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School of Education

Knowledge Building among School Students Working in a Networked Computer Supported Learning Environment

by

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ABSTRACT

FACULTY OF LAW, ARTS AND SOCIAL SCIENCES

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KNOWLEDGE BUILDING AMONG SCHOOL STUDENTS WORKING IN A NETWORKED COMPUTER SUPPORTED LEARNING ENVIRONMENT

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The National Curriculum for Science in England requires science teachers to teach about scientific enquiry, and contains details of the expectations of practical investigations connected with this teaching. Although such investigations are intended to be open-ended and to lead to a range of possible outcomes, the dual rôle of practical work as it functions as a warrant for belief can often lead to investigations serving both rôles in an unsatisfactory fashion.

This study describes an investigation into the use of online discussion forums (both asynchronous and synchronous) to support Year 9 students (aged 13/14 years) in two English schools as they conducted science investigations. These investigations were carefully chosen to provide ample scope for students to produce scientific explanations for simple phenomena (the behaviour of a prototype toy and the digestion of cooked egg white by biological washing powder) without the need to focus on replicating accepted scientific theories. Whilst working on their investigations, students made use of online resources designed to enable them to communicate with other members of the group and to share ideas whilst outside the science classroom. These online resources were structured through the application of activity theory, the focus being directed towards three aspects of the online interactions: Subject-Community-Object (knowledge-building); Rules-Community-Object (sociology of science); Tools-Community-Object (epistemology of science).

Analysis of the logfiles of online discussions was conducted by identification of critical incidents in order to focus attention on interactions between students which merited deeper investigation, making use of taxonomic frameworks derived from literatures associated with studies of the nature of science. Further explication of critical incidents was sought through critical incident recall using group interviews with students, providing them with an opportunity to contribute to the construction of meaning relating to their discussions. The outcomes of this analysis suggest that students employ a range of tacit tools and rules when engaging in knowledge-building, and that the process of critical incident identification and recall used in the research may be employed as a valuable pedagogical tool when online discussion is used with students.

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The gods did not reveal, from the beginning,
All things to us, but in the course of time
Through seeking we may learn and know things better.
But as for certain truth, no man has known it,
Nor shall he know it, neither of the gods
Nor yet of all things of which I speak.
For even if by chance he were to utter
The final truth, he would himself not know it:
For all is but a woven web of guesses.

Xenophanes (570-475 BCE)

Translation from Karl Popper
"The Problem of Induction"

When in a Search of any Nature the Understanding stands suspended, then Instances of the Fingerpost shew the true and inviolable Way in which the Question is to be decided. These Instances afford great Light, so that the Course of the Investigation will sometimes be terminated by them. Sometimes, indeed, these Instances are found among that Evidence already set down.

Francis Bacon, *Novum Organum Scientarum*
Section XXXVI, Aphorism XXI

The idea that science can, and should, be run according to fixed and universal rules, is both unrealistic and pernicious. It is unrealistic, for it takes too simple a view of the talents of man and of the circumstances which encourage, or cause, their development. And it is pernicious, for the attempt to enforce the rules is bound to increase our professional qualifications at the expense of our humanity. ... All methodologies have their limitations and the only 'rule' that survives is 'anything goes'.

Paul Feyerabend, *Against Method*
(Concluding chapter)

Chapter 1

Setting the scene

Introduction

This research concerns the use of networked computers as a medium for the discussions of secondary school students relating to practical science investigations. The work is influenced by two areas of knowledge, one concerned with science education, the other with the use of networked computers. In this chapter these influences are considered in order to provide the background to the research; the problem to be solved is described, and the significance of the research is discussed.

Defining terms

In this thesis the term *networked computers* is used to describe computers connected together as a means of sharing resources (these may be information or physical objects such as printers, scanners etc), on whatever scale. When computers (whether networked or not) are used to support and promote shared learning among and between individuals, the term generally used in the research literature to describe this activity is "CSCL" (Computer Supported Collaborative Learning), although Lipponen points out that the latter "C-word" may also stand for *co-operative*, *collective* or *coordinated* (Lipponen, 2001:7). The focus on learning distinguishes CSCL from CSCW – where W is "Work" – in which the intention is to promote the performance of a task (Crawley, 1997b). In the context of the study described in this thesis the term CSCL is used in a quite specific sense – to describe the activity that occurs when students work together in pursuit of a common goal in an environment containing networked computers, the intention being to promote shared learning. CSCL has been described as involving *collaboration*, *co-operation*, *coordination* AND *collective action* – the precise definition of the second "C" word lies somewhere among all of these, as will be shown. As part of CSCL, students

communicate using computers as a medium (for example, through email) – the general term for this process is "Computer Mediated Communication", or CMC.

Background

In order to describe the context in which this work is set it is necessary to describe something of the history and the thinking associated with the use of science practical work in schools and with the use of networked computers in learning. This is a necessary precursor to the discussion of the particular problem explored by the research and the significance of this problem.

Science education

In the last 15 years, many books have been published concerning the variety of challenges to be met by secondary science education (for example Woolnough, 1991a; Wellington, 1994; Levinson, 1994; Levinson & Thomas, 1997; Ratcliffe, 1998a; Monk & Osborne, 2000; Sears & Sorensen, 2000; Wellington, 2000). In all of these, science practical work (its nature, purposes and conduct) and the nature of science (in the context of developing young people's understanding of how scientists work and the powers and limitations of scientific knowledge) are explored in considerable depth. Often, the exploration of these two themes is closely related: Millar argues for the need to teach "practical techniques" of scientific enquiry and "inquiry tactics" as a way of developing students' understanding of the way in which scientific knowledge is acquired (Millar, 1991: 51); Monk & Dillon are concerned that students should understand the rôle of theory in guiding the collection of experimental data (Monk & Dillon, 2000: 79); and Wellington raises issues relating to the images of science that are presented to students through their experiences of practical work (Wellington, 2000:226-248).

The lack of clarity of purpose of much science practical work carried out in schools is likened by Woolnough to an extract from *The House at Pooh Corner* where Winnie the Pooh first meets Tigger (Milne, 1928:21):

> *... and with one loud Worraworraworraworraworra he jumped at the end of the tablecloth, pulled it to the ground, wrapped himself up in it three times, rolled to the other end of the room, and, after a terrible struggle, got his head into daylight again, and said cheerfully: 'Have I won?'*
>
> (Woolnough, 1991a:3)

One reason for this lack of clarity is that teachers state a wide variety of reasons for carrying out practical work, which include motivating students, encouraging accurate observation and aiding understanding (Kerr, 1963; Woolnough & Allsop, 1985); these reasons have remained remarkably consistent over the last 35 years (Swain, Monk & Johnson, 2000). Yet the purposes of practical work in science lessons as evidenced in documents that currently inform and guide science teaching on a working, day-by-day level are quite unambiguous:

> *During Key Stage 3 pupils ... use scientific ideas and models to explain phenomena and events ... do more quantitative work, carrying out investigations on their own and with others. They evaluate their work, in particular the strength of the evidence they and others have collected ... They communicate clearly what they did and its significance ... learn how scientists work together ... and about the importance of experimental evidence in supporting scientific ideas.*
>
> (DFEE, 1999:28)

The function of practical work in such a context is clear, and divides into two different areas:

a) providing students with evidence for a particular theory; and
b) providing a way of helping students to develop some understanding of the methods used by scientists as they develop scientific theories.

These are considered below.

Providing students with evidence

In many cases, practical work is seen as a "warrant for belief" (Brickhouse et al, 2000), providing students with opportunities to make observations that support the theories that they are learning; for example, the increase in mass recorded when magnesium is heated in

air is commonly used as a way of "showing" students that chemical combination produces an increase in mass.

As Hodson points out, there are problems – both philosophical and pedagogical – with the use of practical work in this manner. Philosophically, the use of a school practical to "test" a scientific theory is seriously flawed, since the outcome is certain by the very nature of the theory being tested. Otherwise it would be impossible to explain the continued existence of Newton's second and third laws of motion when there is daily proof from school science laboratories that momentum is *not* conserved in collisions:

> *... children are seriously misled by teachers who pretend that they are testing a theory when, in reality, they are illustrating it. The so-called rigorous testing of hypotheses by experimental methods that is given pride of place in the Nuffield courses is something of a sham, because success is guaranteed and is under-written by the assumptions of the very theory that is supposed to be under test.*
>
> (Hodson, 1988:27)

Lakin and Wellington (1994) write about the strong link that exists between teachers' classroom practice and their views on the nature of science. They describe the results of a small study in which these views were explored, noting that the teachers were insecure about their ideas, and had had little opportunity for reflection on them as part of their initial training or their teaching experience. An extensive review of the literature related to teacher's conceptions of the nature of science (Abd-El-Khalik & Lederman, 2000) supports these conclusions, and notes that "it should be emphasized that possessing adequate understandings of NOS [the nature of science] is not sufficient to enable teachers to enhance students' conceptions of the scientific enterprise." (Abd-El-Khalik and Lederman, 2000:696). The implication of Hodson's concern when coupled with these conclusions suggests that a poor understanding of the nature of science among science teachers is highly likely to lead to potentially confusing messages being sent to students through poor pedagogy. More positively, Bartholomew, Osborne and

Ratcliffe argue that teachers' knowledge and understanding of the nature of science is only one of five *dimensions of practice* concerned with teaching students ideas about science. They believe that there are reasons to think that teachers may be equipped to provide students with insights into the nature of science even if they express a lack of confidence in their ability to do so (Bartholomew, Osborne & Ratcliffe, 2004).

To many teachers, engaged in a pragmatic search for meaningful experiences for students as part of their science education such concerns may seem irrelevant or even trite. But pedagogical issues relating to the use of the outcomes of practical work as a rhetorical device to convince students of the correctness of a particular interpretation of the world also raise concerns.

Most science teachers are familiar with situations in which students undertaking practical work obtain conflicting results. Such a situation may arise due to inconsistencies *within* data collected during a single investigation, or due to inconsistencies *between* datasets collected during several instances of a particular investigation. The collection of oxygen (demonstrated through the rekindling of a glowing splint) from pondweed illuminated by bright light is an example of this (Nott & Smith, 1995:403).

Personal observation of this lesson taught by many trainee science teachers over the years has found this piece of practical work to be extremely problematic, in the sense that there is always one or more sets of results which clearly show that the gas collected extinguishes a glowing splint and is therefore not oxygen. In every case the role of the practical work as a warrant for belief was very clear to the teacher, who wanted to be able to say (effectively) to the students – "you've seen this happen for yourselves!". For this reason, the need to find a convincing way to "explain away" the anomalous results is very strong,

and the experienced teacher has many such explanations. (There is also evidence to suggest that experienced teachers may resort to dubious practices ("fiddling" and "conjuring") in anticipation of such problems (Nott and Smith, 1995).) Students are generally quite well-aware of their own shortcomings and of the shortcomings of the school's apparatus when it comes to practical work, and will normally defer to such explanations.

Despite their apparently willing acceptance by students, the messages, both overt and covert, that teachers convey when they provide plausible explanations for the outcomes of practical work that has "gone wrong" (Nott and Smith, 1995:399) can be very undesirable. For example, Driver points out that when teacher and textbook appear as a kind of "revealing authority", their message carrying weight by virtue of its status, the outcome may well be a kind of dual-belief system:

> *... learners [may] accept what they are presented with through books, teacher talk and guided experimental work because of its authoritative status. This can and does get in the way of students making sense of the ideas for themselves ... [so] that students may have one belief system which operates in the classroom, and a quite separate set of beliefs which operate elsewhere – hardly a recipe for scientific literacy.*
> (Driver, 1989:103)

This tension between the "real world" and "school science" (which from now on in this thesis will be referred to respectively as "scientists' science" and "students' science") is there to be resolved within any kind of activity involving science investigations. Not only does the teacher in search of a warrant need to explain why the results obtained by student A differ from those obtained by student B; it is also very frequently necessary to explain why the outcomes of scientists' science differ from those of students' science. Concerning this, Millar writes :

> *... students in science classes construct their own meanings for events and phenomena ... The science teacher (and the textbook) have access to one preferred set of meanings which have been constructed by scientists and [which] ... necessarily carry greater weight than students' personal meanings ... But this does not negate the need to* ***discuss*** *and* ***negotiate*** *the meaning of observation and experiment in the science classroom.*
>
> (Millar, 1989a:56 [original's emphasis])

The need for discussion and negotiation of meaning relates closely to the second function of practical work in school science, which concerns the desire for students to develop some understanding of the methods used by scientists as they develop scientific theories.

Helping students understand the methods of science

The role of practical work in science as a vehicle for gaining an understanding of the methods used by scientists first came to prominence in curriculum developments in the 1960s and 70s, with the Nuffield vision of the "pupil as scientist" (Millar, 1998:17). The Nuffield projects presented students with a model in which scientific thought develops through the engagement of scientists with experiments concerned with manipulation and observation of the natural world. Through the involvement of students with the natural world in a similar way, the projects aimed to provide them with a better understanding of scientific theories, this deriving from having "discovered" or "proved" such theories themselves to their own satisfaction:

> *Even at school it is not too early for young people to think about scientific things in the way that practising scientists do. Thus the objective ... is to encourage children to think freely and courageously about science. ... the best way to awaken original thinking in children studying science is to engage them in experimental and practical enquiry.*
>
> (Nuffield Foundation, 1964:5-6)

The philosophical shortcomings of this approach have already been touched upon earlier in this chapter. There is also evidence to suggest that students have considerable difficulty in making links between their

practical work and theories of scientific knowledge (Solomon, 1991). Citing work carried out in the UK and Canada, Solomon observes that:

> *Neither project gives much hope that a student diet of laboratory work would automatically yield understanding of* ***the nature of science.***
> (Solomon, 1991:97 [original's emphasis])

The Nuffield courses with their emphasis on practical work were succeeded by the "process science" movement of the 1980s (Nuffield Foundation, 1999:6). This movement saw science as having a set of processes such as observing, classifying, hypothesising etc which are entirely distinct from processes concerned with everyday life. Two well-known examples of schemes teaching materials produced using such a philosophy were *Warwick Process Science* (Screen, 1986) and *Science in Process* (Wray, 1987). The presentation in these teaching schemes is one in which science consists of a unique, hierarchical set of processes in which observation precedes theory. This is based on a model of science that has as its chief characteristic *naïve inductivism* (Chalmers, 1982), an epistemological position widely regarded by philosophers of science as unsound (see, for example, Chalmers, 1982:2-11 and O'Hear, 1989:12-34). The idea therefore that any reasonable picture of the methods used by scientists could arise from such schemes is quite unrealistic, embodying as they do a picture of science that is rejected both by philosophers and by science studiers (the term used by Yearley (1994) "to embrace historians and the whole variety of social analysts of science"), and from within the science education community itself (Millar, 1989b; Selley, 1989).

