 (2)	6 (5)	30 (25)	69 (57)	14 (11)
	B.Ed2	0 (0)	3 (3)	18 (20)	47 (52)	23 (25)
	B.Ed3	0 (0)	0 (0)	5 (8)	41 (60)	22 (32)
	B.Ed4	1 (1)	1 (1)	13 (16)	48 (58)	20 (24)
	PGCE	4 (3)	6 (5)	22 (19)	69 (60)	15 (13)
[Resources]	All	7 (2)	16 (3)	88 (18)	274 (57)	94 (20)
Science lessons should be based around textbooks and worksheets	B.Ed1	0 (0)	12 (10)	34 (28)	59 (49)	16 (13)
	B.Ed2	0 (0)	3 (3)	15 (17)	45 (49)	28 (31)
	B.Ed3	0 (0)	1 (2)	9 (13)	47 (69)	11 (16)
	B.Ed4	0 (0)	5 (6)	13 (16)	57 (69)	8 (9)
	PGCE	1 (1)	14 (12)	19 (16)	64 (55)	18 (16)
[Resources]	All	1 (-)	35 (7)	90 (19)	272 (57)	81 (17)
Pupils should be given responsibility for identifying resources to carry out experiments	B.Ed1	7 (6)	71 (59)	24 (20)	16 (13)	2 (2)
	B.Ed2	10 (11)	66 (73)	11 (12)	3 (3)	1 (1)
	B.Ed3	0 (0)	48 (71)	19 (28)	1 (1)	0 (0)
	B.Ed4	8 (10)	50 (60)	14 (17)	9 (11)	2 (2)
	PGCE	8 (7)	54 (47)	26 (22)	26 (22)	2 (2)
[Resources]	All	33 (7)	289 (60)	94 (20)	55 (11)	7 (2)
Pupils should be allowed to use resources to discover scientific principles for themselves	B.Ed1	14 (12)	82 (68)	19 (15)	6 (5)	0 (0)
	B.Ed2	17 (19)	59 (66)	9 (10)	5 (5)	0 (0)
	B.Ed3	15 (22)	43 (63)	8 (12)	2 (3)	0 (0)
	B.Ed4	21 (26)	50 (61)	9 (11)	2 (2)	0 (0)
	PGCE	20 (17)	61 (53)	25 (21)	9 (8)	1 (1)
[Resources]	All	87 (18)	295 (62)	70 (15)	24 (5)	1 (-)

Note: Figures in brackets are percentages.

Key:
1 — Strongly agree
2 — Agree
3 — Uncertain
4 — Disagree
5 — Strongly disagree.

❖ Teaching and learning in science: Investigative approaches

Statements:	Year	1	2	3	4	5
Pupils should observe experiments which are demonstrated by the teacher	B.Ed1	34 (28)	47 (39)	21 (17)	12 (10)	7 (6)
	B.Ed2	8 (9)	36 (39)	23 (25)	17 (19)	7 (8)
	B.Ed3	6 (9)	24 (37)	8 (12)	20 (30)	8 (12)
	B.Ed4	4 (5)	28 (33)	23 (28)	18 (22)	10 (12)
	PGCE	23 (20)	52 (45)	17 (15)	18 (16)	5 (4)
[Investigation]	All	58 (14)	155 (39)	82 (20)	73 (18)	34 (9)
Pupils should gain direct experience of science through practical activity	B.Ed1	70 (58)	47 (39)	4 (3)	0 (0)	0 (0)
	B.Ed2	55 (60)	32 (35)	4 (5)	0 (0)	0 (0)
	B.Ed3	50 (74)	18 (26)	0 (0)	0 (0)	0 (0)
	B.Ed4	54 (65)	27 (33)	2 (2)	0 (0)	0 (0)
	PGCE	56 (48)	56 (48)	1 (1)	3 (3)	0 (0)
[Investigation]	All	245 (60)	148 (36)	10 (3)	2 (1)	0 (0)
Lessons should engage pupils in investigative approaches	B.Ed1	47 (39)	68 (57)	5 (4)	0 (0)	0 (0)
	B.Ed2	29 (32)	59 (65)	2 (2)	0 (0)	1 (1)
	B.Ed3	32 (48)	35 (52)	0 (0)	0 (0)	0 (0)
	B.Ed4	29 (35)	49 (59)	5 (6)	0 (0)	0 (0)
	PGCE	49 (42)	64 (55)	0 (0)	1 (1)	2 (2)
[Investigation]	All	186 (39)	275 (58)	12 (2)	1 (-)	3 (1)
Lessons should involve pupils in exploring, observing and ordering	B.Ed1	48 (40)	67 (55)	6 (5)	0 (0)	0 (0)
	B.Ed2	27 (30)	56 (61)	8 (9)	0 (0)	0 (0)
	B.Ed3	38 (56)	30 (44)	0 (0)	0 (0)	0 (0)
	B.Ed4	39 (47)	35 (42)	7 (9)	1 (1)	1 (1)
	PGCE	51 (44)	63 (54)	0 (0)	0 (0)	2 (2)
[Investigation]	All	203 (42)	251 (53)	21 (4)	1 (-)	3 (1)
Pupils should be given opportunities to devise methods of testing ideas	B.Ed1	29 (24)	77 (63)	13 (11)	2 (2)	0 (0)
	B.Ed2	20 (22)	60 (66)	9 (10)	0 (0)	2 (2)
	B.Ed3	21 (31)	44 (65)	3 (4)	0 (0)	0 (0)
	B.Ed4	22 (26)	47 (57)	14 (17)	0 (0)	0 (0)
	PGCE	25 (22)	74 (64)	15 (13)	2 (1)	0 (0)
[Investigation]	All	117 (25)	302 (63)	54 (11)	4 (1)	2 (-)
Investigative work is inappropriate in science	B.Ed1	3 (3)	10 (8)	7 (6)	52 (43)	49 (40)
	B.Ed2	0 (0)	8 (9)	4 (4)	43 (48)	35 (39)
	B.Ed3	4 (6)	1 (1)	0 (0)	27 (40)	36 (53)
	B.Ed4	0 (0)	4 (5)	5 (6)	40 (48)	34 (41)
	PGCE	3 (3)	6 (5)	0 (0)	62 (53)	45 (39)
[Investigation]	All	10 (2)	29 (6)	16 (3)	224 (47)	199 (42)

Note: Figures in brackets are percentages.

❖ Teaching and learning in science: Investigative approaches (2)

Statements:	Year	1	2	3	4	5
It is not necessary to engage in practical activity in science lessons	B.Ed1	1 (1)	11 (9)	16 (13)	48 (40)	45 (37)
	B.Ed2	0 (0)	6 (6)	17 (19)	37 (41)	31 (34)
	B.Ed3	4 (6)	16 (23)	5 (7)	14 (21)	29 (43)
	B.Ed4	5 (6)	10 (12)	2 (2)	37 (45)	29 (35)
	PGCE	5 (4)	12 (10)	3 (3)	55 (48)	41 (35)
[Investigation]	All	15 (3)	55 (11)	43 (9)	191 (40)	175 (37)
The teacher should plan investigative activities for the pupils	B.Ed1	14 (11)	60 (50)	37 (31)	9 (7)	1 (1)
	B.Ed2	10 (11)	56 (62)	16 (17)	6 (7)	3 (3)
	B.Ed3	12 (18)	39 (57)	7 (10)	9 (13)	1 (2)
	B.Ed4	19 (23)	46 (55)	12 (14)	3 (4)	3 (4)
	PGCE	25 (21)	56 (48)	17 (15)	17 (15)	1 (1)
[Investigation]	All	80 (17)	257 (54)	89 (18)	44 (9)	9 (2)
The basic purpose of investigative work is to illustrate scientific theories	B.Ed1	8 (6)	54 (45)	45 (37)	13 (11)	1 (1)
	B.Ed2	4 (4)	23 (25)	46 (51)	15 (17)	3 93)
	B.Ed3	1 (1)	8 (12)	28 (41)	27 (40)	4 (6)
	B.Ed4	6 (7)	32 (39)	31 (37)	12 (15)	2 (2)
	PGCE	7 (6)	44 (38)	45 (39)	19 (16)	1 (1)
[Investigation]	All	26 (5)	161 (34)	195 (41)	86 (18)	11 (2)

Note: Figures in brackets are percentages.

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

❖ Teaching and learning in science: Organisation

Statements:	Year	1	2	3	4	5
Science lessons are an ideal opportunity for pupils to work collaboratively in groups	B.Ed1	61 (50)	55 (49)	4 (3)	1 (1)	0 (0)
	B.Ed2	42 (46)	48 (53)	1 (1)	0 (0)	0 (0)
	B.Ed3	36 (53)	32 (47)	0 (0)	0 (0)	0 (0)
	B.Ed4	51 (62)	31 (37)	1 (1)	0 (0)	0 (0)
	PGCE	47 (41)	62 (53)	2 (2)	5 (4)	0 (0)
[Organisation]	All	205 (50)	190 (47)	7 (3)	3 (1)	0 (0)
Science lessons should mostly involve pupils in working by themselves	B.Ed1	1 (1)	11 (9)	35 (29)	55 (45)	19 (16)
	B.Ed2	2 (2)	9 (10)	29 (32)	38 (42)	13 (14)
	B.Ed3	0 (0)	0 (0)	15 (22)	44 (65)	9 (13)
	B.Ed4	0 (0)	6 (7)	15 (18)	46 (56)	16 (19)
	PGCE	3 (3)	7 (6)	21 (18)	74 (64)	11 (9)
[Organisation]	All	3 (1)	29 (7)	101 (25)	213 (53)	59 (14)
Whole class lessons should be the norm in science	B.Ed1	6 (5)	18 (15)	56 (46)	36 (30)	5 (4)
	B.Ed2	5 (6)	11 (12)	32 (35)	39 (43)	4 (4)
	B.Ed3	6 (9)	15 (22)	32 (47)	10 (15)	5 (7)
	B.Ed4	1 (1)	14 (17)	34 (41)	32 (39)	2 (2)
	PGCE	6 (5)	26 (22)	36 (31)	40 (35)	8 (7)
[Organisation]	All	24 (5)	84 (17)	190 (40)	157 (33)	24 (5)
To be effective, science needs to be related to other areas of the curriculum	B.Ed1	3 (2)	31 (26)	55 (45)	26 (22)	6 (5)
	B.Ed2	9 (10)	24 (26)	41 (45)	17 (19)	0 (0)
	B.Ed3	3 (4)	20 (29)	23 (34)	22 (33)	0 (0)
	B.Ed4	6 (7)	32 (39)	27 (32)	17 (21)	1 (1)
	PGCE	5 (4)	47 (41)	40 (34)	22 (19)	2 (2)
[Organisation]	All	26 (5)	154 (32)	186 (39)	104 (22)	9 (2)
Science lessons should consist mostly of group activity with only some whole class work	B.Ed1	14 (12)	50 (41)	35 (29)	21 (17)	1 (1)
	B.Ed2	7 (8)	40 (44)	35 (38)	9 (10)	0 (0)
	B.Ed3	2 (3)	25 (37)	39 (57)	2 (3)	0 (0)
	B.Ed4	5 (6)	36 (44)	26 (32)	13 (16)	2 (2)
	PGCE	6 (5)	57 (49)	39 (34)	14 (12)	0 (0)
[Organisation]	All	34 (7)	208 (44)	174 (36)	59 (12)	3 (1)
Science should be taught as separate lessons	B.Ed1	5 (4)	33 (27)	57 (48)	24 (20)	1 (1)
	B.Ed2	4 (4)	17 (19)	48 (53)	19 (21)	3 (3)
	B.Ed3	2 (3)	17 (25)	12 (18)	30 (44)	7 (10)
	B.Ed4	2 (2)	11 (13)	37 (45)	30 (36)	3 (4)
	PGCE	6 (5)	29 (25)	38 (33)	40 (34)	3 (3)
[Organisation]	All	19 (4)	107 (22)	192 (40)	143 (30)	17 (4)

Note: Figures in brackets are percentages.

❖ Teaching and learning in science: Organisation (2)

Statements:	Year	1	2	3	4	5
Pupils should engage in evaluation of the outcomes of science lessons for themselves	B.Ed1	13 (11)	70 (58)	23 (19)	13 (11)	1 (1)
	B.Ed2	8 (9)	60 (66)	20 (22)	3 (3)	0 (0)
	B.Ed3	8 (12)	53 (79)	5 (8)	1 (1)	0 (0)
	B.Ed4	12 (15)	43 (52)	21 (25)	6 (7)	1 (1)
	PGCE	12 (10)	85 (73)	15 (13)	4 (4)	0 (0)
[Organisation]	All	53 (11)	311 (65)	84 (18)	27 (6)	2 (-)
The teachers should direct pupils towards the correct scientific answer to problems	B.Ed1	12 (10)	39 (32)	45 (37)	21 (18)	4 (3)
	B.Ed2	6 (7)	27 (30)	32 (35)	23 (25)	3 93)
	B.Ed3	0 (0)	19 (28)	24 (35)	20 (29)	5 (8)
	B.Ed4	5 (6)	24 (29)	26 (31)	27 (33)	1 (1)
	PGCE	4 (3)	49 (42)	39 (34)	23 (20)	1 91)
[Organisation]	All	27 (5)	158 (33)	166 (35)	114 (24)	14 (3)

Note: Figures in brackets are percentages.

