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Does practical work work? A study of the effectiveness of practical work as a teaching and learning method in school science

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Introduction

One of the features of science education in many countries that sets it apart from most other school subjects is that it involves practical work – activities in which the students manipulate and observe real objects and materials. In countries with a tradition of practical work in school science (such as the UK), practical work is often seen by teachers and others (particularly scientists) as central to the appeal and effectiveness of science education. The House of Commons Science and Technology Committee (2002), for example, commented that: ‘In our view, practical work, including fieldwork, is a vital part of science education. It helps students to develop their understanding of science, appreciate that science is based on evidence and acquire hands-on skills that are essential if students are to progress in science. Students should be given the opportunity to do exciting and varied experimental and investigative work.’ (para. 40). The influential Roberts (2002) report, on the supply of people with science, technology, engineering and mathematics skills, highlights the quality of school science laboratories as a key concern. These it argues ‘are a vital part of students’ learning experiences… and should play an important role in encouraging students to study [science] at higher levels’ (p. 66). It goes on to recommend ‘that the Government and Local Education Authorities prioritise school science… laboratories, and ensure that investment is made available to bring all such laboratories up to… a good or excellent standard… by 2010: a standard which is representative of the world of science and technology today and that will help to inspire and motivate students to study these subjects further.’ (ibid.)

There is also evidence that students find practical work relatively useful and enjoyable as compared to other science teaching and learning activities. In survey responses of over 1400 students (of a range of ages) (Cerini et al., 2003), 71% chose ‘doing an experiment in class’ as one of the three methods of teaching and learning science they found ‘most enjoyable’. A somewhat smaller proportion (38%) selected it as one of the three methods of teaching and learning science they found ‘most useful and effective’. In both cases, this placed it third in rank order.

Despite the widespread use of practical work as a teaching and learning strategy in school science, and the commonly expressed view that increasing its amount would improve science education, some science educators have raised questions about its effectiveness. Hodson (1991), for example, claims that: ‘As practiced in many schools it [practical work] is ill-conceived, confused and unproductive. For many children, what goes on in the laboratory contributes little to their learning of science’ (p. 176). From a similar viewpoint, Osborne (1993) proposes and discusses a range of alternatives to practical work. Wellington (1998) suggests that it is ‘time for a reappraisal’ (p. 3) of the role of practical work in the teaching and learning of science.

This article presents findings from a study of the effectiveness of practical work as it is typically used in science classes for 11-16 year old students in maintained schools in England. The research question the study addressed was essentially: how effective is practical work in school science, as it is actually carried out, as a teaching and learning strategy? The study looked at both cognitive and affective outcomes of practical work; this article focuses on cognitive outcomes – the effectiveness of practical work in enhancing students’ knowledge and understanding, either of the natural world or of the processes and practices of scientific enquiry. Throughout we will use the term ‘practical work’, rather than ‘laboratory work’ or ‘experiments’, to describe the kind of lesson activity we are interested in. An ‘experiment’, particularly in philosophy of science, is generally taken to mean a planned intervention in the material world to test a prediction derived from a theory or hypothesis. Many school science practical tasks, however, do not have this form. And whilst many practical lessons are undertaken in specifically designed and purpose-built laboratories (White, 1988), the type of activity we are interested in is characterised by the kinds of things students do, rather than where they do them.

A framework for considering the effectiveness of practical work

Practical work, as several authors have pointed out, is a broad category that encompasses activities of a wide range of types and with widely differing aims and objectives (Millar et al., 1999; Lunetta and Tamir, 1979). It does not make sense, therefore, to ask if practical work *in general* is an effective teaching and learning strategy. Rather we need to consider the effectiveness of *specific* examples of practical work, or *specific* practical tasks. To develop an analytical framework, the present study started from a model of the processes involved in designing and evaluating a practical task (Figure 1) proposed by Millar et al. (1999).

[Figure 1 near here]

The starting point (Box A) is the teacher’s learning objectives – what he or she wants the students to learn. This might be a specific piece of substantive scientific knowledge, or a specific aspect of the process of scientific enquiry (about, for example, the collection, analysis or interpretation of empirical evidence). Once this has been decided, the next step (Box B) is to design (or select) a practical task that might enable the students to achieve the desired learning objectives. The next stage of the model (Box C) asks what the students actually do as they undertake the task. For various reasons, this may differ to a greater or lesser extent from what was intended by the teacher (or the author of the practical task). For example, the students might not understand the instructions; or they may understand and follow them meticulously, but be prevented by faulty or inadequate apparatus from doing or seeing what the teacher intended. Even if the task is carried out as intended, and the apparatus functions as it is designed to do, the students still may not think about the task and the observations they make using the ideas that the teacher intended (and perhaps indeed expected) them to use. We can think of this as a matter of whether or not students do the things the teacher intended with *ideas*, i.e. their mental actions as distinct from their physical actions. The final stage of the model (Box D) is then concerned with what the students learn as a consequence of undertaking the task. This model therefore distinguishes two senses of 'effectiveness'. We can consider the match between what the teacher intended students to do and what they actually do (the effectiveness of the task at level 1); and the match between what the teacher intended the students to learn and what they actually learn (the effectiveness of the task at level 2). 'Level 1 effectiveness' is therefore concerned with the relationship between boxes B and C in Figure 1, whilst 'level 2 effectiveness' is concerned with the relationship between boxes A and D.

In the discussion above, we have already alluded to a further dimension – the kind of action (physical or mental), and hence learning, involved. The fundamental purpose of practical work in school science is to help students make links between the real world of objects, materials and events, and the abstract world of thought and ideas

(Millar et al., 1999; Brodin, 1978; Shamos, 1960). Tiberghien (2000) characterises practical work as trying to help students make links between two 'domains' of knowledge: the domain of objects and observables (o) and the domain of ideas (i) (Figure 2).

[Figure 2 near here]

Some school science practical tasks deal only, or mainly, with the domain of observables; others involve both domains. Combining the two-level model of effectiveness with this two-domain model of knowledge leads to the analytical framework shown in Table 1 for considering the effectiveness of a given practical task. This framework can apply equally to practical tasks in which the focus is on students' learning of substantive scientific knowledge or on learning about some aspect of scientific enquiry procedures.

[Table 1 near here]

The four cells of Table 1 are not independent. It seems unlikely, for example, that a task could be effective at level 2:i unless it were also effective at level 1:i, and perhaps in turn at level 1:o. And we are more likely to be interested in evidence of successful learning at level 2:o if the task has been effective at level 1:o (in other words the actions and observations that the students recall are the ones we wanted them to make). Despite these interdependencies, this framework provides a useful tool for analysing examples of practical work in school science. Table 2 shows how it might apply to a practical task in which the students are investigating electric currents in parallel branches of an electric circuit, where the teacher's aim is that students should develop their understanding of the scientific model of current as moving charges. If the teacher's focus were instead on developing students' understanding of how to deal with 'messy' real data, then domain o thinking would focus on the actual observations and data collected, whereas domain i thinking would see these as an instance of a more general phenomenon, measurement error (or uncertainty).