At the end of the 1980s, the Education Reform Act of 1988 brought the introduction of a National Curriculum for science to all maintained schools in England and Wales. Introduced in 1989, the statutory orders setting out what was to be taught consisted of 17 "Attainment Targets", one of which ("Attainment Target 1" or "AT1") was concerned with students' practical work. Influenced at least in part by the process science movement that had come before it, AT1 required students to

undertake science investigations which were assessed. The model of science behind the investigations required by AT1 lay very much in the sphere of naïve induction, with variables to be controlled, varied and measured in pursuit of testing a hypothesis. While students were required to assess the extent to which the data collected in a particular investigation could be regarded as "reliable" and thus to evaluate the strength of their conclusions drawn from it, there was no suggestion in AT1 that scientists' science involves a process of evaluating knowledge claims within a social arena. Yet elsewhere in the orders (in AT17 – "Exploration of Science") students were required to *be able to demonstrate that different interpretations of experimental evidence are possible* (Department of Education and Science, 1988).

The introduction of this model of practical work, overlaid by a complex system of assessment, did not go smoothly, and revisions to the curriculum followed, the most radical being in 1991 (table 1.1). The first column in this table shows how the 1991 revision reduced the number of Attainment Targets and stipulated that students should consider different interpretations of experimental evidence as part of investigations which were to be based on accepted scientific knowledge. Subsequent revisions, in 1995 and 1999 (see the second and third columns in table 1.1), introduced statements relating to teaching students about the nature of scientific knowledge, whilst retaining the requirements relating to experimental evidence and accepted scientific knowledge. This brought about a conflict that, even today, teachers find hard to reconcile – if students' investigative work is to be based on accepted scientific knowledge and is also to be assessed, what exactly is being investigated? As Donnelly *et al* observe:

> *What [do investigations] test: the scientific idea or the pupil's experimental procedures? If, as must surely be the case, the latter, why make the linkage to the former at all? And if, as seems likely to have been the case, the established outcome was clear, in what sense was the investigation open?*
>
> (Donnelly *et al*, 1996:47)

1991	1995	1999
Number of Attainment Targets reduced to four. AT1 and AT17 combined to produce "Sc1". Students required to carry out investigations involving the relationship between variables, and to consider different interpretations of experimental evidence. Investigations must be based upon accepted scientific knowledge. Sc1 is based on three "strands" – *asking questions, hypothesising and predicting*; *carrying out investigations*; and *interpreting results and evaluating scientific evidence.*	Preamble to the Programme of Study for each Key Stage is added. This sets a context within which the study of science is to take place: • *systematic enquiry* • *application of science* • *the nature of scientific ideas* • *communication* • *health and safety* This part of the science curriculum is dubbed "Sc0" by science teachers. It is not assessed directly, and therefore its impact on classroom practice is limited. The three "strands" of Sc1 become four – *Planning experimental procedures*; *Obtaining evidence*; *Analysing evidence and drawing conclusions*; and *Evaluating evidence.*	Principles of "Sc0" in 1995 revision combined with Sc1, requiring teachers to incorporate ideas about the nature of science into investigations and other teaching. Use of ICT in science curriculum compulsory. National Curriculum document includes *non-statutory guidance* highlighting "ICT opportunities" – examples of the use of ICT in teaching specific aspects of the science curriculum.

Table 1.1 – revisions to the National Curriculum for Science

Science investigations are problematic due to the confusion in rôles demanded by teachers, reinforced by the statutory curriculum. At the same time as acting to provide a vehicle for the student gathering data to test a hypothesis or to understand the relationship between several variables, the practical work is also required to provide a warrant for belief, meaning that students' science must not only get an answer which does not challenge scientists' science, but must also do so using plausible methods.

Networked computers and CSCL

If recent publications dealing with the challenges to be met by science education in secondary schools have been consistently concerned with the rôle of practical work and students' understanding of the nature of science, the literature relating to the use of computers in schools over the same period has been much less static. Largely this is due to the technological changes that have happened in this period; but also of

importance is a developing understanding of the *affordances* (Gibson, 1977; Gaver, 1992; Mynatt et al, 1998; Conole & Dyke, 2004; Boyle & Cook, 2004) of computers in the context of the school science classroom.

CSCL in non-school settings

The birth of networked computing in 1969 (Zakon, 2004) provided technologists and educators with a new medium to explore for the purposes of bringing learners together. While the very earliest computer resources involved little more than knowledge representation and transmission (eg the MacMan medical simulations used in Canada in the early 1970s (Darby, 2002:17)), by the 1980s the opportunities offered by computer networks as a means of communication were becoming apparent. During this decade the distribution of videoconferencing data over computer networks became possible (Bretz, 1983:244), and by 1987 the introduction of the *Minitel* service in France had produced the world's largest email community, leading also to the establishment of social bulletin boards or *messageries*, the first public, online communities (Lemos, 1996). Already this new medium had begun to be exploited for educational purposes, with a pedagogy unique to this setting beginning to emerge (Feenberg, 1987). It was, however, the introduction of the hypertext transfer protocol which brought about CSCL as a reality (Darby, 2002:17); the first Web server was established in the USA in 1991 (Gromov, 2003).

The following year, the fourth international research conference on computer supported cooperative work (CSCW) was held in Toronto; as implied by the title, the conference was concerned with the use of networked computers in workplace settings and their rôle in the "shift from an industrial to a post-industrial age" (Kumon, 1992). A similar optimism for the transformative rôle of computers pervades some writing about the potential for networked computers in learning from around this period, for example: "... this medium can be more effective

than either the traditional classroom or one-way distance education delivery" (Hiltz, 1992:206); "... distance education systems should place more emphasis on active and cooperative learning strategies ... CSCL might well play a major role in this process" (Kaye, 1995:142). Whether this optimism was well-placed or not, the employment of CSCL in university courses at the start of the 1990s was certainly not limited to a few isolated courses (Hiltz, 1992:188).

During the following decade the rapid development of new technologies (both software and hardware) opened up the possibilities for CSCL. Reviewing the technologies for CSCL, McConnell describes four factors leading to wider use of CSCL, based on: accessibility of computer technologies at home and at work; the increasing sophistication and ease of use of software; increasing availability of access to networked computers; and the incorporation of the Web and the Internet into people's everyday lives (McConnell, 2000:67-68). This situation has given rise to the widespread adoption of CSCL in higher education, where course tutors and leaders are " ... in an enviable position of having a variety of media to choose from in the organization of teaching and learning" (McAteer et al, 2002:309). It is also the case in organisations outside education, for example, in industry:

> *Video-conferencing technologies are used in corporations to enable distributed groups to work together regularly without the need for frequent travel. On-line computer conferences and chat rooms provide ... additional ways to post materials and interact with students in large lecture classes.*
>
> (Ruhleder, 2002)

CSCL in schools

Despite the widespread adoption of CSCL in settings outside schools the implications of this new technology for school science teaching in the early 1990s was yet to be considered. At this time science educators working on the use of computers in teaching and learning science were concerned to develop software and techniques for data-logging, for simulating laboratory practical work and for small-scale databases

(Kahn, 1985; Rogers, 1990; Lunetta & Hofstein, 1991). The absence of any significant interest in the use of networked computers at this stage to support science education is reflected in the ImpacT Report (King's College, 1993). Describing the outcomes of a two-year longitudinal study carried out in London schools between 1989 and 1991, this makes no mention of the use of networked computers in schools.

With the growth of the Web, the use of networked computers in schools for educational purposes appeared to grow during the 1990s and into the early part of the 21st century, according to official figures (table 1.2). Comparison between the figures over this period is difficult since the basis on which data were collected changed with a new administration in 1997; the emphasis in later years lay in measuring the growth of Internet connections with greater bandwidth, in connection with the government target of connecting all schools to the Internet via a broadband connection of 2Mbit/s or greater by 2006 (DfES, 2003:3). Nevertheless, the two surveys cited in table 1.2 clearly show the growth of computer networks in schools over this period, although the more recent report provides no information concerning the nature of students' use of this equipment.

Although a high proportion of computers used for teaching and learning in secondary schools are connected to the Internet, the ImpaCT2 Report (Harrison et al., 2003) shows that these machines may not receive extensive use. Based on a survey of 60 schools in England carried out between 1999 and 2002, 31% of students in Key Stage 3 reported "using ICT at least some weeks in lessons in 2001", while "30% reported using computers at home in some weeks" (Harrison et al., 2003:6); figures for Key Stage 4 were very similar. Much of this employment of computers in science appears to be "Internet use" (Harrison et al., 2003:33), but the report provides no further insight into the nature of this use other than to speculate as to the nature of the "research activities" to which this use may relate.

1996	2002-03

"In the secondary sector, the most commonly used service was electronic mail, used by 58 per cent of schools."
(DfEE, 1997:18)

"Pupils used WorldwideWeb [sic] and text only Internet services in 30 per cent and 20 per cent of schools respectively."
(DfEE, 1997:18)

	2002	2003
Secondary schools with Internet connection	>99%	>99%
Connection by modem	1%	1%
Connection by ISDN2	28%	9%
Connection >128kbit/s <2Mbit/s	3%	5%
Connection >2Mbit/s	68%	86%

Proportion of computers connected to the Internet in schools:	2002	2003
Teaching and learning	82.9%	86.5%
Management	80.8%	87.3%

(DfES, 2003:17)

Table 1.2 – Government statistics for the use of computers in schools in the UK

Two sources provide further insights into the way in which computers are currently used in secondary science teaching. The first of these is a special edition of the Association for Science Education's *School Science Review* (SSR) devoted to ICT in science education (Wellington, 2003b), and the second is a report of by the Office for Standards in Education (Ofsted) examining the effect of government ICT initiatives on the teaching of science in secondary schools in England and Wales (Ofsted, 2002). These two sources and their findings are described below.

The SSR special edition contains ten articles by teachers and researchers designed to argue the case that "ICT has made and can make a difference to science education, when used thoughtfully and reflectively" (Wellington, 2003a:39). Whilst there is no claim in this editorial piece that the articles are intended to comprise a complete review of all possible uses of ICT in science teaching, it is reasonable to assume that the intention of this collection is to cover the major areas of ICT likely to be of interest to science teachers and educators involved in working with students in secondary schools.

A survey of the articles in the SSR special edition produces the list of ICT applications shown in table 1.3, in which those relating to networked computers are marked with an asterisk (5 out of 13). The division of these uses of networked computers falls into two classes: searching for information and sharing/communicating information (table 1.4). This division has been noted by Fullick, in the context of motivating students to use the Internet for school science work where sharing/communicating information engages students more actively in making sense of scientific ideas than simply searching for information (Fullick, 1997).

• "Office" applications for worksheets and presentations • digital photography • production of a Website * • using GCSE online resources together with an online student portfolio * • spreadsheets • datalogging	• wordprocessing • CD-ROMs • Internet for research * • online real-time quiz * • Websites for revision * • digital microscope • video and CDs for modelling and simulations

Table 1.3 – uses of ICT in SSR no 309 on ICT in science teaching

Classification	Use
retrieving information	• Internet for research • Websites for revision • using GCSE online resources
communicating/sharing information	• production of a Website • online student portfolio • online real-time quiz

Table 1.4 – classes of networked computer use in SSR no 309

The Ofsted report on the effect of government ICT initiatives on science teaching in secondary schools is based on school inspection evidence collected between May and December 2001 (Ofsted, 2002:4). It identifies three "principal approaches" to the use of ICT in science classrooms:

- *... computer-linked instrumentation to support pupils' practical work*
- *single computers and data-projectors or whiteboards*
- *computer suites for ... interactive software or information retrieval*

(Ofsted, 2002:5)

Only the third of these approaches employs networked computers, and simply in the sense of information retrieval, not information sharing. Nowhere in the Ofsted report is there any evidence to suggest that networked computers are used in secondary school science in the UK to encourage students to share their ideas with other students in a dynamic way – employing them to foster co-operative learning (McConnell, 2000). Surveys two years later also contain no mention of the use of networked computers in science lessons (Ofsted, 2004b) or in any other areas of the school curriculum (Ofsted, 2004a), all descriptions of computer networks relating solely to their employment in distributing access to hardware and software resources. The absence or near-absence of the educational use of networked computers in schools is a situation also found outside the UK (Lakkala, Rahikainen, & Hakkarainen, 2001:24).

Networked computers and science learning

The importance of the personal and social construction of knowledge in science classrooms was raised earlier in this chapter, in the context of students making sense of the outcomes of science practical work.
In view of the influence of constructivism in science education (Driver, 1994; Leach & Scott, 2000; Scaife, 2000), the lack of any mention of CSCL in the literature relating to priorities for the development of school science education is surprising, since CSCL has a strong tradition of constructivism, as chapter 2 will show. It is also some cause for concern, for two reasons.