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

❖ Professional skills (1)

Statements:	Year	1	2	3	4	5	CI
Focusing the teaching of science on knowledge and understanding of science	B.Ed1	4 (3)	40 (33)	68 (56)	9 (8)	0 (0)	**2.7**
	B.Ed2	3 (3)	40 (44)	43 (47)	5 (6)	0 (0)	**2.5**
	B.Ed3	5 (7)	46 (68)	17 (25)	0 (0)	0 (0)	**2.2**
	B.Ed4	13 (16)	51 (61)	15 (18)	4 (5)	0 (0)	**2.1**
	PGCE	3 (3)	49 (43)	51 (44)	12 (10)	0 (0)	**2.6**
	All	28 (6)	226 (47)	194 (41)	30 (6)	0 (0)	**2.5**
Focusing the teaching of science on the skills of science	B.Ed1	5 (4)	47 (39)	58 (48)	11 (9)	0 (0)	**2.6**
	B.Ed2	2 (2)	37 (41)	49 (54)	3 (3)	0 (0)	**2.6**
	B.Ed3	8 (12)	45 (66)	15 (22)	0 (0)	0 (0)	**2.1**
	B.Ed4	9 (11)	47 (57)	22 (26)	5 (6)	0 (0)	**2.3**
	PGCE	3 (3)	45 (39)	51 (44)	16 (14)	0 (0)	**2.7**
	All	27 (6)	221 (46)	195 (41)	35 (7)	0 (0)	**2.5**
Using the assessment process to plan group learning in science	B.Ed1	7 (6)	42 (35)	63 (53)	6 (5)	1 (1)	**2.6**
	B.Ed2	4 (4)	31 (34)	48 (53)	8 (9)	0 (0)	**2.7**
	B.Ed3	6 (9)	48 (71)	14 (20)	0 (0)	0 (0)	**2.1**
	B.Ed4	13 (16)	54 (65)	16 (19)	0 (0)	0 (0)	**2**
	PGCE	4 (4)	42 (36)	50 (43)	18 (16)	1 (1)	**2.7**
	All	34 (7)	217 (46)	191 (40)	32 (7)	2 (-)	**2.5**
Reporting on pupils' attainment in knowledge and understanding	B.Ed1	6 (5)	62 (52)	47 (39)	5 (4)	0 (0)	**2.4**
	B.Ed2	4 (5)	54 (59)	24 (26)	9 (10)	0 (0)	**2.4**
	B.Ed3	4 (6)	52 (76)	12 (18)	0 (0)	0 (0)	**2.1**
	B.Ed4	20 (24)	53 (64)	9 (11)	1 (1)	0 (0)	**1.9**
	PGCE	6 (5)	55 (48)	42 (36)	11 (10)	1 (1)	**2.5**
	All	40 (8)	276 (58)	134 (28)	26 (6)	1 (-)	**2.3**
Reporting on pupils' attainment in practical investigative skills	B.Ed1	10 (8)	52 (43)	47 (39)	10 (8)	1 (1)	**2.5**
	B.Ed2	2 (2)	47 (52)	38 (42)	4 (4)	0 (0)	**2.5**
	B.Ed3	5 (7)	50 (74)	13 (19)	0 (0)	0 (0)	**2.1**
	B.Ed4	16 (20)	50 (60)	16 (19)	1 (1)	0 (0)	**2**
	PGCE	5 (4)	58 (51)	39 (34)	12 (11)	0 (0)	**2.5**
	All	38 (8)	257 (54)	153 (32)	27 (6)	1 (-)	**2.3**
Using whole class teaching to introduce and consolidate work in science	B.Ed1	9 (8)	49 (41)	46 (38)	16 (13)	0 (0)	**2.6**
	B.Ed2	6 (7)	52 (57)	31 (34)	2 (2)	0 (0)	**2.3**
	B.Ed3	14 (21)	43 (63)	11 (16)	0 (0)	0 (0)	**2**
	B.Ed4	15 (18)	44 (53)	21 (25)	3 (4)	0 (0)	**2.1**
	PGCE	7 (6)	54 (47)	39 (34)	14 (12)	1 (1)	**2.5**
	All	51 (11)	242 (51)	148 (31)	35 (7)	1 (-)	**2.3**

Note: Figures in brackets are percentages.

❖ Professional skills (2)

Statements:	Year	1	2	3	4	5	C1
Organising pupils into science ability (attainment) groups	B.Ed1	11 (9)	46 (39)	40 (34)	22 (18)	0 (0)	**2.6**
	B.Ed2	0 (0)	34 (37)	37 (41)	20 (22)	0 (0)	**2.8**
	B.Ed3	5 (8)	28 (41)	22 (32)	13 (19)	0 (0)	**2.6**
	B.Ed4	13 (16)	32 (39)	25 (30)	9 (11)	3 (4)	**2.4**
	PGCE	3 (2)	32 (28)	54 (47)	25 (22)	1 (1)	**2.9**
	All	32 (7)	172 (36)	178 (37)	89 (19)	4 (1)	**2.7**
Using interactive (e.g. engaging in discussion, questioning etc) teaching methods with ability groups in science	B.Ed1	16 (13)	56 (46)	36 (30)	12 (10)	1 (1)	**2.4**
	B.Ed2	5 (6)	53 (58)	23 (25)	10 (11)	0 (0)	**2.4**
	B.Ed3	14 (21)	43 (63)	11 (16)	0 (0)	0 (0)	**2**
	B.Ed4	25 (30)	44 (53)	12 (15)	2 (2)	0 (0)	**1.9**
	PGCE	14 (12)	61 (53)	32 (28)	8 (7)	0 (0)	**2.3**
	All	74 (15)	257 (54)	114 (24)	32 (7)	1 (-)	**2.2**
Developing homework linked to science topics	B.Ed1	12 (10)	50 (41)	45 (37)	12 (10)	2 (2)	**2.5**
	B.Ed2	4 (4)	47 (52)	31 (34)	9 (10)	0 (0)	**2.5**
	B.Ed3	2 (3)	49 (72)	17 (25)	0 (0)	0 (0)	**2.2**
	B.Ed4	13 (16)	46 (55)	16 (19)	8 (10)	0 (0)	**2.2**
	PGCE	11 (10)	44 (38)	50 (43)	9 (8)	1 (1)	**2.5**
	All	42 (9)	236 (49)	159 (33)	38 (8)	3 (1)	**2.4**
Organising resources for science topics	B.Ed1	16 (13)	48 (40)	49 (40)	8 (7)	0 (0)	**2.4**
	B.Ed2	9 (10)	47 (52)	32 (35)	3 (3)	0 (0)	**2.3**
	B.Ed3	7 (10	48 (71)	12 (18)	1(1)	0 (0)	**2.1**
	B.Ed4	20 (24)	47 (57)	14 (17)	2 (2)	0 (0)	**2**
	PGCE	12 (10)	49 (43)	48 (42)	6 (5)	0 (0)	**2.4**
	All	64 (14)	239 (50)	155 (32)	20 (4)	0 (0)	**2.3**
Defining attainment targets in science	B.Ed1	5 (4)	64 (53)	38 (31)	13 (11)	1 (1)	**2.5**
	B.Ed2	3 (3)	57 (63)	26 (29)	5 (5)	0 (0)	**2.4**
	B.Ed3	14 (21)	40 (59)	11 (16)	3 (4)	0 (0)	**2**
	B.Ed4	12 (15)	50 (60)	17 (20)	4 (5)	0 (0)	**2.2**
	PGCE	5 (4)	35 (30)	56 (49)	19 (17)	0 (0)	**2.8**
	All	39 (8)	246 (52)	148 (31)	44 (9)	1 (-)	**2.5**
Anticipating likely areas of confusion in relation to scientific concepts	B.Ed1	5 (4)	47 (39)	54 (45)	15 (12)	0 (0)	**2.7**
	B.Ed2	3 (3)	32 (35)	38 (42)	18 (20)	0 (0)	**2.8**
	B.Ed3	6 (9)	37 (54)	19 (28)	6 (9)	0 (0)	**2.4**
	B.Ed4	14 (17)	38 (46)	23 (28)	6 (8)	1 (1)	**2.3**
	PGCE	5 (4)	29 (25)	49 (43)	29 (25)	3 (3)	**2.9**
	All	33 (7)	183 (38)	183 (38)	74 (16)	4 (1)	**2.6**

Note: Figures in brackets are percentages.

❖ Professional skills (3)

Statements:	Year	1	2	3	4	5	CI
Developing 'thinking skills' (e.g. problem solving, drawing conclusions etc)	B.Ed1	8 (7)	46 (39)	55 (46)	10 (8)	0 (0)	**2.5**
	B.Ed2	3 (3)	36 (40)	38 (42)	14 (15)	0 (0)	**2.7**
	B.Ed3	12 (18)	39 (57)	17 (25)	0 (0)	0 (0)	**2.1**
	B.Ed4	10 (12)	56 (67)	14 (17)	3 (4)	0 (0)	**2.1**
	PGCE	4 (3)	54 (47)	46 (40)	10 (9)	1 (1)	**2.5**
	All	37 (8)	231 (48)	170 (36)	37 (8)	1 (-)	**2.4**
Assisting pupils in carrying out science investigations	B.Ed1	14 (12)	67 (55)	36 (30)	4 (3)	0 (0)	**2.2**
	B.Ed2	8 (9)	56 (62)	25 (27)	2 (2)	0 (0)	**2.2**
	B.Ed3	18 (27)	46 (67)	4 (6)	0 (0)	0 (0)	**1.8**
	B.Ed4	23 (28)	51 (61)	9 (11)	0 (0)	0 (0)	**1.8**
	PGCE	8 (7)	61 (53)	40 (35)	6 (5)	0 (0)	**2.4**
	All	71 (15)	281 (59)	114 (24)	12 (2)	0 (0)	**2.1**
Assessing the discrete investigative skills (e.g. planning an activity)	B.Ed1	9 (8)	53 (44)	51 (42)	7 (6)	0 (0)	**2.4**
	B.Ed2	2 (2)	43 (47)	36 (40)	10 (11)	0 (0)	**2.6**
	B.Ed3	6 (9)	36 (53)	24 (35)	2 (3)	0 (0)	**2.3**
	B.Ed4	12 (15)	48 (58)	17 (20)	6 (7)	0 (0)	**2.2**
	PGCE	7 (6)	53 (46)	42 (37)	13 (11)	0 (0)	**2.5**
	All	36 (7)	233 (49)	170 (36)	38 (8)	0 (0)	**2.4**
Managing practical science learning activities in different ways (e.g. groups, rotating between work stations etc)	B.Ed1	7 (6)	55 (46)	50 (41)	9 (7)	0 (0)	**2.5**
	B.Ed2	6 (7)	47 (52)	35 (38)	3 (3)	0 (0)	**2.4**
	B.Ed3	6 (9)	48 (71)	14 (20)	0 (0)	0 (0)	**2.1**
	B.Ed4	18 (22)	50 (60)	13 (16)	2 (2)	0 (0)	**2**
	PGCE	6 (5)	51 (44)	43 (38)	15 (13)	0 (0)	**2.6**
	All	43 (9)	251 (53)	155 (32)	29 (6)	0 (0)	**2.4**
Differentiating science lessons to meet the needs of pupils	B.Ed1	8 (7)	35 (29)	62 (51)	16 (13)	0 (0)	**2.7**
	B.Ed2	7 (8)	31 (34)	39 (43)	14 (15)	0 (0)	**2.7**
	B.Ed3	7 (10)	34 (50)	24 (35)	1 (2)	2 (3)	**2.2**
	B.Ed4	10 (12)	44 (53)	21 (25)	8 (10)	0 (0)	**2.3**
	PGCE	1 (1)	27 (24)	52 (45)	35 (30)	0 (0)	**3**
	All	33 (7)	171 (36)	198 (41)	74 (16)	2 (-)	**2.7**
Encouraging and responding to pupils' questions in science topics	B.Ed1	5 (4)	58 (48)	48 (40)	8 (6)	2 (2)	**2.5**
	B.Ed2	8 (9)	40 (44)	27 (30)	16 (17)	0 (0)	**2.6**
	B.Ed3	6 (9)	29 (43)	16 (23)	17 (25)	0 (0)	**2.6**
	B.Ed4	14 (17)	50 (60)	14 (17)	5 (6)	0 (0)	**2.1**
	PGCE	6 (5)	51 (44)	44 (39)	14 (12)	0 (0)	**2.6**
	All	39 (8)	228 (48)	149 (31)	60 (13)	2 (-)	**2.5**

Note: Figures in brackets are percentages.