[Table 2 near here]

A possible objection to this theoretical framework is that all observation is 'theory-laden', so there is no clear distinction between observables and ideas. Hanson (1958) argues that even basic observation statements that report sensory experience are dependent upon the theoretical framework within which the observer operates (for examples of this in science education contexts, see Gott and Welford, 1987; Hainsworth 1956). Feyerabend (1988) goes further, asserting that 'observation statement[s] are not just theory-*laden*… but *fully theoretical*' (p. 229, italics in original). He argues, however, that a pragmatic distinction can nonetheless be made between observational and theoretical statements. A statement can be regarded as observational, Feyerabend suggests, if it is a 'quickly decidable sentence', that is:

> [a] singular, nonanalytic sentence such that a reliable, reasonably sophisticated language user can very quickly decide whether to assert or deny it when he is reporting on an occurrent situation. (Feyerabend, cited in Maxwell, 1962: 13)

The distinction that we draw in this study between the domain of objects and observables and the domain of ideas (and hence between statements about these domains) is a pragmatic one, along these lines. We accept that all observations are, at some level ‘theory-laden’, but would argue that the extent of their ‘theory-ladenness’ differs considerably, and that the theory with which a given statement is ‘laden’ is often not at issue or under test in the context in which the statement is being asserted. The distinction between observables and ideas is, we believe, a valuable and important one in analysing the effectiveness of practical tasks.

Research strategy and methods

Large-scale quantitative studies of school science practical work in the UK, the most recent of which is now over twenty years old (Beatty and Woolnough, 1982; Thompson, 1975; Kerr, 1964), have provided insights into the views of teachers and students. These studies did not, however, compare expressed views on practical work with observations of actual practice. They might therefore be seen as studies of the rhetoric of practical work, rather than the reality. It has been suggested by Crossley and Vulliamy (1984) that questionnaire-based surveys are unlikely to provide accurate insights into the reality of teaching within its natural setting but are more likely to reproduce existent rhetoric. An interview study is open to the same objection (Cohen et al., 2000; Hammersley and Atkinson, 1983). In contrast, this study sought to explore critically the reality of practical work in the school laboratory. This requires a strategy that brings the researcher into closer contact with teachers and students as they undertake practical work, collecting data in the teaching laboratory, focusing on observation of actual practices augmented by interviews conducted in the context of these observations. Such a strategy may achieve a higher degree of *ecological validity* (Bracht and Glass, 1968), that is, external validity and generalisability to other settings. When an interviewee is aware that the interviewer has observed the practice being discussed, responses are more effectively anchored to realities, and less likely to be 'rhetorical' in nature.

For these reasons a case-study approach was chosen. There are a number of precedents for the use of such a strategy to explore, in a critical manner, the relationship between rhetoric and reality within an educational context (see for example Ball, 1981; Sharp and Green, 1976). To avoid what Firestone and Herriott (1984) term the 'radical particularism' of the traditional single in-depth case study, we used a multi-site approach, involving a series of 25 case studies in different settings, similar in scale to those undertaken by Firestone and Herriott (1984) and Stenhouse (1984). Schofield (1993) suggests that 'the possibility of studying numerous heterogeneous sites makes multi-site studies one potentially useful approach to increasing the generalizability of qualitative work' (p. 101).

Eight schools were approached and the head of the science department asked for permission to observe one or more science lessons at national curriculum Key Stage 3 or 4 (students aged 11-14 and 15-16 respectively) that involved some student practical work, to talk to the teacher about the lesson, and perhaps also to talk to some of the students. In some science lessons in English schools, students are assessed on their performance of a practical investigation, and this contributes to their national test score at age 14 and their grade in the General Certificate of Secondary Education (GCSE) at age 16. We asked that the lessons observed should not be of this kind (indeed we thought that schools were unlikely to give us permission to observe these, as a researcher's presence could have been an unnecessary distraction). Some possible consequences of this are discussed below. All the schools approached were maintained state comprehensive schools, in a variety of urban, suburban and rural settings. Some of their characteristics are shown in Table 3; the school names listed are pseudonyms. As a group they were broadly representative of secondary schools in England.

[Table 3 near here]

We had limited control of the content or subject matter of the lessons actually observed in each school. Typically, a date was agreed for the observation visit, and a number of lessons with different teachers were offered as possibles when the researcher arrived. Choices were made on the basis of practical considerations of timing to allow pre- and post-lesson teacher interviews, and with the aim, as the study proceeded, of achieving reasonably even coverage of the five school years in Key Stages 3 and 4, and ensuring that the sample included biology, chemistry and physics topics. The distribution of the lessons observed across Key Stages and science subjects is shown in Table 4. The lower number of biology lessons observed is a reflection of the number of student practical tasks that appear to be carried out by students in biology lessons as compared with chemistry and physics. The lesson observations later in the sequence seemed to raise the same issues as earlier ones, suggesting that data saturation had been achieved by this point. The content of the 25 lessons observed is summarised in Table 5, along with details of the teacher and the age of the students involved. The teachers' names are all pseudonyms; the initial letter of their surname matches that of their school (in Table 3).

[Tables 4 and 5 near here]

Field notes were taken in each lesson observed and tape-recorded interviews were carried out with the teacher before and after the lesson. The pre-lesson interview was used to get the teacher's account of the practical work to be observed and of his or her view of the learning objectives of the lesson. The post-lesson interview collected the teacher's reflections on the lesson and on its success as a teaching and learning event. Where possible, conversations with groups of students during and after the lesson were also tape-recorded. These were used primarily to gain insights into the students' thinking about the task that were not apparent from observation alone, or to confirm the impression gained from observation.

Findings

Introduction

The analytical framework shown in Table 1 was used in analysing the data, and will also be used here to structure the discussion. We will begin by considering the effectiveness of tasks at level 1 (in getting students to do what the teacher intended), and then go on to consider effectiveness at level 2 (in promoting the learning the teacher intended). Throughout this discussion, each teacher is given a pseudonym. In extracts from interviews with students, each is identified by a code consisting of the first and last letters of the teacher's surname (to identify the lesson involved) and a number.

Deleted: As explained above, the data collected on each case study consisted of detailed field-notes on the lesson observed, plus audio-recordings of interviews with the teacher before and after the lesson, and with some students after (and in some cases also during) the practical activity.