First, as described in the earlier part of this chapter, CSCL has been used to extend traditional learning communities in Higher Education and Continuing Education for some time. In addition to the straightforward provision of resources via the Web, online learning in these settings commonly makes use of tools that allows learners to communicate with one another in order to foster discussion and so encourage the social construction of knowledge – for example, the open source learning

environment *Moodle* (Dougiamas & Taylor, 2003). The use of online learning environments in universities has been the subject of considerable research which could potentially be used to inform the development of computer networks as a tool for learning in schools (Lakkala, Rahikainen, & Hakkarainen, 2001).

Second, despite the fact that they do not commonly encounter computer networks as a means of actively communicating and sharing knowledge in school, children do use make use of them outside school. There is an emerging literature relating to children's out of school use of networked computers that shows that they make use of them to establish, maintain and develop relationships with other students, both known and unknown to them at school (Livingstone, 2002; Holloway & Valentine, 2003; Facer *et al*, 2003; Livingstone & Bober, 2004). Research conducted in 2001 suggests that at that time 20% of young people in the UK between the ages of 7 and 16 used chatrooms, and 12.5% used instant messaging programs (Cyberspace Research Unit, 2002); it therefore seems likely that a small but significant proportion of school students make use of networked computers as a communication tool, much as previous generations made use of the telephone; in fact, many young people see the primary purpose of their Internet use as keeping in contact with friends:

> *Children's motivations for going online centre on new opportunities for communication and identity play. While the conversational content is often mundane, being readily in touch with their friends is important to them.*
>
> (Livingstone & Bober, 2003:2)

The proportion of school students using the Internet in this way continues to grow. Based on a survey in early 2004, Livingstone and Bober report that "among the 84% of 9-19 year olds who use the internet daily or weekly ... 55% [use it] to send and receive instant messages" (Livingstone & Bober, 2004:1). Another study found that "... young people find some forms of on-line communication more private and more intimate than off-line communication – they use MSN/IM

[instant messaging software] to discuss personal problems, ask for advice from peers, etc." (Media Awareness Network, 2004:12). This literature suggests that the lives of children in the UK today are intertwined inextricably with technology, a relationship that has been described as a "powerful association" in which children and technology are "natural bedfellows" (Facer *et al*, 2003:4).

The research problem

This chapter has shown that an important current issue for science education research is the use of investigations and practical work as means of developing school students' understanding of the nature of science. A particularly promising approach appears to be by means of discussion, engaging students in the active construction of meaning through language, creating knowledge that is new to the learners both in a sense that is both personal and collective (Sutton, 1996). At the same time, there is widespread adoption of CSCL outside school education. The growing body of research into the use of this form of learning therefore provides an opportunity to inform enquiry into how CSCL might be used in schools to encourage students to participate in the joint construction of scientific meanings, extending discussions about practical work beyond the classroom using a medium in which many students already feel comfortable. Evidence for young people's growing use of the Internet as a communication medium serves to support the idea that this is a very timely proposition, especially given the lack of use and awareness of CSCL in school education.

The question that arises from considering the use of CSCL to support practical science investigations is:

> Can CSCL be used to provide secondary school students with a way of sharing and discussing ideas relating to practical science investigations?

As the following chapter will show, this is a particularly important question because there is little research in this area, and the lack of use of CSCL in schools does not reflect its widespread use in areas such as universities and continuing education, nor its rôle in the lives of young people. Figure 1.1 shows how the inquiry into this question was planned, and the relationship of this plan to the structure of the thesis.

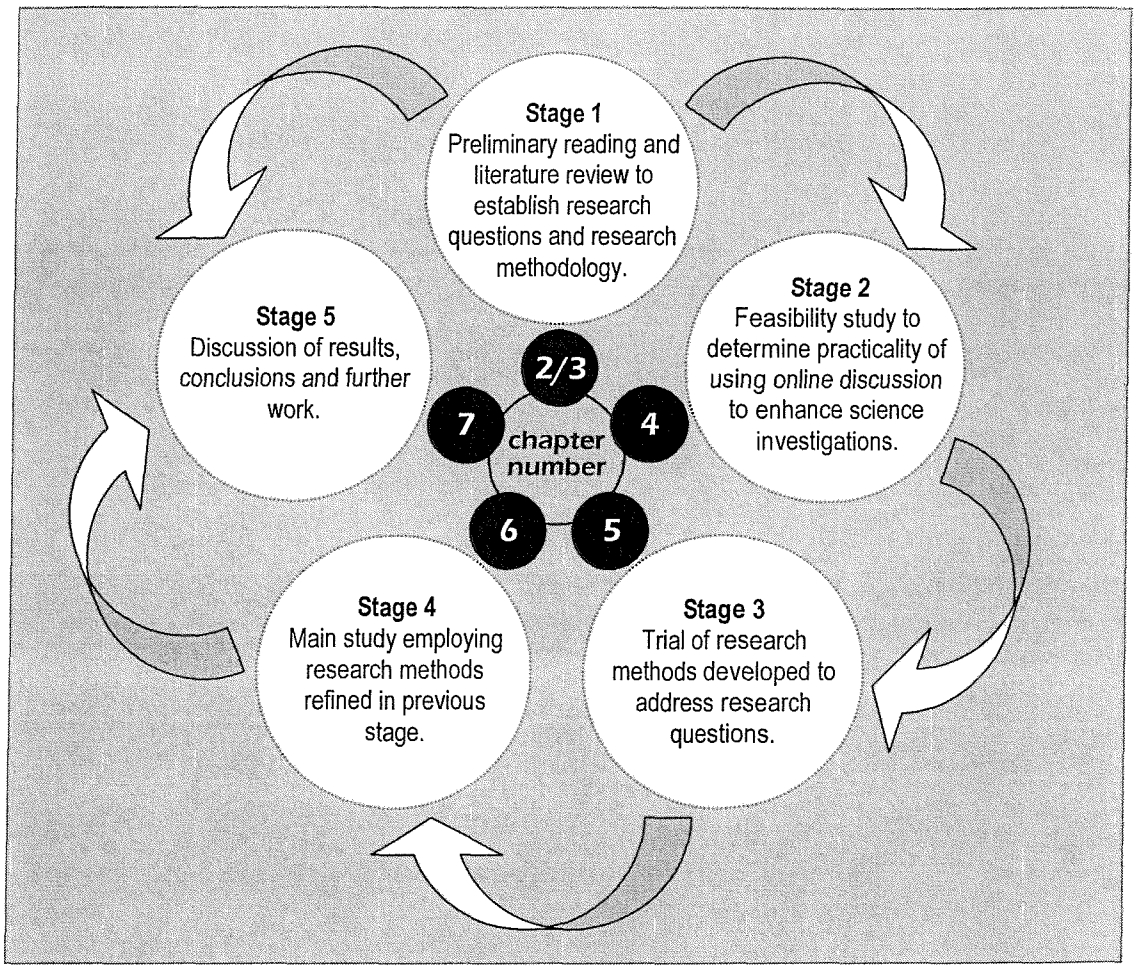


Figure 1.1 – research plan and thesis structure

Chapter 2

Surveying the literature

The previous chapter described two broad areas of knowledge relevant to this study – one concerning science education, the other the use of networked computers in learning. In addition, the influence of policy in respect of these two areas is important. Having posed the question "Can CSCL be used to provide secondary school students with a way of sharing and discussing ideas relating to practical science investigations?" at the end of chapter 1, this chapter examines the research literature in the two areas of knowledge and considers the effects of policy (as formulated by governments and other influential institutions). The model for this examination is shown in figure 2.1.

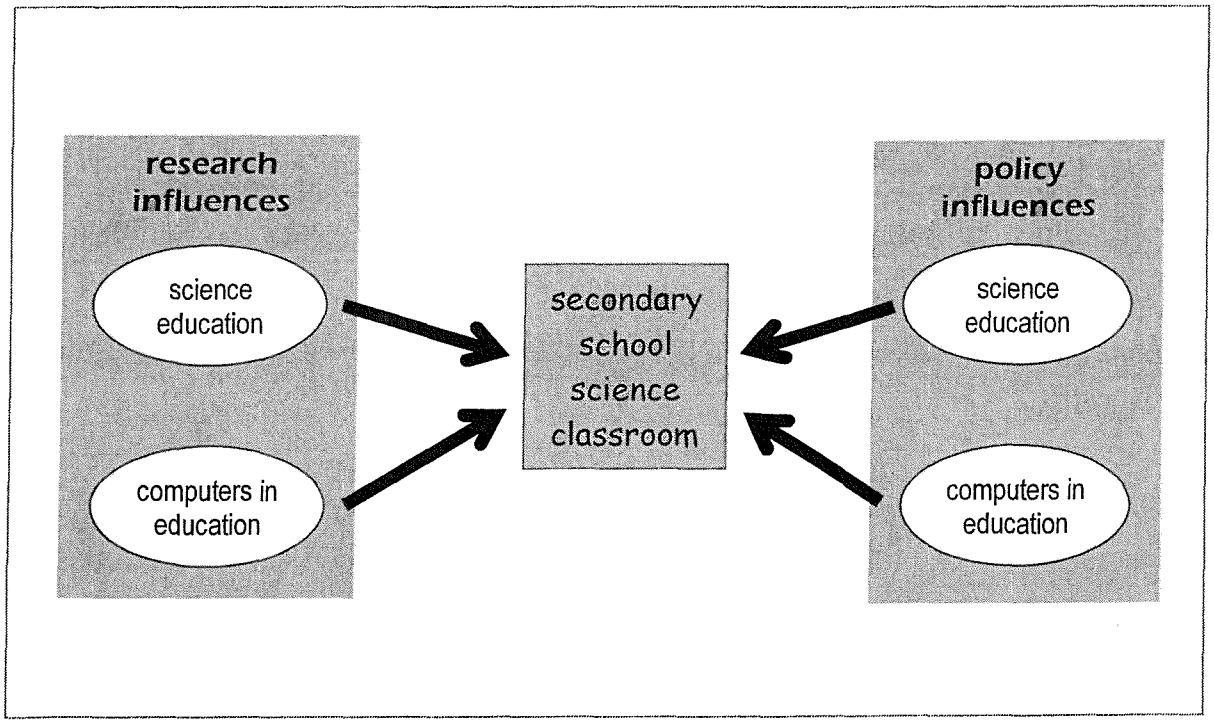


Figure 2.1 – the model for the literature review

Science education research

Two areas of science education literature provide particularly useful insights into the background to this study, relating to:

- science practical work and investigations; and
- developing students' understanding of the nature of science.

The sections that follow examine the research literature in these areas, concluding with an exploration of the implications for classrooms in which science practical work is intended to lead to an increased understanding of the nature of science.

Practical work

The dual rôle of practical work has already been noted, and the problem of linking student investigations to established scientific theories discussed. As this discussion showed, it is often problematic to use students' direct practical experience as a warrant for belief, and pre-service science teachers need to develop a repertoire of responses to questions like "what's the right answer?" if they are to use practical work in this way. In student science, "what happened?" can ultimately be answered by appeal to the teacher as authority (or, if the teacher is unsure, there can be an appeal to a textbook or other authoritative source). The resolution of conflicts of interpretation of this kind has no exact parallel in the world of scientists' science, where there is no higher authority to whom an appeal for arbitration may be made, at least when a dispute about science outside *normal science* is concerned (Kuhn, 1970:10). This situation has been dubbed *the experimenter's regress* (Collins & Pinch, 1994:97-8). The manner of the resolution of the experimenter's regress quite clearly differentiates the practice of students' science from that of scientists' science. Whilst scientists carry out what are usually referred to as *experiments*, in which the observations and their interpretations form quite legitimately the subject for debate and resolution among the community of scientists themselves, school students are held to carry out science *investigations*. These are generally closed, insofar as they concern situations in which the science involved is well-known and understood by scientists themselves, and is not a matter for genuine discussion (Sutton calls this kind of science knowledge *finished* (Milne, Sutton, &

Martin, 2002)). For this reason, school science investigations are epistemologically dead; they are closed to debate, and the opinions of the participants (student scientists) count for very little.

The situation is not always as clear-cut as this, however. One way in which some science educators have addressed the closed nature of school science investigations has been to narrow down the particular focus of investigation so that students investigate something quite specific. Thus, in the activity "Breakthrough" (Fullick *et al*, 1996b:96), students are invited to produce explanations for the ability of bluetits to peck holes in the foil caps of milk bottles based on ideas of pressure. Such explanations will be, by their very specificity, non-threatening to generalised scientific theories, being what Wenham refers to as *singular problems* (Wenham, 1992). For Millar this process, in which students "measure the efficiency of *this* bow and arrow or *this* motor; ... investigate the pollution of the *local* stream ... [original's emphasis]" is problematic (Millar, 1989a:43) due to the nature of its outcomes, which are *locally* rather than *generally* valid (Millar's terms). Wenham disagrees, suggesting that such investigations in *applied science* (Wenham's term) are far from second-rate, and comparing them to the puzzle-solving of Kuhnian normal science.

The contrasting social practices in students' science and scientists' science highlight the essential difference between the two – that where the practice of scientists' science is quite clearly aimed at the production of new knowledge *ab initio*, the practice of students' science is concerned with knowledge that is new only in the sense that students encounter it for the first time.

Types of school science practical work

Despite current distinctions between students' science and scientists' science, this demarcation has not always been so strongly drawn. The justifications given by teachers for using practical work and an

examination of the use of language used to describe it document a change in the approach to science practical work which occurred during the latter part of the last century.