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

❖ Professional skills -- Planning

Statements:	Year	1	2	3	4	5
Focusing the teaching of science on knowledge and understanding of science	B.Ed1	4 (3)	40 (33)	68 (56)	9 (8)	0 (0)
	B.Ed2	3 (3)	40 (44)	43 (47)	5 (6)	0 (0)
	B.Ed3	5 (7)	46 (68)	17 (25)	0 (0)	0 (0)
	B.Ed4	13 (16)	51 (61)	15 (18)	4 (5)	0 (0)
	PGCE	3 (3)	49 (43)	51 (44)	12 (10)	0 (0)
	All	28 (6)	226 (47)	194 (41)	30 (6)	0 (0)
Focusing the teaching of science on the skills of science	B.Ed1	5 (4)	47 (39)	58 (48)	11 (9)	0 (0)
	B.Ed2	2 (2)	37 (41)	49 (54)	3 (3)	0 (0)
	B.Ed3	8 (12)	45 (66)	15 (22)	0 (0)	0 (0)
	B.Ed4	9 (11)	47 (57)	22 (26)	5 (6)	0 (0)
	PGCE	3 (3)	45 (39)	51 (44)	16 (14)	0 (0)
	All	27 (6)	221 (46)	195 (41)	35 (7)	0 (0)
Using the assessment process to plan group learning in science	B.Ed1	7 (6)	42 (35)	63 (53)	6 (5)	1 (1)
	B.Ed2	4 (4)	31 (34)	48 (53)	8 (9)	0 (0)
	B.Ed3	6 (9)	48 (71)	14 (20)	0 (0)	0 (0)
	B.Ed4	13 (16)	54 (65)	16 (19)	0 (0)	0 (0)
	PGCE	4 (4)	42 (36)	50 (43)	18 (16)	1 (1)
	All	34 (7)	217 (46)	191 (40)	32 (7)	2 (-)
Using whole class teaching to introduce and consolidate work in science	B.Ed1	9 (8)	49 (41)	46 (38)	16 (13)	0 (0)
	B.Ed2	6 (7)	52 (57)	31 (34)	2 (2)	0 (0)
	B.Ed3	14 (21)	43 (63)	11 (16)	0 (0)	0 (0)
	B.Ed4	15 (18)	44 (53)	21 (25)	3 (4)	0 (0)
	PGCE	7 (6)	54 (47)	39 (34)	14 (12)	1 (1)
	All	51 (11)	242 (51)	148 (31)	35 (7)	1 (-)
Developing homework linked to science topics	B.Ed1	12 (10)	50 (41)	45 (37)	12 (10)	2 (2)
	B.Ed2	4 (4)	47 (52)	31 (34)	9 (10)	0 (0)
	B.Ed3	2 (3)	49 (72)	17 (25)	0 (0)	0 (0)
	B.Ed4	13 (16)	46 (55)	16 (19)	8 (10)	0 (0)
	PGCE	11 (10)	44 (38)	50 (43)	9 (8)	1 (1)
	All	42 (9)	236 (49)	159 (33)	38 (8)	3 (1)
Anticipating likely areas of confusion in relation to scientific concepts	B.Ed1	5 (4)	47 (39)	54 (45)	15 (12)	0 (0)
	B.Ed2	3 (3)	32 (35)	38 (42)	18 (20)	0 (0)
	B.Ed3	6 (9)	37 (54)	19 (28)	6 (9)	0 (0)
	B.Ed4	14 (17)	38 (46)	23 (28)	6 (8)	1 (1)
	PGCE	5 (4)	29 (25)	49 (43)	29 (25)	3 (3)
	All	33 (7)	183 (38)	183 (38)	74 (16)	4 (1)
Developing 'thinking skills' (e.g. problem solving, drawing conclusions etc)	B.Ed1	8 (7)	46 (39)	55 (46)	10 (8)	0 (0)
	B.Ed2	3 (3)	36 (40)	38 (42)	14 (15)	0 (0)
	B.Ed3	12 (18)	39 (57)	17 (25)	0 (0)	0 (0)
	B.Ed4	10 (12)	56 (67)	14 (17)	3 (4)	0 (0)
	PGCE	4 (3)	54 (47)	46 (40)	10 (9)	1 (1)
	All	37 (8)	231 (48)	170 (36)	37 (8)	1 (-)

Note: Figures in brackets are percentages.

❖ Confidence indices: Planning

Statements:	Year	1	2	3	4	5	CI
Focusing the teaching of science on knowledge and understanding of science	B.Ed1	4	80	204	36	0	2.7
	B.Ed2	3	80	129	20	0	2.5
	B.Ed3	5	92	51	0	0	2.2
	B.Ed4	13	102	45	16	0	2.1
	PGCE	3	98	153	48	0	2.6
	All	28	452	582	120	0	2.5
Focusing the teaching of science on the skills of science	B.Ed1	5	94	174	44	0	2.6
	B.Ed2	2	74	147	12	0	2.6
	B.Ed3	8	90	45	0	0	2.1
	B.Ed4	9	94	66	20	0	2.3
	PGCE	3	90	153	64	0	2.7
	All	27	442	585	140	0	2.5
Using the assessment process to plan group learning in science	B.Ed1	7	84	189	24	5	2.6
	B.Ed2	4	62	144	32	0	2.7
	B.Ed3	6	96	42	0	0	2.1
	B.Ed4	13	108	48	0	0	2
	PGCE	4	84	150	72	5	2.7
	All	34	434	573	128	10	2.5
Using whole class teaching to introduce and consolidate work in science	B.Ed1	9	98	138	64	0	2.6
	B.Ed2	6	104	93	8	0	2.3
	B.Ed3	14	86	33	0	0	2
	B.Ed4	15	88	63	12	0	2.1
	PGCE	7	108	117	56	5	2.5
	All	51	484	444	140	5	2.3
Developing homework linked to science topics	B.Ed1	12	100	135	48	10	2.5
	B.Ed2	4	94	93	36	0	2.5
	B.Ed3	2	98	51	0	0	2.2
	B.Ed4	13	92	48	32	0	2.2
	PGCE	11	88	150	36	5	2.5
	All	42	472	477	152	15	2.4
Anticipating likely areas of confusion in relation to scientific concepts	B.Ed1	5	94	162	60	0	2.7
	B.Ed2	3	64	114	72	0	2.8
	B.Ed3	6	74	57	24	0	2.4
	B.Ed4	14	76	69	24	5	2.3
	PGCE	5	58	147	116	15	2.9
	All	33	366	549	296	20	2.6
Developing 'thinking skills' (e.g. problem solving, drawing conclusions etc)	B.Ed1	8	92	165	40	0	2.5
	B.Ed2	3	72	114	56	0	2.7
	B.Ed3	12	78	51	0	0	2.1
	B.Ed4	10	112	42	12	0	2.1
	PGCE	4	108	138	40	5	2.5
	All	37	462	510	148	5	2.4

❖ **Confidence indices: Planning (continued)**

Confidence index calculated as follows:

- the product for each cell is calculated by multiplying the row number with the value assigned to its column, for example
  BEd 1: Developing 'thinking skills' -- 8 x 1, 46 x 2, 55 x 3, 10 x 4, 0 x 5;
- the sum of the products for each row is calculated;
- the confidence index is calculated as a'mean' using the population sample for each of the year cohorts.

❖ Professional skills: Classroom organisation

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

Statements:	Year	1	2	3	4	5
Organising pupils into science ability (attainment) groups	B.Ed1	11 (9)	46 (39)	40 (34)	22 (18)	0 (0)
	B.Ed2	0 (0)	34 (37)	37 (41)	20 (22)	0 (0)
	B.Ed3	5 (8)	28 (41)	22 (32)	13 (19)	0 (0)
	B.Ed4	13 (16)	32 (39)	25 (30)	9 (11)	3 (4)
	PGCE	3 (2)	32 (28)	54 (47)	25 (22)	1 (1)
	All	32 (7)	172 (36)	178 (37)	89 (19)	4 (1)
Organising resources for science topics	B.Ed1	16 (13)	48 (40)	49 (40)	8 (7)	0 (0)
	B.Ed2	9 (10)	47 (52)	32 (35)	3 (3)	0 (0)
	B.Ed3	7 (10	48 (71)	12 (18)	1(1)	0 (0)
	B.Ed4	20 (24)	47 (57)	14 (17)	2 (2)	0 (0)
	PGCE	12 (10)	49 (43)	48 (42)	6 (5)	0 (0)
	All	64 (14)	239 (50)	155 (32)	20 (4)	0 (0)
Managing practical science learning activities in different ways (e.g. groups, rotating between work stations etc)	B.Ed1	7 (6)	55 (46)	50 (41)	9 (7)	0 (0)
	B.Ed2	6 (7)	47 (52)	35 (38)	3 (3)	0 (0)
	B.Ed3	6 (9)	48 (71)	14 (20)	0 (0)	0 (0)
	B.Ed4	18 (22)	50 (60)	13 (16)	2 (2)	0 (0)
	PGCE	6 (5)	51 (44)	43 (38)	15 (13)	0 (0)
	All	43 (9)	251 (53)	155 (32)	29 (6)	0 (0)
Differentiating science lessons to meet the needs of pupils	B.Ed1	8 (7)	35 (29)	62 (51)	16 (13)	0 (0)
	B.Ed2	7 (8)	31 (34)	39 (43)	14 (15)	0 (0)
	B.Ed3	7 (10)	34 (50)	24 (35)	1 (2)	2 (3)
	B.Ed4	10 (12)	44 (53)	21 (25)	8 (10)	0 (0)
	PGCE	1 (1)	27 (24)	52 (45)	35 (30)	0 (0)
	All	33 (7)	171 (36)	198 (41)	74 (16)	2 (-)

Note: Figures in brackets are percentages.

❖ Confidence indices: Classroom organisation

Statements:	Year	1	2	3	4	5	CI
Organising pupils into science ability (attainment) groups	B.Ed1	11	92	120	88	0	2.6
	B.Ed2	0	68	111	80	0	2.8
	B.Ed3	5	56	66	52	0	2.6
	B.Ed4	13	64	75	36	15	2.4
	PGCE	3	64	162	100	5	2.9
	All	32	344	534	356	20	2.7
Organising resources for science topics	B.Ed1	16	96	147	32	0	2.4
	B.Ed2	9	94	96	12	0	2.3
	B.Ed3	7	96	36	4	0	2.1
	B.Ed4	20	94	42	8	0	2
	PGCE	12	98	144	24	0	2.4
	All	64	478	465	80	0	2.3
Managing practical science learning activities in different ways (e.g. groups, rotating between work stations etc)	B.Ed1	7	110	150	36	0	2.5
	B.Ed2	6	94	105	12	0	2.4
	B.Ed3	6	96	42	0	0	2.1
	B.Ed4	18	100	39	8	0	2
	PGCE	6	102	129	60	0	2.6
	All	43	502	465	116	0	2.4
Differentiating science lessons to meet the needs of pupils	B.Ed1	8	70	186	64	0	2.7
	B.Ed2	7	62	117	56	0	2.7
	B.Ed3	7	68	72	4	10	2.2
	B.Ed4	10	88	63	32	0	2.3
	PGCE	1	54	156	140	0	3
	All	33	342	594	296	10	2.7

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

❖ Professional skills: Interaction with pupils

Statements:	Year	1	2	3	4	5
Using interactive (e.g. engaging in discussion, questioning etc) teaching methods with ability groups in science	B.Ed1	16 (13)	56 (46)	36 (30)	12 (10)	1 (1)
	B.Ed2	5 (6)	53 (58)	23 (25)	10 (11)	0 (0)
	B.Ed3	14 (21)	43 (63)	11 (16)	0 (0)	0 (0)
	B.Ed4	25 (30)	44 (53)	12 (15)	2 (2)	0 (0)
	PGCE	14 (12)	61 (53)	32 (28)	8 (7)	0 (0)
	All	74 (15)	257 (54)	114 (24)	32 (7)	1 (-)
Assisting pupils in carrying out science investigations	B.Ed1	14 (12)	67 (55)	36 (30)	4 (3)	0 (0)
	B.Ed2	8 (9)	56 (62)	25 (27)	2 (2)	0 (0)
	B.Ed3	18 (27)	46 (67)	4 (6)	0 (0)	0 (0)
	B.Ed4	23 (28)	51 (61)	9 (11)	0 (0)	0 (0)
	PGCE	8 (7)	61 (53)	40 (35)	6 (5)	0 (0)
	All	71 (15)	281 (59)	114 (24)	12 (2)	0 (0)
Encouraging and responding to pupils' questions in science topics	B.Ed1	5 (4)	58 (48)	48 (40)	8 (6)	2 (2)
	B.Ed2	8 (9)	40 (44)	27 (30)	16 (17)	0 (0)
	B.Ed3	6 (9)	29 (43)	16 (23)	17 (25)	0 (0)
	B.Ed4	14 (17)	50 (60)	14 (17)	5 (6)	0 (0)
	PGCE	6 (5)	51 (44)	44 (39)	14 (12)	0 (0)
	All	39 (8)	228 (48)	149 (31)	60 (13)	2 (-)

Note: Figures in brackets are percentages.