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First, however, one general point should be made. In *all* the lessons we observed, the teacher's focus appeared to be firmly (indeed almost exclusively) on the substantive science content of the practical task. There was almost no discussion in any of the lessons observed of specific points about scientific enquiry in general, or any examples of use by the teacher of students' data to draw out general points about the collection, analysis and interpretation of empirical data. In some lessons where there were clear opportunities to do this, they were not exploited. So, in the discussion below, our focus is largely on the use of practical work to develop students' understanding of substantive science ideas – not because our framework excluded other aspects of learning, but because this reflects what we actually observed. Readers familiar with the English national curriculum for science might see this as a consequence of our decision not to observe lessons in which students were being assessed. Donnelly et al. (1996), in a detailed study of the 'Scientific Enquiry' component of the English national curriculum (Attainment target Sc1), found that extended, and more open-ended, investigative practical tasks were rarely used to teach students about specific aspects of scientific enquiry, but almost entirely to assess their ability to conduct an empirical enquiry 'scientifically'. It would seem, therefore, that an unintended consequence of the introduction of Attainment target Sc1 may be that teachers overlook opportunities that arise in the course of illustrative practical work (that is, practical tasks primarily intended to let students observe a phenomenon, or to help them understand a scientific idea or explanation) to highlight and discuss the rationale for the design of the task, or issues about data analysis and interpretation thrown up by the data actually collected – seeing this as a distinct strand of the science curriculum with which they deal on other occasions.

What students do with objects and materials (level 1:o)

The practical work observed was, in most cases, effective in enabling the majority of students to do what the teacher intended with the objects provided – that is, successfully to 'produce the phenomenon' (Hacking, 1983). Various factors contributed to this, in particular the widespread use of 'recipe style' tasks (Clackson and Wright, 1992; Kirschner, 1992). In many of the lessons observed, teachers focused their efforts on ensuring that students understood the procedure they had to follow. A particular piece of practical work (often the central feature of a lesson) was likely to be considered successful by the teacher if the students had managed to produce the desired phenomena and make the desired observations.

Many teachers in the study, particularly those teaching outside their subject specialism, explained their choice of the practical task observed by referring to a departmental scheme of work, as in the following except:

Researcher:	Why did you choose to do this as a practical?
Mrs Ramsgill:	It was part of the new scheme of work [a commercially produced scheme that the department had recently purchased] we are now using.
Researcher:	So it wasn't really your choice?
Mrs Ramsgill:	No, no, it wasn't.
Researcher:	Is that the same for the work sheets?
Mrs Ramsgill:	Yes, they are part of the same scheme.

This moved responsibility for the choice of question to be addressed and/or phenomenon to be produced (as well as other issues relating to the task) on to the author(s) of a published or departmentally produced scheme of work, and portrayed their own responsibility primarily in terms of 'delivering' an activity judged appropriate by others. Fourteen of the 25 teachers observed said they were following a scheme of work that included the practical activity observed. Nine used worksheets that were part of such a scheme. Use of both was greater amongst teachers for whom the lesson was outside their science specialism. Table 6 shows that 4 (of 9) teachers teaching in their subject specialism were following a scheme of work, compared with 10 (of 16) teachers teaching outside their subject specialism. Similarly whilst only 2 (of 9) teachers teaching within their subject specialism used worksheets, this rose to 7 (of 16) for those teaching outside their subject specialism. Whilst the sample size (n=25) is too small to generalise with confidence from these data, the pattern is consistent with the findings of other research (for example, Hacker and Rowe, 1985) that teachers working outside their specialist subject tend to rely more on routine and controllable activities, which reduce the likelihood of unexpected events or questions.

[Table 6 near here]

Some teachers explained their use of ‘recipe style’ tasks on the basis that there was, in their opinion, simply insufficient time within a typical hour-long practical lesson to be confident that most of the students would successfully design and set up the apparatus, produce a particular phenomenon, and record and analyse the results, if the task were presented in a more open and unstructured manner. In Dr Kepwick’s words, ‘I think they need to come in, be told how to do it, and get a result.’ Similarly, Mr Normanby commented that, ‘Often the practicals are designed to be student friendly. You know, to make sure that within your double [period lesson] they’ll see, at least most of them will, what you want.’

The overwhelming sense, from the set of lessons observed, was that a high priority for teachers is ensuring that the majority of students can produce the intended phenomenon, and collect the intended data. This is not surprising, as effectiveness of a practical task in all the other cells of Table 1 depends on its effectiveness at level 1:o. If, however, this ceases to be merely a priority and becomes the sole aim, the learning value of practical work is very significantly limited.

What students do with ideas (level 1:i)

The meaning of ‘what students do with objects and materials’ is self-explanatory. ‘What students do with ideas’, however, is less immediately clear. We use ‘doing with ideas’ to refer to mental actions – the process of thinking (and hence talking) about objects, materials and phenomena *in terms of theoretical entities or constructs that are not directly observable*. Clearly not all thinking is synonymous with ‘doing with ideas’ in this sense. For example, a student may think about the readings on a voltmeter entirely in terms of *observables* – the position of a pointer on a scale – rather than as measures of potential difference. Or they may see variation in repeated measurements of the same quantity as a sign of inadequate equipment, or as a real effect, rather than as an example of a general issue facing all empirical data collection. Getting students to think about objects, materials and phenomena, within a particular framework of ideas can be difficult, as these ideas do not present themselves directly to their senses.

Almost all of the twenty-five tasks listed in Table 5 provided opportunities for students to think about observables using specific scientific ideas, though the extent to which this might have had a significant impact on their actions or on the possible learning outcomes varied from task to task. As discussed in the previous section, the overwhelming majority of tasks appeared to be effective in enabling the students to do what was intended with objects and materials. There was, however, considerably less evidence that they were as effective in getting the students to think about those same objects and materials using the ideas that were implicitly or explicitly intended by the teacher. One possible reason for this was that, in many of the tasks observed, the students appeared unfamiliar with the ideas that the teacher intended them to use. This lack of familiarity did not necessarily mean that the idea had not been taught. For example, despite Mrs Uckerby's confirmation that the students in her Year 11 class had been taught about electric circuits at several times in the preceding five years, some were still evidently unfamiliar with the basic idea that a voltmeter measures a difference of some kind between two points. An understanding of this might have made them more likely to place the voltmeter in parallel rather than in series:

> Researcher: [Observing as UY7 places the voltmeter in series.] So how have you got your voltmeter connected? [UY7 ignores the question.] How would you say your voltmeter is connected in the circuit?
> UY8: [Interrupting] It needs to be on parallel lines doesn't it.
> Researcher: [To UY7] So how have you got it?
> UY7: I'm not sure. I don't know.