Although teachers' reasons for carrying out practical work have remained remarkably constant over time (see page 3), Watson notes that teachers rate four reasons more highly in recent studies than in earlier studies – these reasons are all connected with the introduction of investigative work in school science:

- *to practise seeing problems and seeking ways to solve them*
- *to develop a critical attitude*
- *to develop an ability to cooperate*
- *for finding facts and arriving at new principles*

(Watson, 2000:58)

This change in emphasis from "verification of facts" (Kerr, 1963:25) towards more open-ended tasks has accompanied a change from the Nuffield science schemes through process science to the National Curriculum, a history documented by Wellington (1998b).

It is not only science teachers' expressed reasons for conducting practical work that provide evidence of this change. Just as the language that science teachers adopt when teaching science provides insight into the mystique of science as enacted in their classroom (Lemke, 1990), so the language of the curriculum – as evidenced in books, curriculum guidance documents and other resources for teachers and students – tells something about the climate of science teaching at the time it was written.

Published as a resource for teachers, *The Science Master's Book: Series II Part I – Physics* (Adlam, 1936) was intended as a collection of helpful articles to support physics teaching in grammar and technical schools. Interspersed with a huge variety of suggestions for ways of adapting items found in hardware and toy shops for science teaching, there are

many articles about suitable "experiments"; one such involves measuring the refractive index of a liquid using a lens:

> *The following experiment was designed to determine the focal length of a convex lens when immersed in a liquid of refractive index less than that of the material of the lens, and hence to obtain the refractive index of the liquid.*
>
> (Potter, 1936:146)

An analysis of this and ten other articles in the same section of this collection (table 2.2) shows that nine are directly concerned with the measurement of some quantity, two of which also describe the construction of the measuring apparatus in some detail. The authors of these articles adopt various descriptions for the activities: "exercise", "method" and "experiment". In five cases there is no word used by the author to describe the nature of the activity.

The nature of the activities described here and elsewhere in this collection places emphasis on the use of practical work to measure quantities such as the critical angle for a glass/air interface, the emf of a cell and the heat conductivity [sic] of rubber; each of these three tasks is described by its author as an "experiment". There is also emphasis on the use of practical work as a means of demonstrating phenomena, including beats, Lenz's law and pressure in a liquid; once again, these are all "experiments".

Thirty years later, the Nuffield Science Teaching Project produced courses for science students undertaking the study of biology, chemistry and physics at levels ranging from the early years of secondary education to GCE Advanced Level (A-level). Materials for teaching chemistry at A-level were published as a set of two students' books, containing descriptions of practical work, problems and background reading. Students' book I (Stokes, 1970) begins by highlighting the importance of experiments:

> *For chemists, as for other workers in science, experiments and ideas go hand in hand. The two are very closely linked ...*
>
> (Stokes, 1970:6)

This relationship is stressed throughout both students' books with the use of the word "experiment" to describe ALL practical activities carried out by the student, eg "Experiment 3.4a: To find the relative masses of molecules by weighing known volumes of gases" (Stokes, 1970:46). A similar description of practical work is made in the materials for younger students (eg Dowdeswell, 1966; Rogers, 1968). This notion of practical experimental work is built upon the idea of students using it to "think freely and courageously about science" (page 7) in order to develop for themselves some notion of what it is to practise science, as well as to develop some feeling for the belief warrants behind particular scientific theories. Whether this is something that many – let alone all – students are capable of doing is very much in doubt, as Solomon has shown: when asked in a school examination to "describe any one school experiment which helped you to understand a scientific theory" most students could describe an experiment, but only 24% could correctly identify the associated theory (Solomon, 1988).

The Process Science teaching schemes that were prominent successors to the Nuffield schemes in lower secondary schools not only embodied a particular view of science but also provided a framework for teaching about the nature of scientific enquiry. The language used in these schemes was one of *process*, scientific enquiry being portrayed as consisting of a set of processes, each of which was regarded as unique to this field of intellectual endeavour. For example, *Warwick Process Science* encouraged teachers to teach explicitly the processes that the team writing the course held to be characteristic of those "engaged when researchers take part in a scientific investigation" (Screen, 1986). In a similar vein, *Science in Process* argued that "what matters is that students learn to work scientifically, keeping the spirit of enquiry they bring with them from the primary school and learning to apply it in a scientific way" (Wray, 1987). There was a degree of commonality in the language used by the teams responsible for these two courses, as table 2.1 shows.

There can be little doubt that the model of science on which these schemes were based is highly flawed (page 8), and that the portrait of science they convey is highly unsatisfactory. To represent science as having a method consisting of a set of discrete processes and to argue that these are unique to science is not only wrong, but impossible to teach (Millar, 1991) and devoid of any context for addressing the nature and purpose of true scientific enquiry (Carey et al, 1989).

Warwick Process Science	Science in Process
• observing • classifying • inferring • predicting • controlling variables • hypothesising • communicating • collaborating	• observing • classifying • inferring • raising questions • investigating • predicting • interpreting • hypothesising • experimenting • evaluating • applying

Table 2.1 – the *processes* in two different process science schemes

The National Curriculum for Science in the late 1980s was described in chapter 1, together with the assessment of practical work that was introduced as a result. At the time, the introduction of assessed practical work in schools for students up to the age of 16 was presented both as maintaining continuity with existing practice in practical work and as a break with the past, the viewpoint depending upon the particular community from which the argument emerged (Donnelly *et al*, 1996:168). Despite this apparent diversity, the influence of the process science movement on practical work conducted under the guidance of the National Curriculum, with its employment of the word *investigation* as the name for a particular kind of practical work conducted by students, has led to a shift in language in which the word *experiment* has been almost completely banished from the written language of practical school science, its meaning taken to refer uniquely to methods used by professional scientists to develop new knowledge

(Gough, 1998:74). (For example, one widely-used scheme of work for students in the 11-14 age range (Johnson, Adamson, & Williams, 2001) adopts a wide variety of terms for practical work conducted by students, with use of the word *investigation* reserved for work requiring students to find out something for themselves; no use of the word *experiment* is made in either of these contexts.) Table 2.2 documents the change in language between science education of the 1930s and that of the late 1990s.

Source: Adlam, 1936		**Source: Johnson, Adamson, & Williams, 2001**	
Activity title	**Description by author(s)**	**Activity title**	**Description by author(s)**
Wollaston's refractometer	"exercise"	*Investigating charges*	"investigation"
Tracing rays through a prism	none	*Electric charges*	"test"
Refractive index of water	none	*Moving charges*	"investigation"
Refractive index of a liquid	"method"	*Making a fire alarm*	"making"
Refractive index of a liquid	"experiment"	*Circuit diagrams*	"predicting"
Refractive index of a highly refracting liquid	none	*Testing ideas*	"testing"
Refractive index by total internal reflection	none	*Measuring currents*	"measuring"
Critical angle for glass	"experiment"	*Current affairs*	"investigation"
Critical angle for a liquid	"experiment"	*Investigating voltage*	"investigation"
Critical angle for glass	"experiment"	*How big is the push?*	"recording"
Critical angle with different colours	none		

Table 2.2 – comparing the language of practical work

The singular modern use of *experiment* to mean an activity concerned solely with the production of new knowledge is somewhat at variance with the view that the work of practising scientists encompasses a wide variety of activities that may be termed *experimental* (Wellington, 1998b:11-12; Coles, 1998), and also goes against the somewhat broader dictionary definition:

> *An action or operation undertaken in order to discover something unknown, to test a hypothesis, or establish or illustrate some known truth.*
>
> (OED, 1989)

> *A test under controlled conditions that is made to demonstrate a known truth, examine the validity of a hypothesis, or determine the efficacy of something previously untried.*
>
> (dictionary.com)

Whether or not the description of school science practical work as *experimental* is problematic is less important than the change of emphasis that the shift in language described above implies. Practice in science practical work (as exemplified by the physics teaching resources earlier in this chapter) earlier in the 20th century emphasised the repetition by students of work conducted by scientists in order to bring about increased understanding (Layton, 1973:173; Woolnough, 1991b:3; Jenkins, 1998:41-2), implicitly based on the belief that students' science is able in some way to "mimic" what happens in scientists' science (McGuiness, Roth, & Gilmer, 2002:37). As curriculum developments occurred during the second half of the 20th century the rôle of practical work as an aid to understanding remained just as strong, but the focus shifted towards the *processes* involved in practical work, culminating in the investigative work described in the National Curriculum, intended to provide not only a warrant for belief but also an insight into the authentic practices of scientists' science (see page 9).

Students' science and authenticity

If students' science is to be authentic, this implies teaching (or the opportunity to teach) about such things as the nature of science and how scientists work. The literature relating to authenticity in science practical work refers to three aspects of authenticity: with respect to *creativity*; with respect to the *nature of the activity*; and with respect to *language*.

Hodson has pointed out the difficulty of achieving any degree of authenticity in school science, arguing that school practical work promotes nine "common myths":

- *observation provides direct and reliable access to secure knowledge*
- *science starts with observation*
- *science proceeds via induction*
- *experiments are decisive*
- *science comprises discrete, generic processes*
- *scientific enquiry is a simple, algorithmic procedure*
- *science is a value-free activity*
- *the so-called 'scientific attitudes' are essential to the practice of science*
- *all scientists possess these attitudes*
  (Hodson, 1998:95)

In order to counter this process of myth-making, Hodson argues for (amongst other things) *creative* practical work in which students frame their own problems, devise their own enquiries and make sense of their own data – a shift that he terms from "student as technician" to "student as creative scientist" (Hodson, 1998:99). Hodson also advocates the use of computers as tools to focus students' attention on the creative aspect of enquiry (Hodson, 1998:104-5).

Other workers in this area see the *nature of the activity* in which students are engaged as another crucial aspect of authenticity. Roth (1995), Woolnough (1998), Helms (1998), McGuiness, Roth & Gilmer (2002) and Bartholomew, Osborne & Ratcliffe (2004) all argue for practical work in which the tasks undertaken by students have some kind of meaning to them, rather than being simply abstract laboratory exercises. This could mean engaging in "solving real problems that do not have a predetermined solution" (Helms, 1998:126); however, at the very least the activity should "tap into 'real world' resources and techniques" (McGuiness, Roth, & Gilmer, 2002:52). One outcome sought in doing this is the motivation of students, who, it is argued, are likely to engage more fully in work that relates to their experiences in their lives outside the science class. It is also argued that by engaging in authentic science students will be provided with an opportunity to develop their understanding of the "personal, craft nature of doing science [which] is fundamental ..." (Woolnough, 1998:111). Such a craft approach to science is described by Polanyi who describes the process of a medical student learning to interpret X-rays that is quite unlike

anything that those involved in Process Science would recognise as observation, involving as it does a construction of personal meaning that also has a social dimension (Polanyi, 1958:101). Clearly the choice of task for student scientists is likely to be very important if this outcome is to be achieved, needing something to which all students can relate, which provides appropriate challenge without depriving students of any hope of producing adequate explanations, and which enables and encourages students to collaborate as they produce their explanations.

The production of explanations provides a link to the third and final aspect of authentic scientific experiences – *authentic language*. Sutton has shown very clearly the change in the language of science and scientists that occurs as discussion of a phenomenon moves from the tentative, speculative realm of the laboratory through the personal communication, the peer-reviewed journal and into the textbook (Sutton, 1996). While initial speculation involves a very personal kind of language ('I reckon ... '; 'I've an idea that ...'), as the idea becomes more and more accepted the language used to describe it adheres more and more closely to the impersonal style that is recognisable as the language of science (Halliday & Martin, 1993). Although students deal in tentative ideas as they formulate their explanations, they are exposed only (through textbooks and other science resources) to language that expresses concepts in passive terms. This implies that knowledge is derived directly from experiment rather than being formulated and refined through a "debate about ideas [that] gradually becomes instead a set of facts to be transmitted" (Milne, Sutton, & Martin, 2002:135), and reinforces the idea that observation leads directly and unproblematically to conclusion. For this reason, the development of a sense of audience as students write about their work also becomes part of the process of developing authenticity. Lemke points out that in learning science students are also "learning to *talk* science" (Lemke, 1990:1 [original's emphasis]), describing how students learn the *thematic patterns* of science topics through interactions with the

teacher. For Lemke, learning the language of science is inextricably linked with learning science, and the process of learning is concerned more with making meaning than with learning it; and meaning making is a social activity (Lemke, 1990:183-190). Mercer also supports this, terming the social construction of meaning through language an *intermental* activity that involves *interthinking* (Mercer, 2000). Wellington and Osborne, basing their discussion on the rôle of science teaching in helping students to understand the world as it is presented outside the science classroom, argue that science teachers are also language teachers (Wellington & Osborne, 2001:5), responsible for ensuring that their students are able, to a varying degree, to read and write science: another example of authenticity.

Summary

Practical work in school science had and continues to have an important rôle in providing students with opportunities to engage with the world around them and to gain insight into some of the explanations for its behaviour that are offered by science. In the latter part of the 20th century the *methods* of practical work have also been seen as important, partly (in the case of those involved in the Process Science movement) in order to develop specific skills but principally to provide students with some understanding of the methods used by scientists as they develop scientific knowledge. In order to function in this way, there is general agreement that school science practical work should have some degree of *authenticity*.