❖ Confidence indices: Interaction with pupils

Statements:	Year	1	2	3	4	5	CI
Using interactive (e.g. engaging in discussion, questioning etc) teaching methods with ability groups in science	B.Ed1	16	112	108	48	5	2.4
	B.Ed2	5	106	69	40	0	2.4
	B.Ed3	14	86	33	0	0	2
	B.Ed4	25	88	36	8	0	1.9
	PGCE	14	122	96	32	0	2.3
	All	74	514	342	128	5	2.2
Assisting pupils in carrying out science investigations	B.Ed1	14	134	108	16	0	2.2
	B.Ed2	8	112	75	8	0	2.2
	B.Ed3	18	92	12	0	0	1.8
	B.Ed4	23	*102*	27	*0*	*0*	*1.8*
	PGCE	8	122	120	24	0	2.4
	All	71	562	342	48	0	2.1
Encouraging and responding to pupils' questions in science topics	B.Ed1	5	116	144	32	10	2.5
	B.Ed2	8	80	81	64	0	2.6
	B.Ed3	6	58	48	68	0	2.6
	B.Ed4	14	100	42	20	0	2.1
	PGCE	6	102	132	56	0	2.6
	All	39	456	447	240	10	2.5

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

❖ Professional skills: Assessment

Statements:	Year	1	2	3	4	5
Defining attainment targets in science	B.Ed1	5 (4)	64 (53)	38 (31)	13 (11)	1 (1)
	B.Ed2	3 (3)	57 (63)	26 (29)	5 (5)	0 (0)
	B.Ed3	14 (21)	40 (59)	11 (16)	3 (4)	0 (0)
	B.Ed4	12 (15)	50 (60)	17 (20)	4 (5)	0 (0)
	PGCE	5 (4)	35 (30)	56 (49)	19 (17)	0 (0)
	All	39 (8)	246 (52)	148 (31)	44 (9)	1 (-)
Assessing the discrete investigative skills (e.g. planning an activity)	B.Ed1	9 (8)	53 (44)	51 (42)	7 (6)	0 (0)
	B.Ed2	2 (2)	43 (47)	36 (40)	10 (11)	0 (0)
	B.Ed3	6 (9)	36 (53)	24 (35)	2 (3)	0 (0)
	B.Ed4	12 (15)	48 (58)	17 (20)	6 (7)	0 (0)
	PGCE	7 (6)	53 (46)	42 (37)	13 (11)	0 (0)
	All	36 (7)	233 (49)	170 (36)	38 (8)	0 (0)

Note: Figures in brackets are percentages.

❖ Confidence indices: Assessment

Statements:	Year	1	2	3	4	5	CI
Defining attainment targets in science	B.Ed1	5	128	114	52	5	2.5
	B.Ed2	3	114	78	20	0	2.4
	B.Ed3	14	80	33	12	0	2
	B.Ed4	12	100	51	16	0	2.2
	PGCE	5	70	168	76	0	2.8
	All	39	492	444	220	5	2.5
Assessing the discrete investigative skills (e.g. planning an activity)	B.Ed1	9	106	153	28	0	2.4
	B.Ed2	2	86	108	40	0	2.6
	B.Ed3	6	72	72	8	0	2.3
	B.Ed4	12	96	51	24	0	2.2
	PGCE	7	106	126	52	0	2.5
	All	36	466	510	152	0	2.4

Key:
1 — Very confident
2 — Confident
3 — Confident with support
4 — Not very confident
5 — Not confident even with support.

❖ Professional skills: Reporting

Statements:	Year	1	2	3	4	5
Reporting on pupils' attainment in knowledge and understanding	B.Ed1	6 (5)	62 (52)	47 (39)	5 (4)	0 (0)
	B.Ed2	4 (5)	54 (59)	24 (26)	9 (10)	0 (0)
	B.Ed3	4 (6)	52 (76)	12 (18)	0 (0)	0 (0)
	B.Ed4	20 (24)	53 (64)	9 (11)	1 (1)	0 (0)
	PGCE	6 (5)	55 (48)	42 (36)	11 (10)	1 (1)
	All	40 (8)	276 (58)	134 (28)	26 (6)	1 (-)
Reporting on pupils' attainment in practical investigative skills	B.Ed1	10 (8)	52 (43)	47 (39)	10 (8)	1 (1)
	B.Ed2	2 (2)	47 (52)	38 (42)	4 (4)	0 (0)
	B.Ed3	5 (7)	50 (74)	13 (19)	0 (0)	0 (0)
	B.Ed4	16 (20)	50 (60)	16 (19)	1 (1)	0 (0)
	PGCE	5 (4)	58 (51)	39 (34)	12 (11)	0 (0)
	All	38 (8)	257 (54)	153 (32)	27 (6)	1 (-)

Note: Figures in brackets are percentages.

❖ Confidence indices: Reporting

Statements:	Year	1	2	3	4	5	CI
Reporting on pupils' attainment in knowledge and understanding	B.Ed1	6	124	141	20	0	2.4
	B.Ed2	4	108	72	36	0	2.4
	B.Ed3	4	104	36	0	0	2.1
	B.Ed4	20	106	27	4	0	1.9
	PGCE	6	110	126	44	5	2.5
	All	40	552	402	104	5	2.3
Reporting on pupils' attainment in practical investigative skills	B.Ed1	10	104	141	40	5	2.5
	B.Ed2	2	94	114	16	0	2.5
	B.Ed3	5	100	39	0	0	2.1
	B.Ed4	16	100	48	4	0	2
	PGCE	5	116	117	48	0	2.5
	All	38	514	459	108	5	2.3

❖ Associations within teaching and learning domains: Methodology (1)

MS 1	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10	MS 11
BEd 1		.21**		.19*							
BEd 2											
BEd 3				.22*	.38**			.305	-.38**	-.59**	
BEd 4			-.25*				-.32**	.27**	-.23*	-.24*	-.31**
PGCE						.29**		.21*	-.21*		
ALL							-.09*	.15**		-.2**	-.1*

MS 2	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10	MS 11
BEd 1	.21**		.16*	.19*		.22**					
BEd 2			.38**								
BEd 3				.3**		.26*	.26*			-.22*	
BEd 4				.27**		.26**	.22*				-.23*
PGCE											
ALL			.13**	.22**		.21**	.14**				

MS 3	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10	MS 11
BEd 1					.2*		.18*				
BEd 2		.38**									.37**
BEd 3					.37**						
BEd 4	-.25*			-.2*			.36**	-.23*	.28**		.24*
PGCE							.24**	-.24**			.39**
ALL		.13**			.16**	.09*	.17**	-.14**	.13**	.098*	.15**

MS 4	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10	MS 11
BEd 1	.19*							.2*	.23**		
BEd 2											
BEd 3	.22*	.3**	.37**						-.29**	-.27*	
BEd 4		.27**	-.2*								
PGCE							.24**				
ALL		.22**					.12**			-.1*	

MS 5	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10	MS 11
BEd 1			.20*			-.26**					
BEd 2						-.19*					
BEd 3	.38**									-.29**	-.43**
BEd 4						-.38**	.22*		.31**		
PGCE							.18*		.25**		
ALL			.16**			-.21**	.14**		.13**		

MS 6	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10	MS 11
BEd 1		.22**			-.26**						
BEd 2					-.19*						.22*
BEd 3		.26*							.28*		
BEd 4		.26**			-.38**			.28**	-.21*		
PGCE	.29**										
ALL		.21**	.09*		-.21**			.12**			

❖ **Associations within teaching and learning domains: Methodology (2)**

MS 7	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10	MS 11
BEd 1			.18*						.24**		
BEd 2								-.29**			.2*
BEd 3		.26*					-.25*	-.25*	.27*		
BEd 4	-.32**	.22*	.36**		.22*				.35**	.2*	
PGCE			.24**	.24**	.18*			-.24**	.25**		
ALL	-.09*	.14**	.17**	.12**	.135**			-.22*	.27**		.1*

MS 8	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10	MS 11
BEd 1				.2*							
BEd 2							-.29**				
BEd 3	.31**						.27**		-.32**		
BEd 4	.27**		-.23*			.28**					-.35**
PGCE	.21*		-.24**				-.24**				-.26**
ALL	.15**		-.14**			.12**	-.22**				-.17**

MS 9	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10	MS 11
BEd 1				.23**			.24**				
BEd 2											
BEd 3	-.38**			-.29**		.28*		-.32**		.33**	
BEd 4	-.23*		.28**		.31**	-.21*	.35**			.34**	
PGCE	-.21*				.25**		.25**			.24**	
ALL			.13**		.13**		.27**			.19**	

MS 10	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10	MS 11
BEd 1											
BEd 2											
BEd 3	-.59**	-.22*		-.27*	-.29**				.33**		
BEd 4	-.24*						.2*		.34**		
PGCE									.24**		
ALL	-.2**		.1*	-.1*					.19**		

MS 11	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10	MS 11
BEd 1											
BEd 2			.37**			.22*	.20*				
BEd 3					-.43**						
BEd 4	-.31**	-.23*	.24*					-.35**			
PGCE			.39**					-.26**			
ALL	-.1*		.15**				.1*	-.17**			

❖ Associations within teaching and learning domains: Resources (1)

RS 1	RS 1	RS 2	RS 3	RS 4	RS 5	RS 6	RS 7	RS 8	RS 9
BEd 1				.19*		.19*			
BEd 2						.23*	.25**		-.21*
BEd 3				.3**					-.23*
BEd 4		-.24*	-.21*		-.4**	.28**	.29**		
PGCE			.17*				.19*		
ALL				.12**	-.15**	.27**	.17**		

RS 2	RS 1	RS 2	RS 3	RS 4	RS 5	RS 6	RS 7	RS 8	RS 9
BEd 1			.19*			.2*			
BEd 2			.23*					.27**	-.3**
BEd 3			.38**				-.21*		
BEd 4	-.24*		.25*						
PGCE			.21*					.2*	
ALL			.24**	-.09*	.12*				

RS 3	RS 1	RS 2	RS 3	RS 4	RS 5	RS 6	RS 7	RS 8	RS 9
BEd 1		.19*			.24**	.28**	.19*		.2*
BEd 2		.23*		-.23*	.23*	.21*	.32**	.24*	-.23*
BEd 3		.38**							
BEd 4	-.21*	.25*			.38**				
PGCE	.17*	.21*		-.22**	.22*		.21*	.22**	
ALL		.24**		-.16**	.23**	.1*	.15**	.14**	

RS 4	RS 1	RS 2	RS 3	RS 4	RS 5	RS 6	RS 7	RS 8	RS 9
BEd 1	.19*						-.20*		
BEd 2			-.23*			-.20*		-.2*	
BEd 3	.30**								-.47**
BEd 4					-.23*				
PGCE			-.22**					-.22**	
ALL	.12**	-.09*	-.16**		-.16**			-.1*	-.09*

RS 5	RS 1	RS 2	RS 3	RS 4	RS 5	RS 6	RS 7	RS 8	RS 9
BEd 1			.24**						
BEd 2			.23*						
BEd 3						.38**	.37**		.24*
BEd 4	-.4**		.38**	-.23*					
PGCE			.22*						
ALL	-.15**	.12*	.23**	-.16**					

RS 6	RS 1	RS 2	RS 3	RS 4	RS 5	RS 6	RS 7	RS 8	RS 9
BEd 1	.19*	.2*	.28**				.18*		.24**
BEd 2	.23*		.21*	-.20*			.19*		-.36**
BEd 3					.38**		.58**		
BEd 4	.28**						.32**	.2*	
PGCE							.23**		
ALL	.27**		.1*				.27**		.16**

❖ **Associations within teaching and learning domains: Resources (2)**

RS 7	RS 1	RS 2	RS 3	RS 4	RS 5	RS 6	RS 7	RS 8	RS 9
BEd 1			.19*	-.20*		.18*			
BEd 2	.25**		.32**			.19*			
BEd 3					.37**	.58**			
BEd 4	.29**	-.21*				.32**			.22*
PGCE	.19*		.21*			.23**			
ALL	.17**		.15**			.27**			.11*
RS 8	**RS 1**	**RS 2**	**RS 3**	**RS 4**	**RS 5**	**RS 6**	**RS 7**	**RS 8**	**RS 9**
BEd 1									
BEd 2		.27*	.24*	-.2*					-.19*
BEd 3									
BEd 4						.2*			
PGCE		.2*	.22**	-.22**					
ALL			.14**	-.1*					
RS 9	**RS 1**	**RS 2**	**RS 3**	**RS 4**	**RS 5**	**RS 6**	**RS 7**	**RS 8**	**RS 9**
BEd 1			.2*			.24**			
BEd 2	-.21*	-.3**	-.23*			-.36**		-.19*	
BEd 3	-.23*			-.47**	.24*				
BEd 4							.22*		
PGCE									
ALL				-.09*		.16**	.11*		