A key reason, however, for the small number of examples of students 'doing things with ideas' appeared to be the extent to which the practical task, and the way the teacher introduced and staged it, helped the students to make productive links between the domains of observables and ideas. To illustrate the practices typically observed and the issues they raise, we will discuss briefly three lessons; further examples can be found in Abrahams (2005). All provided opportunities for the students to think about the observables using scientific ideas that might have made their observations more meaningful. The two tasks used by Mr Drax and Mrs Risplith, however, were used solely to enable the students to generate a data set in which they should see a pattern between observables.

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Mrs Risplith's task required the students to measure and then compare their pulse rate (observable) with their heart rate (observable) in order to recognise the similarity of these values, and perhaps realise that they were measuring the same thing. Mrs Risplith chose not to discuss the circulatory system before they began, explaining when interviewed that she believed the connection between heart rate and pulse rate would emerge from the data. This rather inductive (‘data first’) view of practical work seemed to underlie the practice of several teachers observed. Unfortunately, by the end of the lesson, when the students’ results had been put up on the board, many had obtained different values for these two readings – so the desired result failed to emerge. As the circulation of blood within the body had not been discussed, most students had no clear idea why the pulse rate should be the same as the heart beat and some, as the following extract shows, were clearly sceptical of Mrs Risplith’s efforts to imply that two different numerical values were essentially the same:

Mrs Risplith:	The question is [pointing to data on board], is the pulse rate the same as the heart beat?
RH15:	No.
RH16:	No, no.
Mrs Risplith:	Right, near enough, who said that? [No response from the students and nobody could be heard saying it on the audiotape.]
RH2:	[Calling out] But 106 and 90 are miles apart.

By the end of the lesson one student (RH19), who appeared confused by the data on the board, asked ‘What is pulse?’ to which Mrs Risplith, without any further explanation replied ‘Your pulse is your heart, is your heart beat’. Had this task started with a discussion of the idea that blood is pumped by the heart around the body, and that the pulse is a consequence of the heart beat and should therefore – if measured at the same time – have the same value, this might have made the task more meaningful to the students and hence more successful. This is one example of the point made earlier, that teachers often overlooked opportunities to develop students’ understanding of specific aspects of scientific enquiry procedure. Here, there was an opportunity, which was not taken, to ask if the measurements provided evidence of real changes in heart rate (perhaps due to a reading having been taken after running around the class to borrow a stethoscope) or were simply a result of measurement error (or uncertainty).

In Mr Drax's lesson, the aim of the practical task was explained to the students as being to answer the question 'what effect does the colour of a can have on its ability to take in heat or not take in heat?' Although expressed in everyday language, this clearly involves theoretical ideas. Whilst temperature might be considered an observable, heat and movement of heat are not. Having introduced the term 'heat', Mr Drax made no further reference to any scientific ideas about heat, or energy, moving from the lamp into or out of the cans. In fact the task was undertaken entirely at the level of observables and its purpose might have been more accurately described as: to see which of a number of differently coloured cans shows the greatest change in thermometer reading when placed near a lamp. Mr Drax later explained that this was in fact what his aim had been, and that he saw the purpose of this particular practical lesson as being to enable the students to carry out a procedure successfully and generate and record data from which 'the ideas of absorption and reflection will be developed in subsequent lessons'. His desire to ensure that the students understood what to do with objects and materials, and could succeed in generating the data, led him to give all of the procedural instructions in descriptive everyday language. Having explained the procedure, he paused briefly before the students began the task to remind them that they had previously used the term 'absorb' to mean 'taking in heat' and 'reflect' to mean 'not taking in heat'. Yet despite this brief reminder of relevant scientific ideas, none of the students was heard to use these as they carried out the task. Indeed almost all of the student discussion observed by the researcher focused on the practicalities of carrying out the task and, in particular, on who would do what with which piece of equipment and when they could swap roles. On the occasions when students were overheard talking about their observations, beyond simple calling out of thermometer readings, their comments referred only to observables. The following extracts are typical:

DX4: [Feeling the black can.] The black can is very hot.
DX5: Let me feel it.
DX6: Let me feel it too.

DX10: [Feeling the black can.] I think the black feels hotter than the green did.
DX11: [Feeling the black can.] Yeah, you're right.

The third lesson stands in marked contrast to the two described above. In it, the teacher, Dr Starbeck, deliberately structured the practical task with so as to assist the students in making links between the domains of observables and ideas. Dr Starbeck's lesson on current and voltage in a parallel circuit was introduced through the use of a model, presented in a short video, in which everyday objects provided an analogy to an electric circuit. Pupils observed a cartoon character picking up boxes from a store, walking around a circular path, and depositing them in a fire before they continued around the path back to the store. Having got the pupils to discuss and understand what was happening in this model, Dr Starbeck used it as a scaffold for getting them to think and talk about an ammeter (in the model this was a device to count people) and then, based on an analogy between people and charges in the scientific model, to think about the function of the ammeter as being to count charges. As the pupils' familiarity and confidence with the use of the scientific ideas and terminology increased, many began to replace colloquial terms that had been used in discussing the model with the appropriate scientific terminology used within a scientific model, as the following extract illustrates:

Researcher: What have you found?

SK5:	I was wrong. [Their initial prediction was based on a current attenuation model.] They all stayed the same except for one where it went up a tiny little bit.
Researcher:	So what's that told you?
SK5:	That amps don't really change.
Researcher:	And what are the amps measuring in the model you're using?
SK5:	The amount of charge going round. The number of people's not changing.

Although the majority of students continued to use a mixture of scientific and colloquial terminology, a small number of students, by the end of the task, were able to discuss (and appeared to understand) the electric circuit situation and could use the appropriate scientific terminology:

Researcher:	So what's the voltmeter actually measuring?
SK21:	The energy.
Researcher:	[Directing the question to SK22] So this voltmeter that you've connected across a bulb, what's it measuring?
SK22:	How much energy is going in, and how much energy is coming out.
SK21:	How much energy it has lost.

Whilst Dr Starbeck was not unique in the sample of teachers observed in *intending* the students to think about the task using specific ideas, he was the only teacher observed who devoted so much of the lesson time to ensuring that the students were not only introduced to the appropriate scientific terminology but also understood what the scientific terms meant and were able to use them appropriately to talk about the task.

Returning to the set of lessons observed, the focus of the teachers on shaping their students' physical actions (rather than their mental ones) is clear from the significantly greater amounts of time spent on this. Table 7 shows estimates of the time spent by the teacher on 'whole class' activities only, as it was not possible from the lesson field notes to estimate accurately the time spent by the teacher on different kinds of activity during periods of small-group or individual work – and this would, in any case, have differed from student to student. Despite this limitation, Table 7 provides a clear indication of the extent of the imbalance in the relative amounts of time spent supporting physical and mental activity. All of the teachers observed devoted 'whole class' time, in some cases an appreciable proportion of the lesson, to ensuring that the students were able to produce the phenomenon successfully and collect the data. Only Dr Starbeck gave appreciable 'whole class' time, and most gave none at all, to discussing the ideas that were necessary to carry out the task with understanding and so make it more than a simple mechanical procedure.