Developing students' understanding of the nature of science

The argument that school students should develop some understanding of the enterprise of science itself in addition to an understanding of science concepts is to be found in many statements about the purposes of science education (for example Association for Science Education, 1981; Solomon et al., 1989; American Association for the Advancement of Science, 1990; Millar & Osborne, 1998; House of Commons Science

& Technology Committee, 2002) and in curriculum documents themselves (for example Department for Education, 1995b; AQA, 2004:10). Indeed, according to Lederman (1992:331-332) arguments for promoting students' understanding of the nature of science can be traced back as far as 1907. The reason for the ubiquity of such aims for science education is largely due to the consensus that such an understanding is essential in order to equip future citizens with the skills and knowledge needed to participate fully in modern life, with all its scientific and technological complexity (eg Royal Society, 1985; Thomas, 1997; Ratcliffe, 1998b; Sorsby, 2000). In an extensive review of the literature relating to the public understanding of science, Driver et al categorise reasons for teaching students about the nature of science under five headings (table 2.3), concluding that these reasons lead to three *key elements* of an understanding of the nature of science:

- *understanding the purposes of scientific work*
- *understanding the nature and status of scientific knowledge*
- *understanding science as a social enterprise*

(Driver *et al*, 1996:23)

Argument	An understanding of the nature of science ...
utilitarian	... is necessary if people are to make sense of the science and manage the technological objects and processes they encounter in everyday life
democratic	... is necessary if people are to make sense of socioscientific issues and participate in the decision-making process
cultural	... is necessary in order to appreciate science as a major element of contemporary culture
moral	... can help develop awareness of ... the norms of the scientific community ...
learning	... supports successful learning of science content

Table 2.3 – arguments for learning about the nature of science (from Driver *et al*, 1996:15-20)

Although there is little difference of opinion about the need to teach about the nature of science, there is a range of ways suggested for going about this, falling into three broad classes: stories about science;

"non-traditional" practical activities; and practical work. These are briefly described below.

Stories about science

Milne highlights the importance of storytelling as part of science education, describing the events in a story as part of a *semiotic circle*, and classifying science stories as:

- *"heroic" (involving a scientist who single-handedly changes the course of science);*
- *"discovery" (when knowledge arises as the outcome of an accident);*
- *"declarative" (involving no sense of having been constructed); and*
- *"politically correct" (when educators attempt a fairer portrayal of science than was the case in the past)*

(Milne, 1998).

Milne uses the notion of a *semiotic circle* – illustrating the relationship between the events of a story, its text and the interpretation of that text – to argue that the use of stories in school science should involve a discussion of the way in which the text of a story has been constructed around the events which form its subject. This is necessary, she says, to avoid a situation in which the readers (in this case, the students) become "captives of the text" (Milne, 1998:177), lacking the situated knowledge needed to recreate the story's events from its narrative.

Miller & Osborne have also argued for the use of stories in the science curriculum as a vehicle for developing understanding of the nature of science as well as science concepts:

> *It is of course important that young people see these 'stories' not as 'given' knowledge but as the product of sustained inquiry by individuals working in social and historical contexts. They should gain some understanding of where these ideas have come from, and of the warrants we have for trusting them as reliable knowledge.*
>
> (Millar & Osborne, 1998:2014)

They argue for a curriculum which is coupled to assessment of the extent to which students are able to demonstrate understanding of these stories, seeing practical work and the interpretation of media reports as an element of teaching methods that could support this approach. The idea that stories alone will be insufficient to produce an

understanding of science, both philosophical and historical, that at least approximates to one that would be recognisable to the science studier is an idea supported by the work of Curtis, who describes the image of science and scientists that many students encounter in descriptions school lessons and textbooks, and in the mass media in terms of a *Baconian narrative*:

> *Successful science, according to this idea, (1) avoids preconceptions, premature speculation and begins with massive fact-gathering; (2) uses the method of induction by elimination; and thus presupposes that (3) all possibly true hypotheses can be tested and all but the true one eliminated; and thus that (4)'eliminative induction ... makes possible the discovery of laws that are uncertain.'*
>
> (Curtis, 1994:435)

Curtis's particular concern is that stories about science in the popular media are often cast in a format which he describes as a "detective-trail narrative". In such a format, the most common plots are those in which:

- *an unqualifiedly good hero succeeds – this causes us to feel satisfaction*
- *a noble hero miscalculates, but only temporarily and his ultimate vindication is satisfying*

(Curtis, 1994:425)

This leads to a model of science in which knowledge about nature arises solely from the heroic struggle of the scientist to collect data about natural phenomena, where "to portray scientists as engaged in debate is to suggest that they do not follow Bacon's method (Curtis, 1994:447).

"Non-traditional" practical activities

Since one of the key problems in students' conceptions of the nature of science lies in the relationship between observation and theory (Desautels & Larochelle, 1998), some writers have proposed activities specifically designed to help students to recognise the theory dependence of such activities as measuring and observing (Nadeau & Desautels, 1984; Hodson, 1998). By their nature these activities tend not to be in the conventional mould of science practical work, incorporating:

- optical, tactile and auditory illusions
- puzzle pictures
- classification tasks
- puzzle boxes
- feely bags
- scavenger hunts

(Hodson, 1998:96)

Sutton has also proposed similar activities to convey the idea that "there is more to seeing than meets the eyeball" (Hanson, 1958) – figure 2.1:

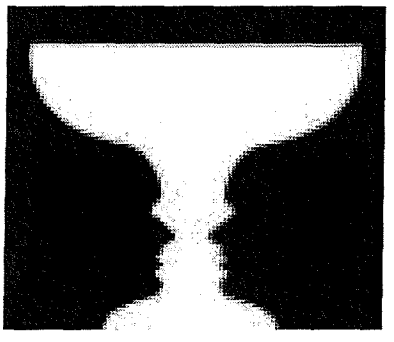


Figure 2.2 – the vase (faces?) [from Sutton (1992:37)]

As with the use of stories, the teacher plays a crucial rôle in the use of these activities. In particular, making the connection between these activities (that some students may see as little more than games) and scientists' science presents a serious problem to the teacher confronted with a class who want to know "what's this got to do with science?!"; the centrality of the laboratory and practical work integrated with theory has been described by Arzi, with all the expectations that this engenders in the minds of students and teachers (Arzi, 1998).

Practical activities

Since the days of Nuffield science, teachers and science educators have looked to practical work as a potential way of developing students' understanding of the nature of science. The differences between practical work in students' science and the kind of laboratory work

undertaken in scientists' science make this something that is much more difficult to accomplish than was envisaged at the time that the Nuffield project was begun. Osborne has argued against the use of the laboratory in school science on these and other grounds (Osborne, 1996; Osborne, 1998) and in favour of methods involving reading, writing and discussion. Yet if practical work has its limitations, it also has strengths, not the least of which is its ability to motivate students (an aim highlighted in the work of Kerr (1963) and that of Beatty and Woolnough (1982), and one given priority by many science teachers in these surveys). Leach also draws attention to the strengths of practical work, including the fact that, in engaging with an investigative practical task "students' attention [can be drawn] to epistemological issues about data and knowledge claims" (Leach, 1998:63).

There is general agreement that, if the epistemological dimension of practical work is to engage students' attention, students need to undertake science investigations in which careful attention has been paid to *authenticity* (Roth, 1995; Leach, 1998; Hodson, 1998; Wellington, 2000; Duggan & Gott, 2000; Bartholomew, Osborne and Ratcliffe, 2004). According to these authors, the conditions under which this may happen vary, but the rôle of the teacher is once again crucial, as it is in the other approaches described in this section.

The teacher's rôle in science investigations

A class of students undertaking a science investigation under the guidance of a teacher involves teacher-student and student-student interactions that are in effect a series of *conversations* (Pask, 1975), language being the medium through which conversation is conducted and through which meanings are constructed and students' understandings are developed – and example of "the persuasive rôle of words [and] their thought-crystallising and thought-provoking power" (Sutton, 1992:4). Mercer describes this as "a guided process of thinking with language, rather than merely a one-way transmission of

information" (Mercer, 2000:43). The use of language in written form is also part of this. Sheeran and Barnes, who view creative writing in science classrooms (as opposed to the formal, passive style of writing often used in writing up reports of such activities) as a powerful means of exploring and clarifying students' ideas, argue that "success in science appears to have a lot more to do with understanding the cognitive and communicative rules that are operating in the classroom environment, rather than being dependent on the use of 'scientific' language" (Sheeran & Barnes, 1991).

Hodson's view of the conversational interactions between students and teacher is based on *situated action* (Nardi, 1996b). He describes the teacher's rôle as a *skilled and experienced practitioner* (Hodson, 1998:100), whose job it is to "provide on-the-job support, criticism and advice" and to conduct the learning environment in such a way that the learners develop the ability to conduct science investigations through a process that Lave & Wenger term *cognitive apprenticeship*, which takes place in a *community of practice* (Lave & Wenger, 1991:29). In order to justify this view, two points must successfully be argued: first, that the setting in which such science learning takes place employs the same kinds of *practices* (Wenger, 1998:45-50) as those found in authentic scientific communities undertaking research; and second, that the individual leading this process is accomplished in such practice. The authenticity of students' science and the conditions which may foster this have already been discussed; the rôle of the teacher is considered below.

If the teacher is responsible for the cognitive apprenticeship of science students with reference to the community of science researchers, then the teacher must be skilled and experienced *in the practice of science research*. One measure of this is the teacher's prospects of being appointed to a research post in a university at some stage in her/his

career. A recent advertisement for a research assistant contains the following requirements:

> *Applicants must have at least a 2:1 honours degree, or equivalent ... and hold or expect to hold within a reasonable period of time a PhD in a relevant subject. A minimum of three years' relevant experience and ... recent publications which are suitable for return as grade 5 or better in ongoing research assessment exercises are also essential.*
>
> (www.jobs.ac.uk)

Since few teachers of science have undertaken studies at postgraduate level[1], it seems unlikely that the majority of science teachers can be regarded as experts in science research, a situation that has been argued elsewhere:

> *It is clearly romantic to suggest ... that students in public schools be enculturated into the cultures of mathematicians, historians, and literary critics ... teachers of these subjects may be the consumers of the outputs of these disciplines, but they are rarely practitioners. History teachers are seldom historians. Practicing mathematicians infrequently teach [in] high school, let alone grade school.*
>
> (Brown et al, 1993:189)

At first sight it appears that this lack of expertise in science research seems fatal to the idea of developing understanding of scientists' science through the practice of students' science. However, this is not the case, since the objective of the school science investigation conducted in this way is not *expertise* in conducting scientific research but simply *insight* into the way in which scientific research is conducted. This is a situation exactly comparable to, for example, an ability to understand what is happening in a cricket match: in order to appreciate the match, the spectator does not need to have played at all. It is enough to have had some experience of the game, of watching it, of reading about it and of discussing it with others; the part played here is not one of *expert practitioner* but of *insightful observer*, exactly comparable with the kind of understanding of the practice of scientific research sought through the use of science investigations.

[1] Although no official figures are available for the UK as a whole, local university recruitment statistics suggest that a maximum of 10% of science graduates currently entering teacher training have achieved the degree of PhD in a science discipline.

Through the mediation of language, interactions among teacher and students bring about understanding through a process in which knowledge is constructed; this is described by Edwards and Mercer as the construction of *common knowledge*, their model of classroom interactions being based on the work of Vygotsky (Edwards & Mercer, 1987). The construction of knowledge has elements that are both personal (Kelly, 1963; Piaget & Inhelder, 1969; Driver *et al*, 1994) and social (Bruner, 1966, Maturana, 1991; Glasersfeld, 1996); the rôle of the teacher in this construction is seen as involving encouraging students to work, under supervision, at a level beyond that at which they are able to work as individuals, referred to as a *zone of proximal development* or ZPD (Vygotsky, 1986:187-9). The ZPD represents potential learning, and is "not a characteristic of the child alone but ... an aspect of the large, complex *system* consisting of the child and his or her environment" (Scaife, 2000:71). In supporting students to work within their ZPD, the teacher must require them to engage with fundamental scientific ideas in a way that encourages them to abandon strongly held *alternate frameworks* (Driver & Easley, 1978) in favour of ideas consistent with the scientific canon. Mercer interprets Vygotsky's work in a way that provides for a collective view of this, describing the way in which students use "talk and joint activity to create a shared communicative space" which he calls their *intermental development zone*, or *IDZ* (Mercer, 2000:141). It is therefore in this sense of being an expert in developing and managing the processes of constructing science knowledge that the teacher must be involved in the classroom in which science investigations are being conducted; all science teachers undertake cognitive apprenticeships in this area (instead of or in addition to science research) through their time as student and beginning teachers. However it should be noted that many recent studies concerning teachers' understanding of the nature of science (Aguirre, Haggerty & Linder, 1990; King, 1991; Lederman, 1992; Rubba & Harkness, 1993; Abell & Smith, 1994; Lakin & Wellington, 1994; Yerrick, Pedersen & Arnason, 1998) indicate that this is an area in

which many teachers feel uncertain and in need of support, their own education in science and cognitive apprenticeships as teachers not having equipped them with expertise to develop students' knowledge about the nature of science. It has already been noted (page 5) that more recent work suggests that teachers' own conceptions of the nature of science are only one part of a complex set of interacting variables which affect the development of students' understanding of the nature of science. The authors of this work argue that it is the opportunity for students to engage in *reflexive epistemic dialogue* which is essential, and that this "is more substantive than simply improving teachers' pedagogical content knowledge or their knowledge of the nature of science" (Bartholomew, Osborne and Ratcliffe, 2004:678).

The research reviewed so far in this section suggests that a group of science students undertaking a science investigation under the guidance of a teacher are best considered as a community engaged in the joint construction of meaning. The model for this is not one in which students develop expertise in the authentic practice of science with the intention of becoming experts, but is one in which the teacher supports students in the development of meanings and understandings of the phenomena under investigation, and through which an insight into the way in which scientific knowledge is generated may arise. The next section considers the nature of such a community in more detail.

The student science community

One of the most powerful aspects of the scientific enterprise (in its broadest sense of seeking to "understand the world") is the ability of research teams to tackle large, complex questions and to produce complex and comprehensive theories which provide powerful insights into the workings of our universe (Lakatos, 1970). Where the science of Newton and Galileo was generally the enterprise of individuals, modern knowledge production is a collaborative enterprise, the success of which is noted by Bereiter and Scardamalia in a review of the nature of

"expertise" and the implications of this for education (Bereiter & Scardamalia, 1993).