❖ **Associations within teaching and learning domains: Investigative Approaches (1)**

IS 1	IS 1	IS 2	IS 3	IS 4	IS 5	IS 6	IS 7	IS 8	IS 9
BEd 1								-.26**	
BEd 2									
BEd 3		-.39**		.24*		-.30**	-.29**		.26*
BEd 4					-.19*				.34**
PGCE									
ALL									.17**

IS 2	IS 1	IS 2	IS 3	IS 4	IS 5	IS 6	IS 7	IS 8	IS 9
BEd 1			.32**	.25**	.32**	.22*	.18*		
BEd 2			.36**	.32**	.24*	.4**	.34**	-.21*	
BEd 3	-.39**				.25*	.35**	.4**		
BEd 4				.52**	.49**	.31**		-.34**	
PGCE			.29**	.33**	.17*	.22*		-.17*	
ALL			.34**	.32**	.27**	.27**	.24**	-.16**	

IS 3	IS 1	IS 2	IS 3	IS 4	IS 5	IS 6	IS 7	IS 8	IS 9
BEd 1		.32**		.54**	.41**	.33**			
BEd 2		.36**		.6**	.22*	.32**			
BEd 3				.42**	.5**	.36**			
BEd 4		.52**		.61**	.38**			-.57**	
PGCE		.29**		.76**	.25**	.25**			
ALL		.34**		.58**	.39**	.27**		-.16**	

IS 4	IS 1	IS 2	IS 3	IS 4	IS 5	IS 6	IS 7	IS 8	IS 9
BEd 1		.25**	.54**		.48**	.26**			
BEd 2		.32**	.6**						
BEd 3	.24*		.42**		.36**				.36**
BEd 4		.49**	.61**		.41**			-.4**	
PGCE		.33**	.76**		.32**	.22*			.18*
ALL		.32**	.58**		.38**	.17**		-.14**	

IS 5	IS 1	IS 2	IS 3	IS 4	IS 5	IS 6	IS 7	IS 8	IS 9
BEd 1		.32**	.41**	.48**		.27**			
BEd 2		.24*	.22*						
BEd 3		.25*	.5**	.36**		.25*	.24**		
BEd 4	-.19*	.31**	.38**	.41**				-.28**	-.33**
PGCE		.17*	.25**	.32**					
ALL		.27**	.39**	.38**		.16**	.12**	-.12**	

IS 6	IS 1	IS 2	IS 3	IS 4	IS 5	IS 6	IS 7	IS 8	IS 9
BEd 1		.22*	.33**	.26**	.27**				
BEd 2		.4**	.32**				.26**	-.23*	
BEd 3	-.30**	.35**			.25*		.33**		
BEd 4		.31**					.25*		
PGCE		.22*	.25**	.22*					
ALL		.27**	.27**	.17**	.16**		.19**	-.09*	

❖ **Associations within teaching and learning domains: Investigative Approaches (2)**

IS 7	IS 1	IS 2	IS 3	IS 4	IS 5	IS 6	IS 7	IS 8	IS 9
BEd 1		.18*							
BEd 2		.34**				.26**			
BEd 3	-.29**	.4**			.24*	.33**			-.26*
BEd 4						.25*			
PGCE									
ALL		.24**			.12**	.19**			

IS 8	IS 1	IS 2	IS 3	IS 4	IS 5	IS 6	IS 7	IS 8	IS 9
BEd 1	-.26**								
BEd 2		-.21*				-.23*			
BEd 3									
BEd 4		-.34**	-.57**	-.4**	-.28**				
PGCE		-.17*							
ALL		-.16**	-.16**	-.14**	-.12**	-.09*			.1*

IS 9	IS 1	IS 2	IS 3	IS 4	IS 5	IS 6	IS 7	IS 8	IS 9
BEd 1									
BEd 2									
BEd 3	.26*			.36**			-.26*		
BEd 4	.34**				-.33**				
PGCE				.18*					
ALL	.17**							.1*	

❖ **Associations within teaching and learning domains: Organisation**

OS 1	OS 1	OS 2	OS 3	OS 4	OS 5	OS 6	OS 7	OS 8
BEd 1		.23**						
BEd 2					.23*			
BEd 3					.27*			
BEd 4					.25*	-.32**	.40**	
PGCE					.36**			
ALL		.13**			.2**			

OS 2	OS 1	OS 2	OS 3	OS 4	OS 5	OS 6	OS 7	OS 8
BEd 1	.23**				.19*			
BEd 2								
BEd 3								
BEd 4			.29**					
PGCE								.17*
ALL	.13**		.09*		.09*			

OS 3	OS 1	OS 2	OS 3	OS 4	OS 5	OS 6	OS 7	OS 8
BEd 1					.19*		-.26**	
BEd 2								
BEd 3								
BEd 4		.29**		-.26**				
PGCE						.26**		
ALL		.09*			.11*			

OS 4	OS 1	OS 2	OS 3	OS 4	OS 5	OS 6	OS 7	OS 8
BEd 1								
BEd 2					.24**			
BEd 3						.26*	.25*	
BEd 4			-.26**				.28**	
PGCE								
ALL					.11*	.14**	.13**	

OS 5	OS 1	OS 2	OS 3	OS 4	OS 5	OS 6	OS 7	OS 8
BEd 1		.19*	.19*			-.17*		-.16*
BEd 2	.23*			.24**				.27**
BEd 3	.27*						.35**	.22*
BEd 4	.25*						.37**	
PGCE	.36**							
ALL	.2**	.09*	.11*	.1*		-.13**	.14**	

OS 6	OS 1	OS 2	OS 3	OS 4	OS 5	OS 6	OS 7	OS 8
BEd 1					-.17*			
BEd 2								
BEd 3				.26*				
BEd 4	-.32**							.25*
PGCE			.26**					
ALL				.14**	-.13**			.13**

OS 7	OS 1	OS 2	OS 3	OS 4	OS 5	OS 6	OS 7	OS 8
BEd 1			-.26**					-.24**
BEd 2								-.34**
BEd 3				.25*	.35**			
BEd 4	.40**			.28**	.37**			
PGCE								
ALL				.13**	.14**			-.12**

OS 8	OS 1	OS 2	OS 3	OS 4	OS 5	OS 6	OS 7	OS 8
BEd 1					-.16*		-.24**	
BEd 2					.27**		-.34**	
BEd 3					.22*			
BEd 4						.25*		
PGCE		.17*						
ALL						.13**	-.12**	

❖ **Associations within Professional Skills (1)**

(blank) p ≤ 0.01 | (pink) p ≤ 0.05 | NS Not significant

PS 1	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6	PS 7	PS 8	PS 9	PS 10	PS 11	PS 12	PS 13	PS 14	PS 15	PS 16	PS 17	PS 18
BEd 1	1	0.639	0.383	0.367	0.326	0.428	0.275	0.255	0.297	0.442	NS	NS	0.191	0.282	0.272	0.368	0.303	0.285
BEd 2	1	0.706	0.484	0.415	0.368	NS	0.277	0.455	0.325	0.25	0.3	0.312	0.389	0.242	NS	0.288	0.336	0.341
BEd 3	1	0.485	0.292	NS	NS	NS	0.349	0.32	0.24	NS	0.229	NS	0.6	0.237	0.363	NS	0.289	NS
BEd 4	1	0.696	0.481	0.699	0.555	0.341	0.351	0.506	0.301	0.426	0.436	0.265	0.438	0.398	0.406	0.434	0.417	0.617
PGCE	1	0.775	0.45	0.304	0.373	0.402	0.257	0.333	0.26	0.277	0.358	0.446	0.364	0.393	0.264	0.204	0.205	0.507
ALL	1	0.691	0.483	0.46	0.418	0.388	0.304	0.411	0.315	0.375	0.337	0.312	0.411	0.36	0.301	0.377	0.385	0.38
PS 2	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	0.639	1	0.463	0.363	0.386	0.41	0.425	0.364	0.276	0.39	0.172	0.212	0.27	0.408	0.404	0.341	0.387	0.429
BEd 2	0.706	1	0.497	0.394	0.423	0.32	0.259	0.438	NS	NS	0.371	0.344	0.384	0.289	0.314	0.402	0.393	0.341
BEd 3	0.485	1	0.367	0.248	0.477	0.283	NS	0.411	0.23	NS	0.24	NS	0.458	0.572	0.344	NS	0.283	NS
BEd 4	0.696	1	0.507	0.507	0.544	0.543	0.33	0.564	0.303	0.441	0.329	0.509	0.489	0.41	0.585	0.508	0.425	0.568
PGCE	0.775	1	0.468	0.341	0.373	0.472	0.329	0.363	0.313	0.347	0.365	0.339	0.41	0.463	0.309	0.275	0.217	0.524
ALL	0.691	1	0.528	0.43	0.483	0.459	0.305	0.474	0.288	0.334	0.334	0.361	0.429	0.453	0.429	0.445	0.401	0.39
PS 3	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	0.383	0.463	1	0.425	0.47	0.405	0.4	0.36	0.351	0.45	NS	0.196	0.29	0.368	0.366	0.245	0.335	0.336
BEd 2	0.484	0.497	1	0.482	0.279	0.266	NS	0.338	0.334	0.318	0.295	0.263	0.23	0.287	0.218	0.256	0.336	0.259
BEd 3	0.292	0.367	1	0.406	0.38	NS	0.228	NS	NS	NS	NS	NS	NS	NS	0.224	NS	NS	NS
BEd 4	0.481	0.507	1	0.573	0.447	0.454	0.405	0.378	0.445	0.389	0.375	0.52	0.294	0.468	0.358	0.45	0.415	0.355
PGCE	0.45	0.468	1	0.583	0.544	0.297	0.305	0.423	0.459	0.453	0.485	0.377	0.42	0.416	0.419	0.381	0.362	0.478
ALL	0.483	0.528	1	0.544	0.485	0.373	0.332	0.372	0.376	0.382	0.292	0.317	0.326	0.395	0.338	0.366	0.368	0.267

❖ **Associations within Professional Skills (2)**

PS 4	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6	PS 7	PS 8	PS 9	PS 10	PS 11	PS 12	PS 13	PS 14	PS 15	PS 16	PS 17	PS 18
BEd 1	0.367	0.363	0.425	1	0.711	0.35	0.426	0.329	0.385	0.412	0.38	0.323	0.2	0.312	0.311	0.289	0.229	NS
BEd 2	0.415	0.394	0.482	1	0.608	0.436	0.266	0.549	0.401	0.343	0.485	0.349	0.41	0.586	0.391	0.465	0.376	0.406
BEd 3	NS	0.248	0.406	1	0.732	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.313	NS	NS	-0.222
BEd 4	0.699	0.507	0.573	1	0.712	0.356	NS	0.525	0.2	0.531	0.308	0.271	0.534	0.558	0.434	0.49	0.313	0.531
PGCE	0.304	0.341	0.583	1	0.779	0.446	0.339	0.6	0.52	0.508	0.426	0.336	0.35	0.437	0.458	0.399	0.353	0.407
ALL	0.46	0.43	0.544	1	0.728	0.385	0.306	0.438	0.361	0.421	0.403	0.301	0.371	0.458	0.378	0.384	0.317	0.276
PS 5	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	0.326	0.386	0.47	0.711	1	0.451	0.506	0.395	0.438	0.45	0.379	0.347	0.324	0.479	0.353	0.322	0.296	0.282
BEd 2	0.368	0.423	0.279	0.608	1	0.268	NS	0.406	0.47	0.365	0.501	0.574	0.441	0.343	0.489	0.454	0.289	0.344
BEd 3	NS	0.477	0.38	0.732	1	NS	NS	NS	NS	NS	0.233	NS	NS	0.275	0.322	NS	NS	NS
BEd 4	0.555	0.544	0.447	0.712	1	0.406	0.196	0.487	0.249	0.603	0.231	0.31	0.554	0.63	0.62	0.533	0.292	0.607
PGCE	0.373	0.373	0.544	0.779	1	0.461	0.402	0.533	0.47	0.532	0.493	0.365	0.417	0.459	0.47	0.4	0.395	0.424
ALL	0.418	0.483	0.485	0.728	1	0.408	0.313	0.456	0.39	0.449	0.393	0.367	0.416	0.491	0.447	0.414	0.317	0.311
PS 6	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	0.428	0.41	0.405	0.35	0.451	1	0.513	0.443	0.382	0.493	0.178	0.335	0.43	0.454	0.257	0.374	0.32	0.467
BEd 2	NS	0.32	0.266	0.436	0.268	1	0.302	0.298	0.254	0.272	0.31	NS	NS	0.409	0.387	0.288	0.457	0.405
BEd 3	NS	0.283	NS	NS	NS	1	0.251	0.363	NS	NS	0.37	0.392	0.28	0.373	NS	0.363	NS	NS
BEd 4	0.341	0.543	0.454	0.356	0.406	1	0.321	0.434	NS	0.372	0.276	0.401	0.604	0.417	0.377	0.557	0.348	0.385
PGCE	0.402	0.472	0.297	0.446	0.461	1	0.347	0.519	0.483	0.435	0.339	0.358	0.369	0.553	0.428	0.397	0.287	0.463
ALL	0.388	0.459	0.373	0.385	0.408	1	0.376	0.437	0.323	0.414	0.333	0.348	0.406	0.468	0.307	0.429	0.343	0.368