[Table 7 near here]

The data in Table 7 do not mean that in only five of the 25 lessons observed did the teacher take any steps to help the students to think about the observables using specific theoretical ideas. Some teachers who had not discussed theoretical ideas with the whole class in advance became aware as the practical task proceeded of the need to introduce such ideas. For example, Mr Oldstead, finding that students were not thinking about the temperature plateau as a liquid cooled and solidified using the ideas that he intended them to use, began to assist the students on a 'group by group' basis:

Mr Oldstead:	Here's a liquid. [stands in front of a small group of students, who had been unable to explain to him the reason for the temperature plateau, and moves his arms about erratically and energetically making a noise like a steam train.] And here's a solid [arms held, and moved, rigidly in front of him whilst making a low humming noise.] I want to change this liquid [waves arms energetically again] into a solid [arms moved rigidly and less energetically]. What's this [arms go from moving energetically and erratically to being held rigidly] got to lose [places strong emphasis on the word 'lose'] to change into a solid?
OD3:	Energy.
OD1:	All its movement.

His interventions might be seen as providing a *scaffold,* something which ‘enables a child or novice to solve a problem, carry out a task, or achieve a goal which would be beyond his unassisted efforts’ (Wood et al., 1976: 90). This was, however, an *ad hoc* response to events in one student group, rather than a planned intervention to address a conceptual challenge that had been recognised in advance and had influenced the design or presentation of the practical task.

To summarise, then, our observations of these twenty-five lessons suggested that the practical tasks used were generally ineffective in helping students to see the task from a scientific perspective, and to use theoretical ideas as a framework within which their actions made sense or as a guide to interpreting their observations. Teachers overtly gave much lower priority to the underlying scientific ideas than to ‘producing the phenomenon’. The design of the practical tasks, and the way they were presented to the students by the teacher and staged in the classroom setting, were strikingly similar across the set of tasks, given their wide variety of content. There were no obvious differences in the design or staging of tasks which depended more critically on students developing links between the domains of objects and observables.

What students learn

The analytical framework presented in Table 1 distinguishes two levels of effectiveness of a practical task. Level 1 concerns whether students *did* the things the task designer intended, level 2 whether they *learned* the things they were intended to learn. We will now consider the effectiveness of the lessons observed at level 2. The difference between level 1 and level 2 is fairly clear for the domain of observables.

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Effectiveness at level 2 would mean that the student could later recall and report accurately on the things they had done with the objects and materials involved, and the phenomena they had observed. The difference between effectiveness at levels 1 and 2 is less clear, however, for the domain of ideas. Here we are making a distinction between being able to 'do things with ideas' during the lesson, and showing understanding of these ideas later. It might be argued that, if a student can use an idea appropriately during a lesson, this indicates that the idea has been 'learned', in which case the only distinction between level 1 and level 2 is that between short- and longer-term retention of what is learned. We might, on the other hand, argue that, if the ability to use an idea is not retained for even a short time (say a few days or weeks), then it is doubtful to claim that it was ever 'learned'. In this study, we took effectiveness at level 2 to mean some evidence of medium- to long-term retention of information and ideas initially obtained through the practical task.

The design of the study, however, means that we can say much less about the effectiveness of practical tasks at level 2 than at level 1, and that anything we do say is based on weaker evidence. We sought and gained permission to observe single lessons that included practical work. Had we asked for wider access to observe subsequent lessons, this would not have been forthcoming in many cases because of the perceived disruption to routines. Follow-up visits, or other actions, to assess students' understanding of the key points of the practical task, either shortly after the lesson observed or later, were also impossible, not least because this would have required that different diagnostic instruments be devised for each lesson observed – which would have introduced many new variables and made general conclusions almost impossible to draw. We therefore decided to limit data collection to a single visit for each practical task. Our judgments about effectiveness at level 2 are based on two main kinds of evidence: evidence of short-term learning within the lessons observed or in post-lesson student interviews, and comments by students during interviews on previous practical work they had done, in some cases on previous occasions on which they had done the same practical task as that observed.

What students learn about observables (level 2:o)

In post-lesson interviews about the lesson observed and about previous practical tasks, many students were able to recollect details of what they had done, or observed their teacher doing, with objects and materials, and what they had seen. Frequently, however, this was all they could recollect. Even when students were able to recollect specific practical tasks they had carried out (or seen their teacher carry out) previously, their recollections typically amounted to little more than recalling that a particular task had 'been done', or focused on some specific detail or aspect of the task.

The tasks about which the students were able to recollect specific details tended to be those that were, in some sense, unusual. These typically exhibited one or more of the following three characteristics:

1. A distinctive visual, aural, or olfactory component ('flashes, bangs, or smells')
2. A novel context or manner of presentation
3. A 'gore' factor

Of the sixty-eight tasks recollected in student interviews, twenty seven were ones in which the students' primary, and in most cases only, recollection related to a distinctive visual, aural, or olfactory component. In a further eighteen, the recollections involved tasks that were presented in a relatively unusual context or manner. For example, they might take place in a location other than the science laboratory, or involve some form of role play or a detective style mystery. A ‘gore’ factor was evident in three of the most vividly recollected biology tasks (the label reflects the way the students spoke of these tasks). Gagné and White (1978) have suggested that it is the act of undertaking a task, rather than merely reading about it or having it demonstrated, that makes its recollection more likely. This study suggests that task recollection depended to a much greater extent on the presence of at least one of the above three characteristics. Interestingly White’s (1979) own example of a practical task that he vividly recollects is not one that he undertook, but the visually spectacular ignition of carbon monoxide *demonstrated* to him by his teacher. Similarly fourteen of the practical tasks recollected by the students in this study (21%) were visually spectacular teacher demonstrations. One of the most frequently mentioned was a demonstration of the Thermite reaction (Conoley and Hills, 1998), which often had both characteristics 1 and 2 above. Students’ recollections invariably focused on the visually and aurally spectacular nature of the reaction itself and the fact that it was undertaken outside the laboratory. For some, the fact of having carried several bricks outside to provide a base on which to place the reagents was the most durable recollection:

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Researcher:	What other practicals do you remember?
RN18:	That one with the brick that we did outside that was quite good.
RN17:	Yeah he put loads of different stuff in it, set light to it, and it just whoosh, that was pretty exciting.
RL9:	Well can you [addressing another student] remember that experiment that we had to do with a brick outside?
Researcher:	Was that with Mr Rainton?
RL9:	Yeah.
Researcher:	What do you remember?

RL9: A big bang and all that.