Given the power of collaborative work in scientists' science, its use in students' science is strangely muted. For example, although the National Curriculum for Science is phrased in the third person plural (eg "they evaluate their work, in particular the strength of the evidence that they and others have collected" (DFEE, 1999:28)), the implication nevertheless is that learning and practising science is an individual accomplishment. Whilst the emphasis on the individual is understandable in the context of assessment, the social nature of knowing suggests that there may be much to gain by considering classrooms as communities that collaborate in producing understanding. Writing about the benefits of discussion in science classrooms, Shapiro argues

> *Much of ... more advanced science learning involves phenomena that are not immediately perceptible ... and ... that must be understood in abstract rather than concrete ways. Reflecting on this change ... [s]tudents may see that their own personal ideas are not necessarily parallel to those of the scientist in order to learn the ideas of the scientist.*
>
> (Shapiro, 1994:31)

If benefits accrue during discussions which are focused on the development of individual understandings it may be argued that, in communities where the construction of meaning is the intended outcome of a group collaborative activity, the collective nature of the activity may enhance understanding of the individual as well as of the community through *interthinking* (Mercer, 2000). Sutton (1992) also argues for a focus on the social construction of meaning rather than on the interpretation of phenomena in order to enhance the quality of science learning. The notion of the social construction of knowledge is at the heart of Bereiter and Scardamalia's model of a *knowledge-building community* (Bereiter & Scardamalia, 1993:201). Whether a science classroom can be regarded as a knowledge-building community

depends upon the nature of the activities in that classroom and upon the rôle of the teacher, as the following discussion will show.

If a science classroom is simply seen as a microcosm of the community of authentic science, then knowledge-building is certainly not one of the outcomes of whatever activities take place within it. This is due to the lack of any authentic science expertise in the classroom – by definition the students do not possess this, and it has already been shown earlier in this chapter that the teacher is not an expert in this sense either. However, if a view is taken in which students are seen as constructing knowledge which, although not new *per se*, is new *to them*, then the idea of a science classroom which has as its intended outcome the construction of new and more powerful meanings that are in accordance with "accepted science" may be consistent with knowledge-building, under three conditions, described by Bereiter and Scardamalia as follows:

1. the process of conducting a science investigation is not regarded as one in which students simply "learn by discovery", pretending to be scientists rediscovering knowledge already known;
2. the process of conducting a science investigation is not regarded as "cognitive apprenticeship" in which the teacher pretends to be an expert scientist;
3. the teacher must play a rôle within the community which devolves control of the investigation to students whilst acting to support and lead the enquiry – "progressive discourse" as opposed to "Socratic dialogue".

(from Bereiter & Scardamalia, 1993:204-9)

Given such requirements, Bereiter and Scardamalia propose a set of nine conditions that may be set in order to characterise a knowledge-building community within a school. These conditions provide guidance on the way in which a knowledge-building community should be constructed and maintained in order that the intended outcome of the community is focused on the construction of meaning (ie knowledge new to the students) which is consistent with scientists' science. These conditions are summarised below:

1. sustained study of topics in depth rather than superficial coverage;
2. focus is on problems rather than on categories of knowledge;
3. enquiry driven by students' questions;
4. explaining is the major challenge;
5. day-to-day focus is progress toward collective goals of understanding and judgement;
6. students typically work in small groups, each with a different task;
7. discourse is taken seriously;
8. teachers can contribute what they know to the discourse, but there are other sources of information;
9. teacher's role shifts to leading it by virtue of being a more expert learner

(adapted from Bereiter & Scardamalia, 1993:210-11)

Bereiter and Scardamalia counter the idea that students are still "pretending to be scientists" by pointing out that the absorption of the students in the process indicates a real commitment, not just to the process but also to the end – that "they think the questions really matter, and they are right" (Bereiter & Scardamalia, 1993:215). They also make the point that

> *It is worth noting that adult scientists and scholars do not spend all their time advancing the frontiers of knowledge. For most of them, that is a rare event. They spend a great deal of their time trying to make sense of what others have found or proposed, and that is not fundamentally different from what we have reported school children to be doing.*
>
> (Bereiter & Scardamalia, 1993:215)

Summary

Practical work in school science may potentially play a rôle in helping students to develop insights into the way in which scientific knowledge is produced. For it to do this the practical work must be *authentic*, and students and teacher should work together to construct meanings through the *shared use of language* in a *knowledge-building community*. Within this community, the teacher is very important as a provider of expertise in the sense of acting to support and scaffold the students as they work within the community's *intermental development zone* (IDZ).

CSCL research

The conditions under which a science classroom may function as a knowledge-building community are potentially enhanced by the use of a CSCL environment in three respects, since this can provide:

1. access to records of what other students are doing, and an opportunity to comment upon it;
2. access to other sources of information (in addition to the teacher and school books);
3. access to experts outside the classroom and school.

In addition to this, a CSCL environment may also provide accounts of discussions, reports of practical work and other records, all of which are available to members of the community and which function as "an objectification of the group's advancing knowledge, much like the accumulating issues of a scholarly journal" (Bereiter & Scardamalia, 1993:212). Furthermore, CSCL may potentially provide an environment which goes beyond the boundaries of the school timetable. In seeking to use this affordance of networked computers, there are two important considerations:

- the technical dimension – determining what is possible and feasible;
- the social dimension – concerned with human interactions and networked computer environments.

The following sections provide an analysis of the research literature in these areas.

The technical dimension of CSCL

Considering the nature of CSCL (in its broadest sense, including the use of computers that are networked as well as those that are not), Bannon reviews a range of studies and concludes that not only is collaborative learning often poorly-defined, but that the nature of the collaboration is often very different in different studies:

> *Who or what is collaborating with whom, and under what conditions? ... for some it consists of a single individual collaborating ... with a computer system ... [or] it is the study of two randomly chosen subjects collaborating ... on a computer ...*
>
> (Bannon, 1995:270)

As a way forward, Bannon proposes a framework (table 2.4) for comparing and contrasting studies of collaborative learning, not as a way of defining any particular approach as "true" CSCL but as a way of highlighting differences in approach that appear possible. Bannon's framework has been developed further by Crawley, drawing on work by Koschmann (1994) and Kaye (1995) – see table 2.4.

Frameworks for conceptualising CSCL

Bannon (1995)	Koschmann (1994)	Kaye (1995)
• nature of the collaborative task • nature of the collaborators • number of collaborators • previous relationship between collaborators • motivation for collaboration • setting of collaboration • time-period of collaboration	• intra-classroom applications (for use in the classroom) • inter-classroom applications (that connect users across classrooms) • extra-classroom applications (for use outside the classroom) • synchronous • asynchronous • applications to present or simulate a problem for study • applications to mediate communication • applications which provide archival storage for the products of group work • applications which support the creation of representational formalisms that enable learners to model their shared understanding of new concepts	• communications systems - *synchronous text, audio, audio-graphics, and video communication; asynchronous electronic mail, computer conferencing, voicemail and fax* • resource sharing systems - *synchronous screen-sharing and electronic whiteboards, concept mapping tools; asynchronous access to file systems and databases* • group support systems - *project management systems, shared calendars, co-authoring tools, voting tools, ideas generation and brainstorming tools*

Table 2.4 – frameworks for conceptualising CSCL (from Crawley, 1997a)

The three frameworks for conceptualising CSCL represent three dimensions – *context* (Bannon), *pedagogy* (Koschmann) and *technology* (Kaye). In developing any CSCL environment consideration must be given to each dimension so as to maximise the opportunities for CSCL successfully to support the intended learning outcomes for which it is to be used.

Considering the use of CSCL as a resource within a science knowledge-building community of school students (the *context*), the two other dimensions suggest that it is pertinent to consider three questions when selecting or designing a system for this purpose:

- is the system for use in school or out of school, or both?
- will it use asynchronous or synchronous communication, or both?
- what other functionality is required – eg resources for file-sharing, generating ideas, voting on proposals etc?

Answers to these questions depend on the availability of appropriate technologies and the contexts in which they are to be used.

Technologies for CSCL

Assembling a suitable CSCL environment depends not only on the provision of suitable software but also its availability to users when and where they are to use it. Reviewing a wide range of technological support for supporting practical science work, Scanlon et al observe that the interactivity available on the Web provides the opportunity for "student-student and student-instructor contact, and ... collaborative projects" where "the real value of web-based courses come from the multimedia and communication aspects of Internet technologies" (Scanlon et al, 2002:94). Recent studies (Hayward et al., 2003; Harrison et al., 2003; Livingstone & Bober, 2004) have shown the generally widespread access to these technologies in the homes of school students through personal computers; this suggests that it is reasonable to propose that students should be supported both in and out of school through the use of CSCL which employs Web-based technology. Care in this respect is necessary however, since it must be acknowledged that "the sharpest, most clearly enumerable divides in cyberspace are those based on where one lives and how much money one has" (Holderness, 1998:37); more recently, Holloway and Valentine have described issues of social exclusion arising from the far from universal access to ICT in the home (Holloway & Valentine, 2003:20-

41). These concerns impact the ethical dimension of the study, discussed at the end of the next chapter.

Adopting Web-based technologies allows a wide range of applications to be considered for CSCL, from "off-the-shelf" software designed specifically to promote collaborative learning and working such as *KnowledgeForum* (www.knowledgeforum.com), *CyberEd* (www.cybered.net) and *iLinc* (www.ilinc.com) to more general software such as email, discussion forums, chat rooms and instant messaging (IM) programs. In making decisions about the adoption of particular software for the CMC element of CSCL (ie programs that allow students to communicate with each other and with the teacher) further decisions must also be made about the use of synchronous and asynchronous communication. In terms of the quality of interactions or the preferences of those using them, to date little work has been done to compare asynchronous and synchronous CMC (Chou, 2002). One recent study has compared synchronous and asynchronous CMC when used to support undergraduate students carrying out tasks which required them to work collaboratively (Veerman & Veldhuis-Diermanse, 2001). The researchers conclude that synchronous CMC gives rise to frequent short messages, meaning that "students have less time to search for information, to produce extended explanations, to evaluate information thoroughly, to ask elaborated questions and so on" (Veerman & Veldhuis-Diermanse, 2001:7). In contrast, asynchronous CMC is characterised by rather richer interactivity in which "students have more time to think, to search for information, to elaborate ideas, explain ideas and to reflect on each other's contributions ... take time to reach shared understanding, to create their own ideas and to formulate points of view as clear as possible" (Veerman & Veldhuis-Diermanse, 2001:7). In contrast to this, Chou compared synchronous and asynchronous interactions among undergraduates engaged in a computer-supported course and found more interactive exchanges

occurring in synchronous communication modes, with more one-way communication occurring in asynchronous modes, where

> *... students seemed to be more interested in expressing opinions than challenging each other's views ... in synchronous mode, there were more questions and answers. Students were more engaged in the synchronous discussions [with] a stronger sense of immediacy to respond to peer's questions in synchronous mode than in asynchronous mode.*
>
> (Chou, 2002)

Spencer and Hiltz suggest that synchronous interaction online is potentially useful "in terms of [its] ability to bring the students closer to the instructor" (Spencer & Hiltz, 2003) and note that students have a positive attitude towards it. Lightfoot is also positive about online synchronous interaction:

> *... the instructor should add as many rich-media synchronous options as possible for distance learners. These media options should allow communication both with the instructor and between groups of students ... email is still an important tool, but it should not be the only communication medium available to remote students.*
>
> (Lightfoot, 2004)

Herring is positive too, especially on grounds of participation:

> *... synchronous CMC both differs from and resembles asynchronous CMC. Some of the differences initially appear to bear out predictions of greater gender equality. Males and females tend to participate more equally in chat environments ... [and] response rates to males and females are also more balanced; if anything, females tend to receive more responses to their messages than males.*
>
> (Herring, 2000)

These studies suggest that asynchronous CMC is likely to provide effective support for knowledge-building and promoting collaborative learning, but that it may also be profitable to explore the use of synchronous CMC in order to provide opportunities for exchanges that are more rapid and which may reflect the flowing nature of everyday, face-to-face conversations and which are more spontaneous in nature (CAP, 2004:3).

While technical considerations are an important aspect informing decisions about the design of CSCL environments, it is also important to

establish a framework for thinking about the way in which such environments may be set up and managed in order to support and promote CSCL – this is considered in the next section.

The social dimension of CSCL

If CSCL is to produce an environment in which students establish meanings through a process of conversation, *interactivity* – involving students engaging in communication in which knowledge is (re)constructed – is "a major factor influencing the learning process" (Henri, 1995:149). Moore's ideas about *transactional distance* provide a useful structure for thinking about this (Moore, 1993); although the work was originally carried out in support of the development of distance learning courses it is applicable to the design of a CSCL environment in which students discuss science investigations due to its emphasis on dialogue and learner autonomy (both involved in the language-mediated social construction of meaning) and the structures associated with these.

Supporting interactivity

Transactional distance theory (TDT) derives from an attempt to develop a model which can be used to understand the characteristics of different types of distance education programmes and has been used to characterise the *pedagogical context* of networked learning communities (McAteer & Marsden, 2004). TDT describes three sets of variables involved in the process of distance education, the first two of which (*dialogue* and *structure*) relate to teaching and learning, and the third (*learner autonomy*) concerns the behaviour of learners (table 2.5).

TDT suggests that a CSCL environment intended to direct students' attention towards the epistemological dimensions of scientific enquiry through the discussion of science investigations should reduce the transactional distance between learners and teacher through:

1. the use of software designed to promote and encourage *dialogue*;

2. provision of *structures* which allow students to work closely with the teacher; and
3. management of both *structure* and *dialogue* to allow students to participate in ways that express their own preferences for *learner autonomy*.