❖ **Associations within Professional Skills (3)**

PS 7	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	0.275	0.425	0.4	0.426	0.506	0.513	1	0.505	0.466	0.453	0.38	0.387	0.345	0.354	0.34	0.428	0.403	0.417
BEd 2	0.277	0.259	NS	0.266	NS	0.302	1	0.432	0.204	NS	0.35	NS	0.369	0.231	0.366	0.233	0.311	0.189
BEd 3	0.349	NS	0.228	NS	NS	0.251	1	NS	0.233	NS	NS	NS	NS	NS	NS	NS	NS	NS
BEd 4	0.351	0.33	0.405	NS	0.196	0.321	1	0.313	0.528	NS	0.324	0.26	NS	0.225	0.215	0.228	0.422	NS
PGCE	0.257	0.329	0.305	0.339	0.402	0.347	1	0.414	0.346	0.404	0.258	0.296	0.26	0.235	0.227	0.309	0.259	0.216
ALL	0.304	0.305	0.332	0.306	0.313	0.376	1	0.393	0.407	0.287	0.287	0.272	0.276	0.277	0.252	0.279	0.365	0.234
PS 8	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	0.255	0.364	0.36	0.329	0.395	0.443	0.505	1	0.517	0.423	0.401	0.483	0.486	0.384	0.36	0.38	0.445	0.461
BEd 2	0.455	0.438	0.338	0.549	0.406	0.298	0.432	1	0.331	NS	0.45	0.296	0.392	0.481	0.47	0.461	0.43	0.395
BEd 3	0.32	0.411	NS	NS	NS	0.363	NS	1	0.411	0.431	0.265	0.275	0.388	0.397	NS	0.4	NS	0.225
BEd 4	0.506	0.564	0.378	0.525	0.487	0.434	0.313	1	0.262	0.479	0.33	0.238	0.483	0.502	0.441	0.389	0.297	0.395
PGCE	0.333	0.363	0.423	0.6	0.533	0.519	0.414	1	0.591	0.558	0.4	0.339	0.489	0.587	0.518	0.418	0.384	0.537
ALL	0.411	0.474	0.372	0.438	0.456	0.437	0.393	1	0.436	0.433	0.404	0.368	0.508	0.497	0.394	0.442	0.404	0.396
PS 9	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	0.297	0.276	0.351	0.385	0.438	0.382	0.466	0.517	1	0.581	0.363	0.381	0.404	0.399	0.384	0.339	0.452	0.298
BEd 2	0.325	NS	0.334	0.401	0.47	0.254	0.204	0.331	1	0.586	0.427	0.384	0.334	0.212	0.364	0.335	0.325	0.254
BEd 3	0.24	0.23	NS	NS	NS	NS	0.233	0.411	1	0.591	NS	NS	NS	0.323	NS	NS	0.326	NS
BEd 4	0.301	0.303	0.445	0.2	0.249	NS	0.528	0.262	1	0.325	0.454	0.317	NS	0.223	0.304	0.241	0.557	0.332
PGCE	0.26	0.313	0.459	0.52	0.47	0.483	0.346	0.591	1	0.645	0.415	0.339	0.469	0.548	0.492	0.484	0.334	0.507
ALL	0.315	0.288	0.376	0.361	0.39	0.323	0.407	0.436	1	0.572	0.351	0.345	0.341	0.36	0.36	0.319	0.446	0.28

❖ **Associations within Professional Skills (4)**

PS 10	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6	PS 7	PS 8	PS 9	PS 10	PS 11	PS 12	PS 13	PS 14	PS 15	PS 16	PS 17	PS 18
BEd 1	0.442	0.39	0.45	0.412	0.45	0.493	0.453	0.423	0.581	1	0.226	0.25	0.395	0.399	0.364	0.45	0.471	0.386
BEd 2	0.25	NS	0.318	0.343	0.365	0.272	NS	NS	0.586	1	0.321	0.35	0.279	0.235	0.269	0.383	0.408	0.338
BEd 3	NS	NS	NS	NS	NS	NS	NS	0.431	0.591	1	NS	NS	NS	NS	0.236	NS	0.323	NS
BEd 4	0.426	0.441	0.389	0.531	0.603	0.372	NS	0.479	0.325	1	0.306	0.327	0.513	0.695	0.511	0.577	0.32	0.621
PGCE	0.277	0.347	0.453	0.508	0.532	0.435	0.404	0.558	0.645	1	0.325	0.356	0.509	0.566	0.544	0.528	0.356	0.429
ALL	0.375	0.334	0.382	0.421	0.449	0.414	0.287	0.433	0.572	1	0.296	0.295	0.384	0.444	0.383	0.45	0.429	0.375
PS 11	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	NS	0.172	NS	0.38	0.379	0.178	0.38	0.401	0.363	0.226	1	0.567	0.386	0.278	0.242	0.409	0.326	0.219
BEd 2	0.3	0.371	0.295	0.485	0.501	0.31	0.35	0.45	0.427	0.321	1	0.416	0.549	0.474	0.585	0.344	0.295	0.38
BEd 3	0.229	0.24	NS	NS	0.233	0.37	NS	0.265	NS	NS	1	0.499	0.258	0.295	NS	0.267	NS	NS
BEd 4	0.436	0.329	0.375	0.308	0.231	0.276	0.324	0.33	0.454	0.306	1	0.475	0.242	NS	NS	0.292	0.407	0.408
PGCE	0.358	0.365	0.485	0.426	0.493	0.339	0.258	0.4	0.415	0.325	1	0.281	0.369	0.351	0.384	0.398	0.32	0.441
ALL	0.337	0.334	0.292	0.403	0.393	0.33	0.287	0.404	0.351	0.296	1	0.514	0.404	0.361	0.29	0.39	0.339	0.287
PS 12	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	NS	0.212	0.196	0.323	0.347	0.335	0.387	0.483	0.381	0.25	0.567	1	0.525	0.315	0.366	0.369	0.384	0.271
BEd 2	0.312	0.344	0.263	0.349	0.574	NS	NS	0.296	0.384	0.35	0.416	1	0.338	0.254	0.417	0.393	0.357	0.287
BEd 3	NS	NS	NS	NS	NS	0.392	NS	0.275	NS	NS	0.499	1	0.375	0.294	NS	NS	NS	NS
BEd 4	0.265	0.509	0.52	0.271	0.31	0.401	0.26	0.238	0.317	0.327	0.475	1	0.268	0.239	0.249	0.392	0.473	0.327
PGCE	0.446	0.339	0.377	0.336	0.365	0.358	0.296	0.339	0.339	0.356	0.281	1	0.525	0.411	0.375	0.388	0.486	0.516
ALL	0.312	0.361	0.317	0.301	0.367	0.348	0.272	0.368	0.345	0.295	0.514	1	0.425	0.331	0.31	0.379	0.411	0.299

❖ **Associations within Professional Skills (5)**

PS 13	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6	PS 7	PS 8	PS 9	PS 10	PS 11	PS 12	PS 13	PS 14	PS 15	PS 16	PS 17	PS 18
BEd 1	0.191	0.27	0.29	0.2	0.324	0.43	0.345	0.486	0.404	0.395	0.386	0.525	1	0.443	0.482	0.306	0.416	0.319
BEd 2	0.389	0.384	0.239	0.41	0.441	NS	0.369	0.392	0.334	0.279	0.549	0.338	1	0.234	0.529	0.336	0.316	0.263
BEd 3	0.6	0.458	NS	NS	NS	0.28	NS	0.388	NS	NS	0.258	0.375	1	0.395	0.398	NS	0.235	0.278
BEd 4	0.438	0.489	0.294	0.534	0.554	0.604	NS	0.483	NS	0.513	0.242	0.268	1	0.497	0.525	0.598	0.323	0.56
PGCE	0.364	0.41	0.42	0.35	0.417	0.369	0.26	0.489	0.469	0.509	0.369	0.525	1	0.607	0.492	0.445	0.373	0.582
ALL	0.411	0.429	0.326	0.371	0.416	0.406	0.276	0.508	0.341	0.384	0.404	0.425	1	0.461	0.511	0.404	0.376	0.371
PS 14	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	0.282	0.408	0.368	0.312	0.479	0.454	0.354	0.384	0.399	0.399	0.278	0.315	0.443	1	0.495	0.299	0.35	0.427
BEd 2	0.242	0.289	0.287	0.586	0.343	0.409	0.231	0.481	0.212	0.235	0.474	0.254	0.234	1	0.334	0.334	0.236	0.432
BEd 3	0.237	0.572	NS	NS	0.275	0.373	NS	0.397	0.323	NS	0.295	0.294	0.395	1	NS	0.427	NS	NS
BEd 4	0.398	0.41	0.468	0.558	0.63	0.417	0.225	0.502	0.223	0.695	NS	0.239	0.497	1	0.487	0.426	0.225	0.419
PGCE	0.393	0.463	0.416	0.437	0.459	0.553	0.235	0.587	0.548	0.566	0.351	0.411	0.607	1	0.706	0.56	0.356	0.661
ALL	0.36	0.453	0.395	0.458	0.491	0.468	0.277	0.497	0.36	0.444	0.361	0.331	0.461	1	0.435	0.422	0.315	0.372
PS 15	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	0.272	0.404	0.366	0.311	0.353	0.257	0.34	0.36	0.384	0.364	0.242	0.366	0.482	0.495	1	0.306	0.379	0.331
BEd 2	NS	0.314	0.218	0.391	0.489	0.387	0.366	0.47	0.364	0.269	0.585	0.417	0.529	0.334	1	0.391	0.353	0.368
BEd 3	0.363	0.344	0.224	0.313	0.322	NS	NS	NS	NS	0.236	NS	NS	0.398	NS	1	NS	0.273	NS
BEd 4	0.406	0.585	0.358	0.434	0.62	0.377	0.215	0.441	0.304	0.511	NS	0.249	0.525	0.487	1	0.539	0.294	0.596
PGCE	0.264	0.309	0.419	0.458	0.47	0.428	0.227	0.518	0.492	0.544	0.384	0.375	0.492	0.706	1	0.621	0.327	0.529
ALL	0.301	0.429	0.338	0.378	0.447	0.307	0.252	0.394	0.36	0.383	0.29	0.31	0.511	0.435	1	0.392	0.351	0.374

❖ **Associations within Professional Skills (6)**

PS 16	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6	PS 7	PS 8	PS 9	PS 10	PS 11	PS 12	PS 13	PS 14	PS 15	PS 16	PS 17	PS 18
BEd 1	0.368	0.341	0.245	0.289	0.322	0.374	0.428	0.38	0.339	0.45	0.409	0.369	0.306	0.299	0.306	1	0.518	0.389
BEd 2	0.288	0.402	0.256	0.465	0.454	0.288	0.233	0.461	0.335	0.383	0.344	0.393	0.336	0.334	0.391	1	0.522	0.401
BEd 3	NS	NS	NS	NS	NS	0.363	NS	0.4	NS	NS	0.267	NS	NS	0.427	NS	1	NS	NS
BEd 4	0.434	0.508	0.45	0.49	0.533	0.557	0.228	0.389	0.241	0.577	0.292	0.392	0.598	0.426	0.539	1	0.319	0.566
PGCE	0.204	0.275	0.381	0.399	0.4	0.397	0.309	0.418	0.484	0.528	0.398	0.388	0.445	0.56	0.621	1	0.358	0.47
ALL	0.377	0.445	0.366	0.384	0.414	0.429	0.279	0.442	0.319	0.45	0.39	0.379	0.404	0.422	0.392	1	0.425	0.4
PS 17	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	0.303	0.387	0.335	0.229	0.296	0.32	0.403	0.445	0.452	0.471	0.326	0.384	0.416	0.35	0.379	0.518	1	0.5
BEd 2	0.336	0.393	0.336	0.376	0.289	0.457	0.311	0.43	0.325	0.408	0.295	0.357	0.316	0.236	0.353	0.522	1	0.576
BEd 3	0.289	0.283	NS	NS	NS	NS	NS	NS	0.326	0.323	NS	NS	0.235	NS	0.273	NS	1	0.469
BEd 4	0.417	0.425	0.415	0.313	0.292	0.348	0.422	0.297	0.557	0.32	0.407	0.473	0.323	0.225	0.294	0.319	1	0.452
PGCE	0.205	0.217	0.362	0.353	0.395	0.287	0.259	0.384	0.334	0.356	0.32	0.486	0.373	0.356	0.327	0.358	1	0.406
ALL	0.385	0.401	0.368	0.317	0.317	0.343	0.365	0.404	0.446	0.429	0.339	0.411	0.376	0.315	0.351	0.425	1	0.482
PS 18	**PS 1**	**PS 2**	**PS 3**	**PS 4**	**PS 5**	**PS 6**	**PS 7**	**PS 8**	**PS 9**	**PS 10**	**PS 11**	**PS 12**	**PS 13**	**PS 14**	**PS 15**	**PS 16**	**PS 17**	**PS 18**
BEd 1	0.285	0.429	0.336	NS	0.282	0.467	0.417	0.461	0.298	0.386	0.219	0.271	0.319	0.427	0.331	0.389	0.5	1
BEd 2	0.341	0.341	0.259	0.406	0.344	0.405	0.189	0.395	0.254	0.338	0.38	0.287	0.263	0.432	0.368	0.401	0.576	1
BEd 3	NS	NS	NS	-0.222	NS	NS	NS	0.225	NS	NS	NS	NS	0.278	NS	NS	NS	0.469	1
BEd 4	0.617	0.568	0.355	0.531	0.607	0.385	NS	0.395	0.332	0.621	0.408	0.327	0.56	0.419	0.596	0.566	0.452	1
PGCE	0.507	0.524	0.478	0.407	0.424	0.463	0.216	0.537	0.507	0.429	0.441	0.516	0.582	0.661	0.529	0.47	0.406	1
ALL	0.38	0.39	0.267	0.276	0.311	0.368	0.234	0.396	0.28	0.375	0.287	0.299	0.371	0.372	0.374	0.4	0.482	1