A practical activity might also be 'unusual' in the way it is staged in class. Several recollections, for example, were of lessons that had involved an element of 'role playing'. Many of Miss Sharow's Year 11 students recollected an 'unusual' practical activity, also on the topic of current conservation and voltage, that they had undertaken in Dr Starbeck's class about a year earlier. This was not the lesson described previously, though it had some similarities to it. Although the students referred to it as a 'practical', it was not an activity in which they had to manipulate or observe the real objects of study. Instead they had to construct a 'circuit' by rearranging the laboratory benches and then walking or standing on these so as to 'act out' (Braund, 1999) the role of electrons, with other objects or features representing battery, lamps, ammeters and voltmeters. A supply of cardboard boxes was used to represent energy being given by the battery to the electrons, and by the electrons to the lamps. The National Curriculum Council (1989) suggests that 'When students act out incidents, the experience can help them to remember' (Section C16, para. 9.3). The fact that this activity, and another more modest kind of role-play involving chromatography in which students were invited to see themselves as forensic scientists and asked to determine which of several given inks was the same as one used to sign a forged cheque, were recalled by many students appears to bear this out.

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Deleted: Even the more modest kind of role-playing involved in setting up a practical activity by giving students a fictitious letter from a person or agency outside the school to which they have to respond in some way appeared to make such lessons more likely to be recalled. One example was a lesson on chromatography in which students were invited to see themselves as forensic scientists, asked to determine which of several given inks was the same as one used to sign a forged cheque.

The nature of students' recollections in this study, however, suggests that memorable aspects or features of a practical task rarely provide an anchor for the associated scientific ideas, as White (1979) has proposed, but rather an anchor for *descriptive* accounts of the task. The students' inability to recollect anything beyond a fragmentary description does not, of course, mean that they may not have learnt more than this from the task. But it does indicate that what the students are *aware of having learnt*, and are able to recollect without assistance, frequently differs markedly from what the teacher had intended them to learn.

Similarly students' recollections about procedures tended to relate to what they had done rather than the ideas this was intended to convey:

Researcher:	What practicals do you remember doing?
SH7:	Distilling stuff.
SH8:	Yeah.
Researcher:	What did you distil, crude oil?
SH7:	Yeah a blue liquid.
SH8:	Yeah it was a blue liquid.
SH7:	Just a blue liquid, we don't know what it was, just a blue liquid and we got water out of it.
Researcher:	You got water out of it, how did that work?
SH7:	Well we got a bottle.
SH8:	We put a liquid in it, put a thermometer in it, put it on a tripod, put a Bunsen burner under it and it went through all the tubes in place and it went into a test tube in a beaker.
SH7:	Hot water went into a beaker.
SH8:	Yeah.
SH7:	And if the temperature goes over too far, over a hundred, you had to take it out and then hold on a bit and then have another go.

As the above example illustrates, students may recollect in some detail a procedure they have followed. But there is no mention in the extract above, or in the conversation from which it is taken, of different boiling points of the components of a mixture of liquids or of how this procedure resulted in their separation. The focus on the observable details is consistent with the emphasis of many of the teachers observed, noted earlier, on getting the students successfully to *do* what they intended with objects and materials, in order to produce a particular phenomenon, reflected in their use of whole class time in lessons (Table 7).

What students learn about ideas (level 2:i)

As we have noted above, data collected during and immediately after a practical activity do not provide strong evidence of students' learning of the ideas the activity aims to help them understand. A practical activity is, of course, likely to be just one element of a planned sequence of activities designed to develop students' understanding of a particular point or topic. For many of the lessons observed, teachers may have used subsequent lessons to tease out the links between observations and ideas. Also, it may be unreasonable to expect lasting learning to stem from any single exposure to an idea, however clear or memorable. Dr Starbeck, for instance, commented that 'what I hope is when they do it [the same science topic] again … although they'll have forgotten it, they'll go "Oh yeah, I remember that" and they'll get it faster the second time'.

Post-lesson student interviews provided little evidence of lasting effects of practical tasks on students' conceptual understanding. Almost all of the students' recollections were in the domain of objects and observables. Even the Year 11 students being taught by Miss Sharow, all of whom had undertaken the same lesson by Dr Starbeck discussed earlier, when the students were guided towards forming links between the domains of observables and ideas, showed no evidence of being able to recall either the observables or the ideas, or the links between them. On the other hand, many did recollect an 'unusual' practical lesson, also taught by Dr Starbeck the previous year, involving the electric circuit role-play described in the preceding section. However, although many of them were able to recollect what they had *done*, none was able, as the extract below illustrates, to recollect the scientific ideas involved:

> SW4: One to do with electric circuits. We put all the tables together so that they made, so that they made, they were the wires.
>
> SW5: Yeah we had to walk on the tables with boxes and people had to pretend to be voltmeters.

Researcher: What did it show you?
SW5: [Laughter] I don't know.
SW4: [Shakes head to indicate that they too do not know]

Even those students who recollected the term 'electron' used it only to describe their role within the role-play, rather than as the name of a negatively charged particle whose movement through wires constitutes an electric current.

Deleted: One student was able to describe the role-play model of the electric circuit in detail, but did not link this to the scientific ideas about electric circuits that the task was designed to teach.

Conclusions and implications

The aim of this study was to obtain a picture of the 'reality' of practical work as it is used in school science classes in England with students aged 11-16. One important finding is the apparent separation, in teachers' thinking and planning, of the teaching of substantive scientific knowledge and of the procedures of scientific enquiry. In a sample of 25 lessons involving practical work, selected essentially on the single criterion that they did not involve assessment of the students, the overwhelming emphasis in the teachers' presentation of the task, and the discussion of students' actions and data, was on the substantive science content rather than on aspects of experimental design or the collection, analysis and interpretation of evidence. The implicit assumption is that students will pick up a tacit understanding of what it means to plan and conduct an enquiry 'scientifically'. So their capability in science investigation can be tested at intervals, but does not have to be explicitly taught (the practice noted by Donnelly et al., 1996). This suggests that we still have some way to go in England (and perhaps more widely) to develop models of practice in the use of practical work that more effectively integrate its roles in developing substantive and procedural understanding.

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In particular, we noted a significant difference between the effectiveness of practical work in the domain of observables and in the domain of ideas. Yet many teachers do expect students to learn theoretical ideas through practical activities – as a consequence of actions carried out with objects and materials. The teachers in the study sample frequently included the learning of scientific ideas amongst their objectives for a practical lesson. This, however, contrasted with the absence of any overt evidence of planning *how* students might learn such ideas from what they did and observed, either in the oral or written instructions on the task or in the way these were presented. Very little time was devoted to supporting the students' development of ideas. Many teachers appeared (tacitly or explicitly) to hold an inductive, 'discovery based' view of learning – to expect that the ideas that they intended students to learn would 'emerge' of their own accord from the observations or measurements, provided only that they produce them successfully (Solomon, 1994). The underlying epistemological flaw in this viewpoint, and the practical problems to which it leads, have long been recognised (see, for example, Driver, 1975). Our study suggests that practical work in science could be significantly improved if teachers recognised that explanatory ideas do not 'emerge' from observations, no matter how carefully these are guided and constrained.