Variables and transactional distance (TD)		
dialogue ...	**structure ...**	**learner autonomy ...**
... between teacher and learner, between learners and learners. TD depends upon: • opportunities for dialogue within and around coursework • opportunities for initiating dialogue • opportunities for responding • freedom to engage in dialogue • opportunities for dialogue linked to feedback on actions	... extent to which learner is guided towards learning goal(s). TD depends upon: • aims / objectives • study guide and assessment guidelines • assessment task/criteria • pacing/deadline management	... interdependent on other aspects. TD depends upon autonomy of learners in terms of: • goals • study strategies and choice of tools and resources • assessment and evaluation

Table 2.5 – the variables associated with transactional distance, based on McAteer & Marsden, 2004:183

Implicit in the concept of transactional distance is the idea of promoting interactivity through encouragement and *motivation*, a factor in CSCL environments that Eales et al refer to as being "an essential but often overlooked ingredient" (Eales, Hall, & Bannon, 2002). Motivation is the first stage in Salmon's model (Salmon, 2004:29) for online education and training (figure 2.2), and is also the subject of Keller's *attention, relevance, confidence and satisfaction* (ARCS) model of learner motivation (Keller, 1983).

Salmon argues that a person beginning to participate in an online environment needs to be motivated to overcome technical problems, and proposes six ways of doing this:

- Recognize that taking part is an act of faith for most participants at this stage.
- Present ... learning online as a new way of learning through networking ... .
- Specify how online will be used in the course or programme.

- Ensure the 'look and feel' of your system is user-friendly for all comers.
- Try to create fun, making online enticing and enjoyable.
- Assure novices that their fear and anxiety will be overcome by trying out online conferencing.

(Salmon, 2004:170-1)

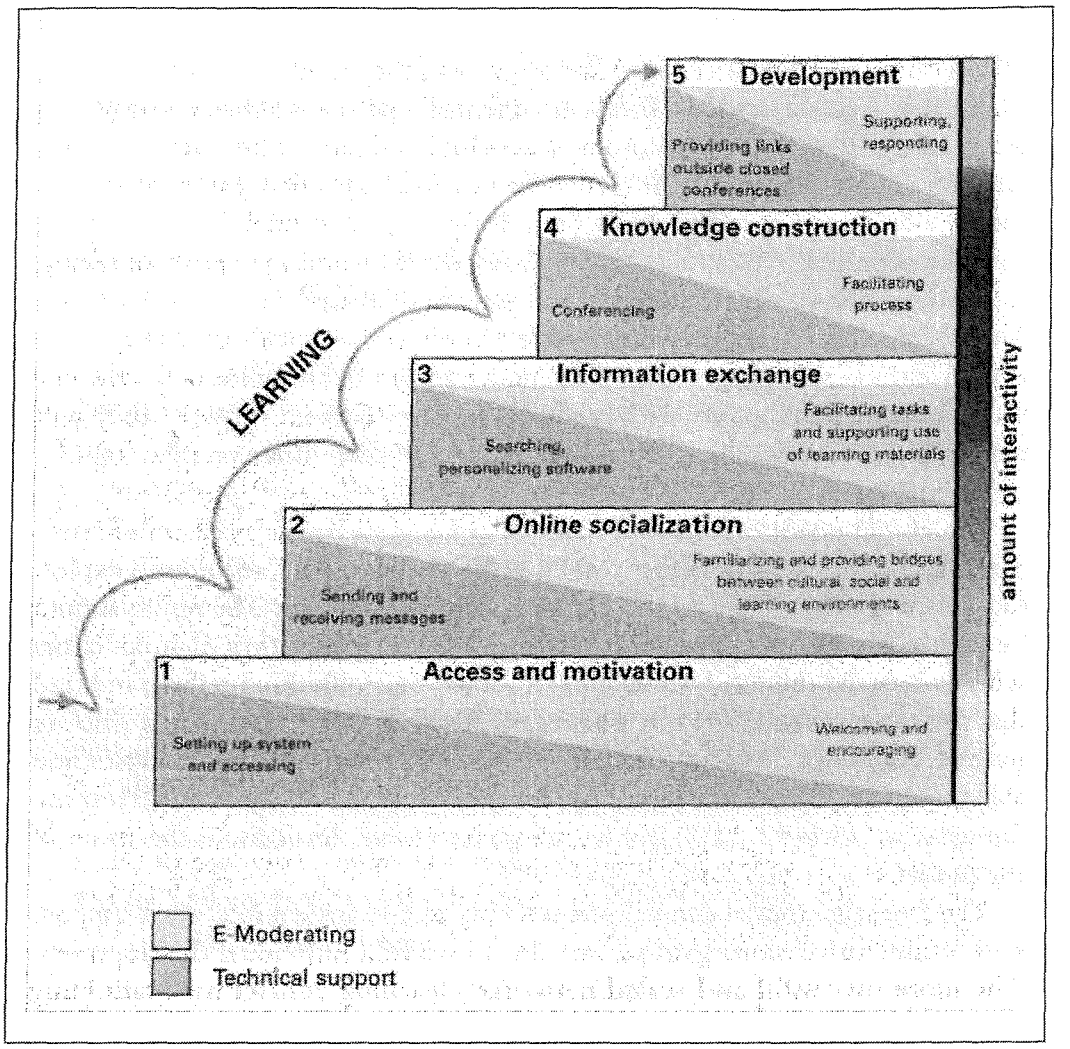


Figure 2.3 – Salmon's model for e-moderating (Salmon, 2004:29)

The stepwise nature of Salmon's model, with the existence of stage 1 as the foundation of the four steps above it, suggests that without the motivation to participate actively in CMC exchanges, an individual is unlikely to interact in meaningful ways with others; this is consistent with the notion of encouraging interaction through a reduction in transactional distance.

Keller's ARCS model was derived from research on psychological motivation and was developed to "[improve] the motivational appeal of

instructional materials, of instructor behaviour, and of the way in which ... courses are designed" (Keller, 1983:140). The model describes four conditions; Keller argues that these conditions must be met in order for an individual to become and to remain motivated in order to engage fully in a learning experience. (Keller, 1983:141-2):

- the individual's **A**ttention must first be gained;
- the individual must see the **R**elevance of engaging in learning;
- the individual must have **C**onfidence that efforts put into engagement will be rewarded;
- the individual must obtain a sense of **S**atisfaction through the engagement.

Although each of these perspectives highlights different elements of effective engagement in online interaction, all three models support the view that an online environment must both motivate and empower individuals to engage in dialogue if proper interactivity is to be seen. Whilst this relates to the *context* for interaction, the importance of the "creation of a social activity through which learning can occur" (Bannon, 1995:273) requires careful consideration of the way in which the CSCL environment is managed.

Managing CSCL

Reflecting the important rôle of the teacher in the management of face-to-face learning in classrooms, Henri considered the part played by "masters" in the conduct of CSCL (Henri, 1995:152). Involving adults rather than school students, Henri's study produced logfiles containing 290 statements derived from six teleconferences involving eleven adult learners. The learners in this study were joined online by two *animateurs/modellers* and three *experts* (Henri, 1995:152); the former were "in charge of pedagogical animation and the flow of exchanges" the latter being there on account of their particular expertise relating to the subject matter of the teleconference. The analysis employed a

definition of interactivity derived from the work of Bretz (1983). This showed the overwhelming importance of the *Master's Voice* (Henri, 1995:158), which occupied a strategic place in encouraging interactivity among members of the teleconference. Henri does not view the importance of the *master* in this context in terms of the social construction of meaning, preferring an explanation that emphasises the rôle played by internal dialogue (Henri, 1995:160). Henri observed little interactivity in this study:

> *... we have been able to show that a large number of learners' messages are not interactive ... [they] are independent, although remaining relevant to the theme under discussion ... the analysis ... did not indicate that the learners participated collectively in the (re)construction of knowledge, as the majority of messages were independent ... a mosaic.*
> (Henri, 1995:158-9)

This provides confirmation of her explanation in terms of individual as opposed to social construction, although the lack of detail provided about the participants in the online interactions make it impossible to suggest why there was so little interaction.

Focusing on the collaborative production of knowledge, Crook (1994:133-8) highlights three aspects of collaborative learning that may play a part when thinking about the construction of online learning communities and the conditions necessary for interactivity: *articulation*, *conflict* and *co-construction*. Crook describes the first of these as involving learners making their thinking public and explicit, and suggests that the benefits of such a process may be ascribed to learners operating in such a situation within their own zone of proximal development (ZPD), as described by Vygotsky (1986:187-9) and already noted on page 39. Continuing the discussion, Crook argues that articulation on its own is insufficient for interactivity, and that *conflict* is also required, noting that this has been "demonstrated to be a distinctive and productive feature of peer-based problem-solving" (Crook, 1994:136). Employing Henri's idea of "animateurs and experts", the notion of the "master" in charge of learning may be extended to encompass students who take on the rôle of enabling others within their

group to operate within their ZPD by providing cognitive conflict as ideas are discussed.

The importance of dialogue and interactivity is also reflected in the conversational model of learning proposed by Laurillard (1993), in which she emphasises the importance of a particular kind of dialogue between students and teacher:

> *a dialogue between student and teacher [must operate] at the level of descriptions of actions in the world, recognising the second order characteristic of academic knowledge*
>
> (Laurillard, 1993:94)

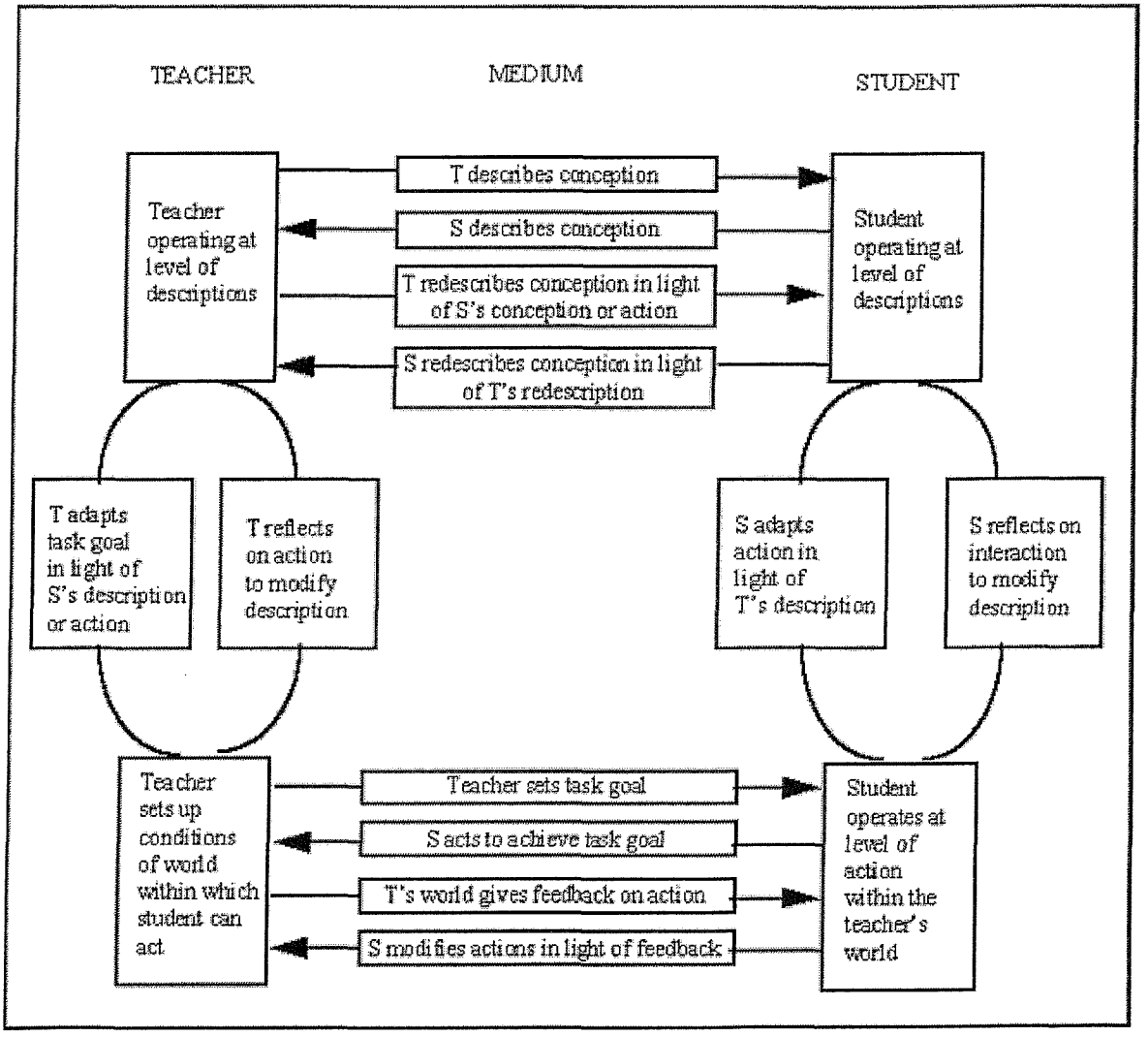


Figure 2.4 – Laurillard's model of conversational learning (Laurillard, 1993)

Laurillard's model (figure 2.4) highlights how the teacher acts to provide tasks that challenge students' current conceptions of the world,

aiming to promote conceptual change through engagement with the world of real objects. It also lays emphasis on the interactive nature of the student-teacher dialogue, and the internal reflective processes necessary within both student and teacher to bring about conceptual change. This is highly relevant in the context of supporting a knowledge-building community through CSCL, where the teacher as expert in managing learning must interact with students online in order to set goals and give feedback on actions ("why don't you try plotting a graph of ..."; "wouldn't it be better if ...?"). This interaction is designed to support both individuals and the community as a whole, operating within the ZPD (in the case of individuals) and the IDZ (in the case of the community as a whole). These interactions coupled with internal dialogue within teacher, individual students and the community are designed to stimulate the development of ideas through interactions related to conceptions ("what does the shape of the graph suggest?"; "does the force vary with extension?").