Front page of observation schedule

Science Activity Record

Primary School: ____________________ Student: ____________________ Date: ____________________

Primary: [ ] Level(s): [ ] Number of pupils: Class [ ]

Science [ ]

Nature of Activity:

[ ]

Equipment / Resources:

[ ]

Copy of materials: Yes / No

Prepared activity: Student [ ]

Teacher [ ]

Published [ ]

Classroom organisation [ ]

Start: [ ] Finish: [ ]

Earth and Space:		Energy and Forces:		Living things and the processes of life:	
Earth in space	[ ]	Properties and uses of energy	[ ]	Variety and characteristic features	[ ]
Materials from Earth	[ ]	Conversion and transfer of energy	[ ]	The processes of life	[ ]
Changing materials	[ ]	Forces and their effects	[ ]	Interaction of living things with their environment	[ ]

Recording sheet (Several recording sheets would be used in a lesson)

20-second intervals	1	2	3	4	5	6	7	8	9	0
Structural Elements										
previous learning										
discussing instructions										
clarification of task										
organisation of task										
task management										
results / progress										
resource management										
pupil feedback (+ve/-ve)										
recap of learning										
non-task management										
Teacher Dialogue										
descriptive / factual										
causal explanation										
intentional explanation										
procedure with reasons										
procedure without reasons										
prediction										
Focus of Interaction										
planning										
raising questions										
hypothesising										
observation										
measurement										
recording										
interpretation										
critical reflection										
no interaction										
Pupil Process Activity										
planning										
raising questions										
hypothesising										
observation										
measurement										
recording										
interpretation										
critical reflection										
Pupil Activity										
writing										
copying										
reading										
oral work										
using resources										
resource management										
listening / watching										
non-active										
Pupil Group										
individual										
group work										
whole class										

Section 1: Structural Elements

Previous learning
This involves recap of previous lesson/learning through statement or through questioning. It may also involve the teacher in finding out what the pupils thoughts are on the learning which is the focus of the lesson – this may be elicited through oral work or written work such as a drawing.

Discussing instructions
This may involve the teacher discussing with the pupils the nature of the task or the pupils discussing amongst themselves.

Clarification of task
This involves the instructions which are provided to support the pupils' understanding of the task. It may be carried out through verbal statements to the class, groups or individuals.

Organisation of task
This involves any activity associated with setting up the task such as collecting materials, distributing materials, preparing equipment/materials. It will also include clearing up after the task has been completed.

Task management
This will involve activities which are aimed at monitoring the work being undertaken by the class. It will include movement accompanied by observation as well as verbal interaction such as issuing instructions or questioning. These may be aimed at keeping the work on track or bringing the task to an end.

Results / progress
This will include assessment events both formal and informal such as marking , recording results.

Resource management
This will involve activities aimed at ensuring that the pupils have the necessary materials and that they are using them appropriately. This may be carried out through observation or verbal interaction.

Pupil feedback (+ve/-ve)
This will include verbal interactions which are positively framed or negatively framed.

Recap of learning
This involves recap of lesson/learning through statement, questioning or an assessment event.

Non-task management
This may include activities such as taking the register and dealing with interruptions.

Section 2: Teacher Dialogue
The classification of the discourse will be determined by what the teacher accepts from the pupil. Thus a question which is framed in terms of a causal relationship may become descriptive if that is the response which the teacher accepts from the pupil. Furthermore within a recording time frame there may be a cluster of questions which are similar. These should be recorded as the same event.

Descriptive / factual (DF)
This may take the form of questioning (QDF) or telling (TDF). The focus is on eliciting a factual response or passing on some factual information (*e.g.* what happens when... ?)

Causal / explanatory (CE)
This may take the form of questioning (QCE) or telling (TCE). The focus is to explain some event or finding. Causal relationships are central to the area of discourse (*e.g.* Why does this occur?).

Procedural (PR)
This may take the form of questioning (QPR) or telling (TPR). The focus will be the task. The interaction will seek to elicit from the pupil that they know what to do.

Predictive (P)
This may take the form of questioning (QP) or telling (TP). This will involve the pupils in gauging what is the likely outcome to some action / event.

The questions asked should be further categorised in terms of whether they are open (O) or closed (C). The focus of the dialogic interaction will be recorded in terms of the process skills.

Section 3: Focus of Interaction

The questions that we are interested in will be framed in terms of the process skills. These will be determined by the context of the lesson.

Planning	What equipment will you need? How are you going to keep a record of your results?
Raising questions	What would happen if...? How can we ...?
Hypothesising	Why do you think... ? What do you think ...?
Observation	What do you see. ...? What do you smell ?
Measurement	What is the rate ...? How long did that take to ...?
Recording	What kind of chart / graph / drawing have you used to ...? Can your results be shown in a different way?
Interpretation	Did you find any connection between ...? What did make a difference to ?
Critical reflection	How can you show that your idea worked? How could you modify your approach?
No interaction	This is when the discourse is about a non-process related matter.

Section 4: Pupil Process Activity

Planning
This will include activities in which the pupils are identifying the steps involved in carrying through an investigation. It may entail a paper exercise, discussion, planning through action *etc*.

Raising questions
This will include activities which require pupils to identify investigable questions. Dialogue will be central to this process as it may be necessary to reformulate 'how' and 'why' questions into specific questions which can be investigated. This may involve discussion, brainstorming sessions, group work *etc* aimed at generating questions to investigate.

Hypothesising
This will include activities which require pupils to explain new observations / data using past experiences / learning. It need not be the scientifically accepted explanation. However, the hypothesis should be framed in such a way that it is testable through investigation.

Observation
This will include activities which require pupils to make use of any of their senses in gathering data / experience. A key component of this will be what the pupils say in relation to their observations.

Measurement
This will include activities which require pupils to quantify some variable. It will usually involve the pupils in using some form of instrumentation. Part of the process will include steps taken to ensure the accuracy of the measurements made.

Recording
This will include activities which require pupils to keep records of the work in progress. They may fill in a table, compile their own notes, *etc*. Mostly this will be in a written form, however, it can also include pupils reporting their findings orally.

Interpretation
This will include activities which require pupils to engage in finding patterns and associations in the data generated from their investigations. Reaching conclusions is an important aspect of this. Interpretations should be consistent with the data generated.

Critical reflection
This will include activities which require pupils to participate in discussions focussed on their findings. The review may look at the notion of the 'fair' test, on how things could be improved, *etc*. This need not necessarily take place at the end of the lesson. It mayor may not include the teacher.

Section 5: Pupil Activity

Writing
This includes any activity which engages the pupils in a self-directed written activity such as making their own notes, recording their results, describing what they have found out, *etc*.

Section 5: Pupil Activity

Writing
This includes any activity which engages the pupils in a self-directed written activity such as making their own notes, recording their results, describing what they have found out, *etc*.

Copying
This includes any written activity which is teacher directed. This may include dictating notes, copying from a textbook, completing a fill sheet, *etc*.

Reading
This includes any activity which is linked to the science lesson.

Oral work
This will include activities when the pupils are engaged on task talk either to the teacher or to other pupils.

Using resources
Involving the use of science equipment or other resources related to the lesson (*e.g.* computer).

Resource management
This will involve the pupils in any activity related to the task such as distributing materials, gathering in materials, *etc*.

Listening / watching
This may involve the pupils focussing on the teacher, other pupils or the activity.

Non-active
This includes any periods when the pupils are non-active such as when they are waiting during the register, for the teacher to start, whilst the teacher is engaged on some other non-task activity, *etc*.

Section 6: Pupil Group

Individual
The pupils are working by themselves.

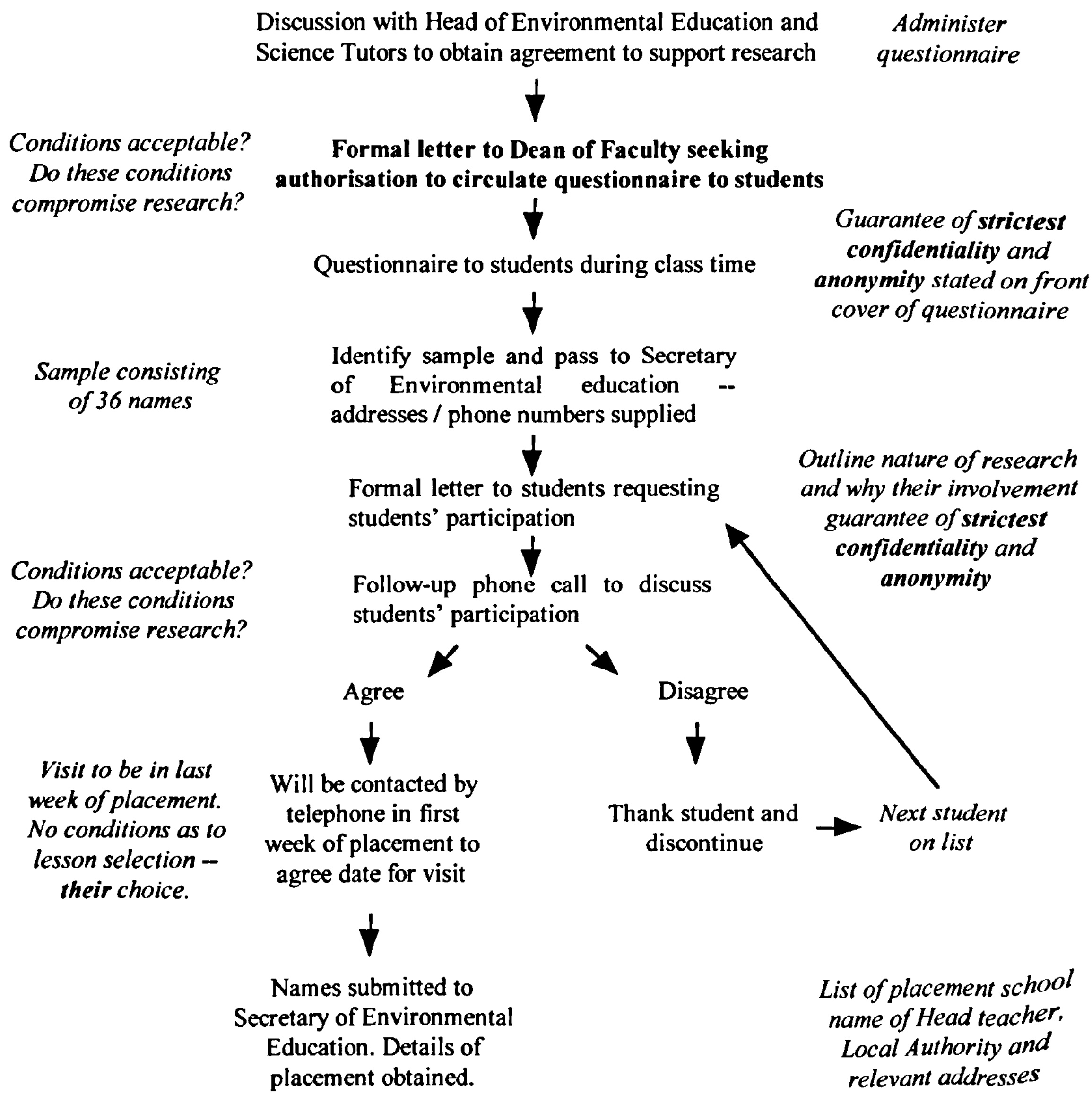
Group work
The pupils are working in groups organised on the basis of ability, or mixed ability or friendship or using no discernible criteria.