Deleted: Our findings challenge the view that practical work, as currently conducted, is a key factor in stimulating students' interest in science as a subject and as a possible future career direction. Whilst our data leave open the possibility that practical work that is well-designed and well-matched to students' current levels of understanding *could* have such an influence, they suggest that much current practical work falls some way short of such an ideal.

Deleted: . Tasks seem generally quite effective in the domain of observables. Students carry out the actions and manipulations they are expected to, and are usually able to make the observations they are intended to make; what they later recall from previous practical tasks is also almost entirely about the observable features of these events. Practical tasks, however, seem much less effective in the domain of ideas. Students rarely talk to each other or to the teacher using the ideas that underpin the observable features of the task and make sense of the actions they are engaged in – and almost none can later recall the scientific ideas that these practical tasks were intended to teach.¶

¶

It seems clear, however, that

Science involves an interplay between ideas and observation. An important role of practical work is to help students develop links between observations and ideas. But these ideas have to be introduced. And it may be important that they are 'in play' *during* the practical activity, rather than introduced after it to account for what has been observed. Solomon (1999) discusses the critical role of 'envisionment' in practical work, of helping students to imagine what might be going on 'beneath the observable surface' as they manipulate the objects and materials and make their observations. This gives purpose to the manipulations made – setting the students' actions within a particular perspective on the event. Millar (1998) discusses the learning function of several common practical tasks in similar terms. The evidence of this study suggests, however, that few practical lessons are designed to stimulate an interplay between observations and ideas *during the practical activity*. Even if these links are developed in subsequent lessons, the fact that the ideas are not available to make sense of the activity (to see its purpose) or of the observations made (to interpret these in the light of the theoretical framework of ideas and models) must reduce the effectiveness of the practical activity as a learning event.

As regards implications for practice, we believe that the two domains model used throughout this paper is a useful tool for teachers in thinking about practical work. First, it draws attention to the two domains of knowledge involved, and their separateness – that one does not simply 'emerge' from the other. Second, it provides a means of assessing the 'learning demand' of the task. Leach and Scott (1995, 2002) have developed the idea of learning demand to discuss teaching and learning in science more generally. They use it to capture the sense that some activities, and the learning steps they are designed to help students take, make significantly greater cognitive demands than others. In the context of practical work, there is a substantial difference in learning demand between tasks in which the primary aim is that students should see an event or phenomenon or become able to manipulate a piece of equipment, and tasks where the aim is that students develop an understanding of certain theoretical ideas or models that might account for what is observed. If teachers could be helped to differentiate more clearly between tasks of relatively low learning demand and those where the learning demand is much higher, this would then allow them to identify those tasks where students might require greater levels of support in order that the intended learning might occur. The only lesson of those observed in which we saw clear evidence, from the way the task was presented to the students and staged in the classroom, that high learning demand had been recognised was Dr Starbeck's lesson on electric circuits.

The principal implications here are for the design of practical tasks, as many of the features of their staging follow from this. We believe, in the light of the data collected in this study, that practical work could be significantly improved were teachers, and other authors of teaching material, more clearly aware that practical tasks requiring students to make links between the domains of objects and of ideas are appreciably more demanding than those that simply require them to observe and remember the observable features of an event or process. Task design might then more clearly reflect an understanding that 'doing' things with objects, materials and phenomena will not lead to the students 'learning' (or even 'using') scientific ideas and concepts unless they are provided with what Wood et al. (1976) term a 'scaffold' (p. 90). The process of scaffolding provides the initial means by which students are helped to 'see' the phenomena in the same 'scientific way' that the teacher 'sees' it (Ogborn et al., 1996). As Lunetta (1998) has argued, 'laboratory inquiry alone is not sufficient to enable students to construct the complex conceptual understandings of the contemporary scientific community. If students' understandings are to be changed towards those of accepted science, then intervention and negotiation with an authority, usually a teacher, is essential' (p. 252). The issue then is the form that this intervention and negotiation with the teacher takes, and the extent to which the need for it is acknowledged and built into the practical task by the teacher or the author of the teaching materials.

Given the clear importance in any practical task of helping the students to do what the teacher intends with objects and materials in the limited time available, ‘recipes’ are likely to continue to have a significant role in science practical work. If, however, the scale of the cognitive challenge for students in linking their actions and observations to a framework of ideas were recognised, teachers might then divide practical lesson time more equitably between ‘doing’ and ‘learning’. These do not, of course, have to be rigidly separated, but teachers need, on the basis of our data in this study, to devote a greater proportion of the lesson time to helping students use ideas associated with the phenomena they have produced, rather than seeing the successful production of the phenomenon as an end in itself.

We have argued above that the analytical framework we have used in this study could assist teachers in assessing the learning demand of practical tasks, and hence in recognising tasks that required more careful design for effective learning to be a possibility. We also think that the use of this framework could help teachers to make more focused evaluations of the effectiveness of their own current practice, perhaps stimulating review and revision of some of the practical activities they use in ways that could significantly increase their ‘payoff’ in terms of student learning.

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Figure 1 **A model of the process of design and evaluation of a practical task**