Whole class
The pupils are engaged as a class.

Consent Pathway

- **Phase 1: Seeking consents within Faculty of Education**

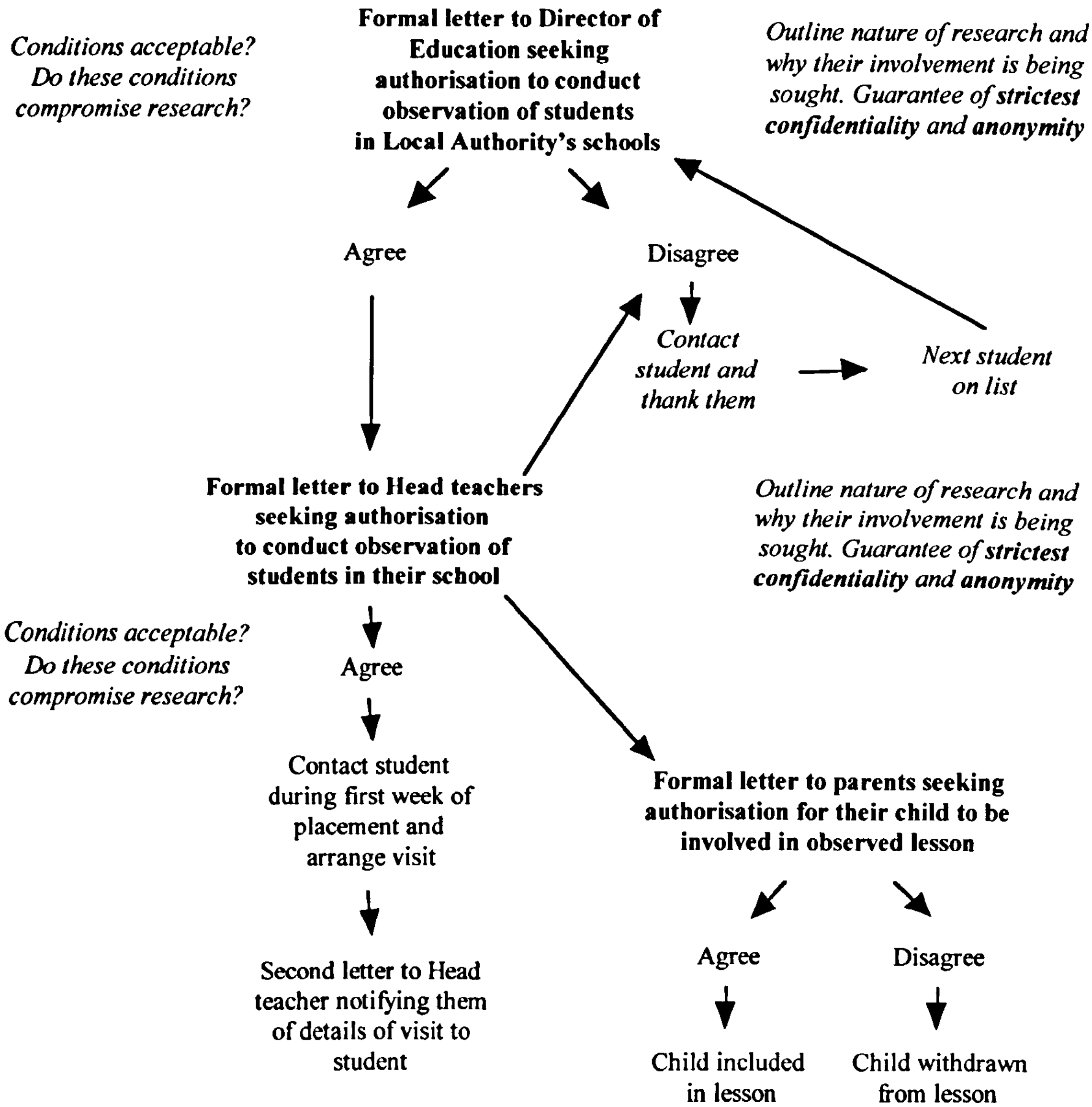
  Each stage of the research involved negotiating consents from various 'gatekeepers', any one of whom could deny their consent for any reason.



It was not assumed that involvement in one stage of the research was an indication of involvement in subsequent stages. Furthermore the students were given a guarantee that their responses would be treated with the strictest confidentiality and anonymity at ***each and every stage of their involvement.***

- **Phase 2: Seeking consents from Local Authorities and schools**

Once the sample had been identified and all of the necessary consents were in place my attention switched to the 'gatekeepers' external to the Faculty of Education.



- **Phase 3: Honouring agreements**

Some of the Local Authorities and a few of the students requested that they be informed of the outcomes of the research. This, I felt did not compromise the research process and as such I agreed to meet this request, once the research has been completed and the thesis agreed. To this effect, on completion of my viva voce, I will prepare a synopsis paper and forward this to those who requested feedback.

Researcher's name
Researcher's address

Student's name
Student's address

Dear ***Student's first name***

During session 2001-2002 the Dean of the Faculty of Education gave me permission to commence a research project looking at the experience of students engaged on primary science courses within the Faculty. As part of the first phase of this project you kindly participated in completing a questionnaire covering a range of issues related to 5-14 Primary Science.

The second phase of this research project, looking at the science teaching that students undertake during their primary school placements, is about to commence. This builds upon a range of interesting findings to come out of the questionnaire study. You are one of twelve students, chosen from BEd years II, III and IV, that are being invited to participate in this phase of the project. You, along with the other students, have been selected as your responses suggest a number of exciting possibilities aimed at improving the experience of student teachers in relation to 5-14 Primary Science.

The aim of the research is to audio record one science lesson that each student would intend delivering in the normal course of their placement. This would not be a lesson suggested by myself. The recordings will then be examined in order to determine the structural elements evident across the science lessons observed. During the visit I would also be grateful for a copy of a lesson plan and any paper materials supplied to the pupils.

Needless to say any information gathered would be treated in the **strictest confidence** and at no point would individual schools or yourself be identified to anyone outside the research team. **I wish to stress that this is not part of the assessment process in the Faculty and your Tutors will not be given access to the recording.**

It would also be my intention to seek approval from the primary schools involved. Seeking such approval would be my responsibility.

I am sensitive to the fact, borne out of my own experience as a student, that this can be a stressful time. We all want to get it right in the hope that the children get something out of our teaching. Clearly you would not want to commit yourself to anything which would involve you in even more work over and above that you agree to undertake for your class teacher and tutors.

Bearing this in mind I would be keen to contact you by telephone in order that I may answer any enquiries that you may have as to the nature of your involvement and/or the purpose of the research.

Yours sincerely

Mike Carroll
BEd, MA, MEd, MCoT

Tel: ***Researcher's home phone number***

14 April 2003

Name of Director of Education
Address of Local Authority's headquarters

Dear

I am Principal Teacher of Geography at Our Lady and St Patrick's High School (Dumbarton) currently engaged in a research project leading to a PhD through the Centre for Science Education at the University of Glasgow under the tutelage of Dr Norman Reid.

My project is looking at the science teaching that students undertake during their primary school placements. Twelve students, chosen from the BEd course at the University of Glasgow have agreed to participate in the second phase of this project. These students have previously participated in a questionnaire study during the first phase of this project. This has provided some useful insights into the nature of BEd students' experience of 5-14 Primary Science.

The aim of the second phase of the research is to audio record one science lesson that each student would intend delivering in the normal course of their placement. This would not be a lesson suggested by myself. The recordings will then be examined in order to determine the structural elements evident across the science lessons observed. The audio recording will be augmented with a paper-based observational schedule.

Needless to say any information gathered would be treated in the **strictest confidence** and at no point would individual schools or students be identified to anyone outside the research team. The recordings themselves would be kept secure in the Centre for Science Education at the University of Glasgow. In addition I have already given my assurance to the students involved that this is not part of the assessment process in the Faculty and that their Tutors will not be given access to any of the detailed information collected.

I would appreciate your agreement, in principle, to permit access to those schools under your jurisdiction in which some of the students have been placed. I would intend approaching the Head teachers of the schools involved to determine if they would be willing to participate. The research would then be conducted at a time to be agreed in negotiation with the students and the respective Head teachers of the schools in which they are placed.

I am sensitive to the fact that primary schools are very busy places. Thus I am aware that even if your permission was forthcoming there is no guarantee that the schools involved would be willing to participate as they may see such a project as a diversion from their first priority, namely the teaching and learning of the children in their care.

I am willing to respond to any enquiries that you may have as to the nature and/or the purpose of the research. I would also be willing, in due course, to provide your representative with a synopsis of the research findings.

Yours sincerely

Michael Carroll
BEd, MA, MEd, MCoT

Tel: ***Researcher's telephone number*** (Work)
Researcher's telephone number (Home)

Student currently placed in a ***Name of Local Authority*** school:
Student's name
School
Headteacher's name

14 April 2003

Headteacher's name
School's address

Dear

I am currently engaged in a research project looking at the science teaching that students undertake during their primary school placements. ***Student's name*** is one of twelve students, chosen from the BEd course at the University of Glasgow who has agreed to participate in the second phase of this project. ***Student's name*** has previously participated in a questionnaire study during the first phase of this project. This has provided some useful insights into the nature of BEd students' experience of 5-14 Primary Science.

The aim of the second phase of the research is, if it is possible, to audio record one science lesson that each student would intend delivering in the normal course of their placement. This would not be a lesson suggested by myself. The recordings will then be examined in order to determine the structural elements evident across the science lessons observed. The audio recording of the lesson will be augmented by a paper-based observational schedule.

Needless to say any information gathered would be treated in the **strictest confidence** and at no point would individual schools or students be identified to anyone outside the research team. The recordings themselves would be kept secure in the Centre for Science Education at the University of Glasgow. In addition, I have already given ***Student's name*** my assurance that this is not part of the assessment process in the Faculty and that her Tutors will not be given access to any information collected.

I would appreciate your agreement, in principle, to permit access to your school in order to conduct the research, at a time in May to be agreed with the student. I am sensitive to the fact that primary schools are very busy places. As such you may see such a project as a diversion from your first priority, namely the teaching and learning of the children in your care.

Bearing this in mind I would be keen to contact you by telephone in order that I may answer any enquiries that you may have as to the nature and/or the purpose of the research.

I am currently in the process of seeking approval from your Local Authority's Education Department. The tight time-frame involved has made it necessary to seek your approval and that of the Local Authority simultaneously. I acknowledge that either approval may not be forthcoming.

Yours sincerely

Michael Carroll
BEd, MA, MEd, MCoT

Tel: ***Researcher's telephone number*** (Work)
Researcher's telephone number (Home)

16 May 2003

Headteacher's name
School's address

Research in Science Teaching

Dear ***Headteacher's name***

Further to my discussion with ***student's first name***. I intend to visit your school on Thursday 29th May at approximately 1.30pm.

I hope that this meets with your approval.

Yours sincerely

Michael Carroll

Glasgow City Council
Education Services

Director
Ronnie O'Connor
BA(Hons) DipEd

Education Services
Glasgow City Council
Nye Bevan House
20 India Street
Glasgow G2 4PF

Phone Direct Line 0141-287-6833
Fax 0141-287 6786
Email john.scougall@education.glasgow.gov.uk

Our Ref JS/Rsrch Your Ref
Date 22 January 2003
If phoning please ask for John Scougall

Mr Michael Carroll
10 MacNeill Drive
Kittoch Glen
East Kilbride
GLASGOW G74 4TR

Dear Mr Carroll

Proposed Research Project – Science teaching that students undertake during their primary school placements.

Thank you for your letter of 7 January regarding the above. My apologies for the delay in replying.

I now write to advise you that this department has no objection to you seeking assistance from our schools for help with your research. There is a concern regarding the use of video recording equipment and it would be preferable therefore if the "back-up plan" referred to in your letter is used. If however you still wish to pursue the use of video equipment I would be happy to discuss this further with a member of the education directorate

I must also emphasise that it is very much up to the Head Teachers to decide whether or not their school participates in such research.

A copy of this letter should be sent to the Head Teacher when contacting the school.

This approval is also on the understanding that there is no pupil involvement regarding this research. A further condition of this approval is that two copies of the final research findings are sent to me, at the above address, when completed.

I hope that this is helpful and that you have success with your research.

Yours sincerely

JOHN SCOUGALL
Assistant Principal Officer
Budget & Central Support

Central Switchboard 0141 287 2000

Amended Recording sheet

(Several recording sheets would be used in a lesson)

20-second intervals	
Structural Elements	
previous learning	
discussing instructions	
clarification of task	
organisation of task	
task management	
results / progress	
resource management	
pupil feedback (+ve/-ve)	
recap of learning	
non-task management	
Pupil Process Activity	
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critical reflection	
non process	
Pupil Activity	
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Pupil Group	
individual	
group work	
whole class	