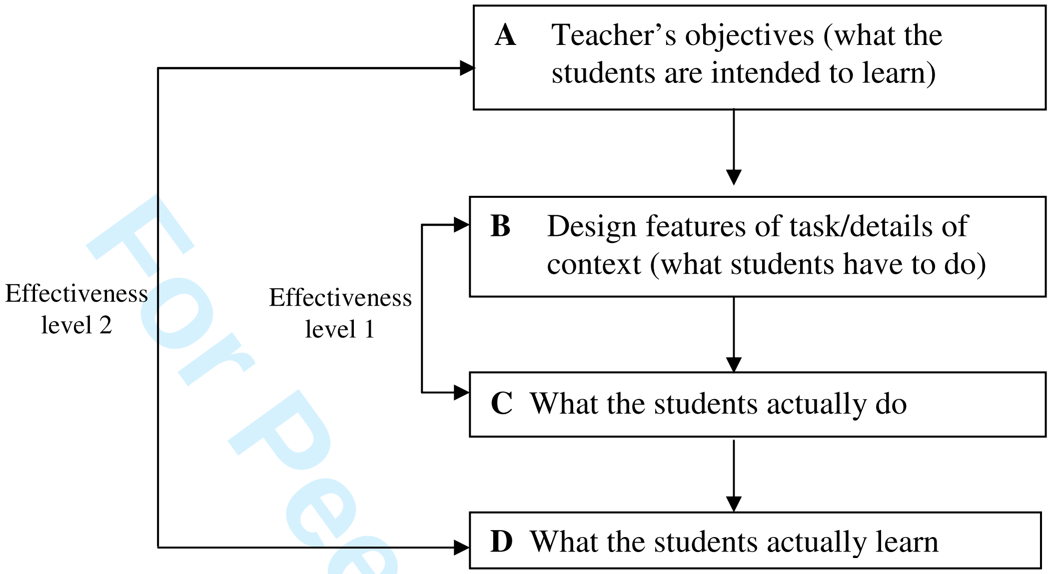

Figure 2 **Practical work: Linking two domains (from Tiberghien, 2000)**

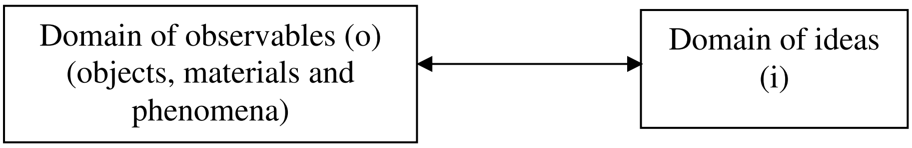

Table 1 An analytical framework for considering the effectiveness of a practical task

Effectiveness	Domain of observables (o)	Domain of ideas (i)
A practical task is effective at level 1 (the ‘doing’ level) if …	…the students do with the objects and materials provided what the teacher intended them to do, and generate the kind of data the teacher intended.	…whilst carrying out the task, the students think about their actions and observations using the ideas that the teacher intended them to use.
A practical task is effective at level 2 (the ‘learning’ level) if …	…the students can later recall things they did with objects or materials, or observed when carrying out the task, and key features of the data they collected.	…the students can later show understanding of the ideas the task was designed to help them learn.

Table 2 Indicators of the effectiveness of a practical task involving an investigation of electric current at each level and domain

Effective	in the domain of observables (domain o)	in the domain of ideas (domain i)
at level 1 (the 'doing' level)	Students set up the parallel circuit correctly from a given diagram and are able to insert an ammeter correctly and read with sufficient accuracy to obtain the pattern of readings intended by the teacher.	Students talk and think about the circuit and the meter readings using the idea of electric current (charges flowing through wires, and the flow dividing and recombining at junction points**.)**
at level 2 (the 'learning' level)	Students are able later to set up a parallel circuit, and can recall that the sum of the ammeter readings in two parallel branches is equal to the reading on an ammeter placed before or after the branch.	Students show understanding of electric current as a flow of charges, and can apply this idea to circuits with parallel branches, for example to explain why the sum of the branch currents is equal to the current before or after the branch.

Table 3 School sample

School	Location	Size	Age Range	Education Authority
Derwent	Urban	500	11-16	A
Foss	Urban	1480	11-18	A
Kyle	Urban	1550	11-18	B
Nidd	Rural	890	11-18	B
Ouse	Rural	630	11-18	B
Rye	Rural	720	11-18	C
Swale	Rural	670	11-16	B
Ure	Rural	1280	11-18	C

Table 4 Sample of lessons observed by science subject and Key Stage

Key Stage (and student age)	Number of lessons observed			
	biology	chemistry	physics	TOTAL
Key Stage 3 (11-14)	2	6	7	15
Key Stage 4 (15-16)	1	3	6	10

Table 5 The practical tasks and teachers observed

Task content		Teacher	Key Stage
1	Food tests – test results	Mrs Ugthorpe	3
2	Heart beat/pulse – numerical equivalence	Mrs Risplith	3
3	Chemical reactions – how to identify	Mr Dacre	3
4	Separation - sand and pepper	Mr Fangfoss	3
5	Separation – iron, salt and sand	Mr Keld	3
6	Chromatography - separation of inks	Miss Nunwick	3
7	Cooling curve – characteristic plateau	Mr Oldstead	3
8	Chromatography- separation of inks	Mr Saltmarsh	3
9	Heat absorption – colour as a variable	Mr Drax	3
10	Electric circuits - current conservation	Mrs Duggleby	3
11	Electric circuits - current conservation	Ms Ferrensby	3
12	Electromagnets – factors effecting strength	Dr Kepwick (female)	3
13	Electromagnets – factors effecting strength	Mrs Kettlesing	3
14	Pulleys and levers - factors affecting	Miss Kilburn	3
15	Magnetic permeability of materials	Mr Overton	3
16	Starch production – factors that effect	Mr Sewerby	4
17	Acid + base = salt + water	Mr Drax	4
18	Electrolysis – increase in cathode mass	Mr Ulleskelf	4
19	Electrolysis – cathode deposits	Mr Rainton	4
20	Lenses and eyes – similarities	Mr Normanby	4
21	Refraction – ray paths	Mr Normanby	4
22	Current in series and parallel circuits	Mrs Uckerby	4
23	Voltage in parallel circuits	Mrs Ramsgill	4
24	Work done in raising mass	Miss Sharow	4
25	Current and voltage in series circuit	Dr Starbeck (male)	4

Table 6 Teachers' use of schemes of work and worksheets

(a) Teachers working within their subject specialism

		Using worksheets	
		Yes	No
Following a scheme of work	Yes	2	2
	No	0	5

(b) Teachers working outside their subject specialism

		Using worksheets	
		Yes	No
Following a scheme of work	Yes	6	4
	No	1	5

Table 7 Allocation of whole class time to different aspects of the lesson

		Time (in minutes) spent		
		by teacher on whole class discussion (and perhaps demonstration) of		by students on
Task	Teacher	what to do with objects and materials	ideas and/or models to be used	manipulating objects and materials
1	Mrs Ugthorpe	13	0	28
2	Mrs Risplith	13	0	10
3	Mr Dacre	4	0	46
4	Mr Fangfoss	11	0	20
5	Mr Keld	17	3	14
6	Miss Nunwick	3	0	30
7	Mr Oldstead	15	0	40
8	Mr Saltmarsh	14	0	18
9	Mr Drax	9	0	28
10	Mrs Duggleby	8	0	23
11	Ms Ferrensby	10	0	28
12	Dr Kepwick (female)	14	0	26
13	Mrs Kettlesing	6	0	34
14	Miss Kilburn	9	4	25
15	Mr Overton	10	0	20
16	Mr Sewerby	21	0	33
17	Mr Drax	11	0	40
18	Mr Ulleskelf	9	5	33
19	Mr Rainton	14	0	23
20	Mr Normanby	2	0	7
21	Mr Normanby	33	0	10
22	Mrs Uckerby	10	0	24
23	Mrs Ramsgill	5	0	34
24	Miss Sharow	11	5	15
25	Dr Starbeck (male)	7	29	14