Conceptual change is therefore the subject of *distributed cognition* (Cole & Engeström, 1993; Salomon, 1993b), occurring among a group of students, and being brought about through the joint construction of what Crook refers to as *cognitive objects* (Crook, 1994); in the context of discussions about science practical work, these include the hypotheses, explanatory theories and descriptions related to real phenomena observed by students in the school science laboratory as part of their practical work. Drawing the work of Henri and Crook together with Laurillard's model suggests that, in a CSCL environment in which there is collaboration in the construction of meaning involving both student-student and teacher-student interactions through CMC, the *medium* through which these interactions occur is the essential component, and careful thought must be given to the way in which CMC is carried out.

Resulting from an extensive review of studies of collaborative learning online, Tolmie and Boyle describe eight factors that best predict successful implementation of CMC to support this process (Tolmie & Boyle, 2000: see table 2.6). They conclude that these eight factors are crucial because they lead to and support the development of a *shared purpose* among those interacting online, testing this hypothesis through a study involving a group of postgraduate students.

Factor	Effect
Group size	"smaller is better"
Knowledge of other participants	"it is better if participants know each other"
Student experience	"it is better if students are experienced communicators under the task conditions involved"
Clarity about task	"it is better if students understand how to go about the task they are engaged in, especially if this understanding is shared"
Ownership of task	"it is better if students have the chance to negotiate what the task is to involve"
Need for system	"it is better if there is a clear function for CMC which cannot be served more easily in another way"
Type of system	"these may be factors, but the important levels are unclear"
Prior experience of CMC	

Table 2.6 – factors for successful use of CMC (Tolmie and Boyle, 2000)

As a result of this study, Tolmie & Boyle make a number of recommendations relating to the use of CMC to support collaborative learning, the first of which is consideration of the eight factors so that "students can readily establish a shared purpose" (Tolmie and Boyle, 2000:135) and the second concerns ensuring the technical reliability of the system. Crucially, however, they argue that the nature of the shared purpose must be carefully managed so as to bring about the right kinds of discussion; Veerman and Veldthuise-Diermanse (2001) also make reference to this. Consonant with the ideas of Laurillard and Crook described above, Tolmie and Boyle suggest that some kind of cognitive conflict may be essential in order to bring this about, advocating "task structures which require individuals to make judgements and then come to a group consensus on these" (Tolmie and

Boyle, 2000:135) and citing McAteer et al (1997) as providing successful examples of this.

CSCL and learning science in schools

Very little research has been published concerning the use of CSCL environments to support students conducting science investigations. Three studies, conducted in North America, have explored the use of CSILE (which became the commercial product *KnowledgeForum* in August 1997) in elementary school science classrooms in which students conducted investigations, but no significant work has been conducted in secondary schools.

Hakkarainen studied five classrooms containing 10/11 year-old students over a period of three years as they undertook science investigations (described by Hakkarainen as *scientific enquiries*) (Hakkarainen, 1998). Hakkarainen's study takes as its perspective the idea that scientific enquiry in science classrooms is a special kind of cultural practice distinct from authentic scientific enquiry, and that this practice is a collaborative one involving *knowledge-seeking* (Hakkarainen, 1998:8) in which

> *the advancement of enquiry can be substantially elicited by relying on socially distributed cognitive resources, emerging through social interaction between the learners, and collaborative efforts to advance shared understanding.*
>
> (Hakkarainen, 1998:15)

Hakkarainen's model makes use of scientific enquiries that are *authentic*, in the sense that students are encouraged to collaborate in creating explanations for phenomena, making both intuitive and scientific ideas and thoughts the focus of inquiry (Hakkarainen, 1998:38). This is supported by CSILE, which promotes distribution of the knowledge seeking process among students and which functions as an "agent for transformative communication" (Hakkarainen, 1998:54), taking internal processes and externalising them through the activity of writing. Hakkarainen has conducted a further study with 10 and 11

year-old students working on science projects in three topic areas (force, electricity and cosmology), being "systematically guided by their teacher to generate their own hypotheses, conjectures, and theories about the physical phenomena being investigated" with support from a CSCL based on KnowledgeForum (Hakkarainen, 2004:982). Hakkarainen concludes that it is "entirely possible for young children, collaborating within a computer-supported classroom, to engage in explanation-driven processes of inquiry", although he acknowledges that success in doing this relies on many factors that may be unknown or impossible to control (Hakkarainen, 2004:994).

A smaller study is described by Hill et al, involving a grade 4 class studying electricity (Hill, Cummings, & van Aalst, 2003). Hill and her colleagues adopt a similar approach to student learning to that of Hakkarainen, which they term *knowledge-building* (Hill, Cummings, & van Aalst, 2003:1), and describe four principles used to "scaffold knowledge building discourse" (Hill, Cummings, & van Aalst, 2003:5-6). Table 2.7 lists these features and provides a brief description of each.

Principle	Features
Working at the cutting edge	The community works to advance its collective knowledge.
Progressive problem solving	Basic understanding is reinvested into new learning.
Collaborative effort	Working on shared goals and values is important in developing community knowledge.
Self-monitoring of knowledge	Metacognition (Shimamura, 1994) is needed for knowledge-building. Requires students to have insight into their own learning processes.

Table 2.7 – principles to scaffold knowledge-building
(Hill, Cummings, & van Aalst, 2003)

As in Hakkarainen's study, Hill and her colleagues employed CSILE as a CSCL environment; through this common feature, all three studies are based on the work of the developers of CSILE (Scardamalia, Bereiter, & Lamon, 1994), which is founded on understandings of the processes used by experts in approaching new learning (Bereiter & Scardamalia, 1993) and in which

> *the notion that knowledge is improved over time by means of a public discourse is central.*
>
> (Hill, Cummings, & van Aalst, 2003:2)

Taken together, these three studies clearly show the potential for a CSCL environment to support knowledge-building in practical science investigations conducted by secondary school students.

Summary

The strongly social dimension of CSCL, in which a community collaborates in order to gain new knowledge (in the sense of knowledge that is new to the community rather than new *per se*), provides an environment which appears to be highly suitable for supporting a knowledge-building community of student scientists. Conditions for this support to be viable point to the crucial nature of the task (which must promote a sense of shared purpose as well as providing some sort of cognitive conflict) which must motivate students. There must also be appropriate management of students' interactions through the expertise of the teacher as a master in managing learning.

The influence of policy

This examination of the current state of investigations in science and of the use of CSCL in learning concludes with a consideration of some of influences of government policies on science teaching and the use of computers in schools, focusing on practical work and the use of computer networks. This consideration encompasses only England, other countries in the UK having education policies that differ, to some extent, from those in England.

Practical science in schools

The educational reforms of the 1970s resulted in the establishment of greater and greater numbers of non-selective schools and this, coupled with the raising of the school-leaving age, led to policy changes concerning science teaching in schools that were enacted during the

1980s (Jenkins, 1998:47). These policy changes were the subject of a consultation carried out by the Secondary Science Curriculum Review (SSCR)[2], which issued a consultation paper in 1983 (SSCR, 1983). This document described the possible nature and content of a science curriculum intended to meet the needs of all students between the ages of 11 and 16; in addition to an understanding of "the key concepts and principles of science that are essential to an understanding of science as a way of looking at the world" (SSCR, 1983:5), the aims of this curriculum included developing in students the ability to "design and carry out experiments, evaluate evidence and solve problems" (SSCR, 1983:5) and developing an understanding of the historical development of science as well as "the limitations of scientific knowledge as an explanation of the human condition" (SSCR, 1983:6).

Two years later, the publication of a statement of government policy on the science curriculum (Department for Education and Science, 1985b) contained ten principles (table 2.8) intended to guide "LEAs, schools, teachers, parents, examination boards, employers, higher and further education institutions and others concerned [with science education]" when thinking about the science curriculum. The approach to thinking about science teaching in schools advocated by the document reflected many of the aspects of the SSCR consultation document, but laid special emphasis on the rôle of practical work (principle (i) in table 2.8, quoted in full) which should be assessed (principle (j) in table 2.8), and which was seen as a vehicle for the development of students' understanding of the methods of science: "The essential characteristic of education in science is that it introduces pupils to the methods of science." (Department for Education and Science, 1985b:3).

[2] Established in 1981, the SSCR was set up to examine the implications of teaching science to all students between the ages of 11 and 16, and was sponsored by the Association for Science Education, the Department for Education and Science, the Health Education Council, the Northern Ireland Council for Educational Development and the Schools Council.

a) breadth – *all students to be introduced to the main concepts in science*	g) progression – *science teaching should lead to progressively greater understanding*
b) balance – *all students to continue the study of science throughout the compulsory age range*	h) links across the curriculum – *science teachers should work closely with other colleagues*
c) relevance – *science should relate to the everyday experiences of students*	i) teaching methods and approaches – *"science teaching is a practical subject, and should be taught at all stages in a way which emphasises practical, investigative and problem-solving activity"*
d) differentiation – *demands made by the science curriculum should be matched to needs of individual students*	j) assessment – *students' progress to be assessed in terms of skills (involved in practical work) as well as knowledge*
e) equal opportunities – *boys and girls should have the same opportunities to study science*	
f) continuity – *science teaching at all stages to build on previous foundations*	

Table 2.8 – ten principles for science education
(Department for Education and Science, 1985b:4-5)

The criteria for science in the new GCSE (General Certificate of Secondary Education) examinations (Department for Education and Science, 1985a) published in the same year emphasised the teaching of skills in investigative work through a process of practical assessment which was to make up 20% of the marks for the new examination to be taken by all students at the age of 16.

The introduction of a National Curriculum came about in 1988 as a result of the Education Reform Act, with the science component of the curriculum (the *National Curriculum for Science*) becoming compulsory for students aged 5 and 11 in 1989. As with the GCSE criteria (which were required to be coherent with the National Curriculum frameworks), practical work and its assessment formed an important part of the new curriculum, with one of the Attainment Targets devoted entirely to this.

In addition to practical work, the National Curriculum for Science also contained statements about students' understanding of the way in which scientists work and the nature of scientific knowledge (see table 1.1). In the initial version of the curriculum, these statements were contained in a separate area of the document, but from the first revision in 1991 (Department of Education and Science, 1991) they have been included in the area of the curriculum document associated with practical work, receiving greater prominence in successive

revisions in 1995 (Department for Education, 1995b) and in 1999 (Department for Education and Skills, 1999).

As a result of government policies over this period the school science laboratory is "a prisoner of the past" (Jenkins, 1998:49), in the sense that the compulsory assessment of practical work through the National Curriculum and GCSE examinations has largely suppressed any widespread examination of the rôle and nature of practical work as part of policy change. One notable exception to this is the report of the *Beyond 2000* seminar series funded by the Nuffield Foundation (Millar & Osborne, 1998), which considered this issue and made a number of recommendations, some of which related directly to practical work and teaching about the nature of science. The influence of this report on consultations concerning future changes to the science curriculum has yet to be seen (QCA, 2003).

Although the assessment of practical work was intended to help students, by providing them with an experience of science that met their needs and enabled them to "develop a fuller understanding of scientific concepts" (Donnelly *et al*, 1996), the effect in practice seems to have been the construction by science teachers of a "bank" of practical exercises that have some relationship with theoretical work being taught to students and which enable students to gain as much credit as possible for their work under the mark schemes of the examination boards:

> *... some investigations were quickly identified as being 'known to work' – they made it possible to reach the higher levels as described in the mark schemes of the different syllabuses. With time and practice, these investigations have formed the basis of the central pool of investigations every science department uses.*
>
> (Shipsides, 2002:63).

There can be little hope that any understanding of the nature of science can be brought about by such activities, designed to achieve high marks rather than for any other purpose.

CSCL in schools

The educational use of ICT in schools over the period since the Education Reform Act of 1988 has been influenced by government policies in two ways – the first concerned with the use of these new technologies in teaching the subjects of the National Curriculum (including science), and the second concerned with development of students' skills in using the technologies. These two influences are apparent in the statement of government policy for the use of computers in schools, published in 1989:

> *IT has a critical rôle in enhancing the learning process at all levels ... through the use of IT, schools will also be helping pupils to become knowledgeable about the nature of information, comfortable with the new technology and able to exploit its potential.*
>
> (Department of Education and Science, 1989)

The initial version of the National Curriculum for Information Technology was published as Attainment Target 5 (*Information Technology Capability*) within the curriculum for design and technology (Department of Education and Science, 1990). As the name of the Attainment Target implies, the curriculum emphasised the development of skills, with five strands relating to *communicating information*; *handling information*; *modelling*; *measurement and control*; and *evaluating applications and effects.* From the outset, information technology was seen by government ministers as being linked to *raising standards*:

> *The Government recognises the tremendous potential of IT as a classroom tool. Our policy is to promote IT in schools and to see that it is used to raise standards.*
>
> (John Butcher, Schools Minister, quoted in NCC, 1991:8)

Problems in implementing the orders for the National Curriculum for Technology (Smithers & Robinson, 1992) led to revision of the technology curriculum as part of overall changes to the National Curriculum published in 1995. These problems, together with the rapid development of computer technology, led to the production of a set of

orders for Information Technology that were completely separate to the other parts of the technology curriculum (Department for Education, 1995a). The new information technology curriculum had a single Attainment Target (with no name or title) covering *communicating and handling information* and *controlling, measuring and modelling*. Although the growing importance of the Internet during the early part of the 1990s had led the government to commission a consultation into the use of networked computers in schools which had concluded that "the skills of network literacy must be recognised and developed" (Department for Education and Employment, 1995:6), there was no mention of networked computers in the National Curriculum orders. Networked computers continued to grow in importance in the world outside school education during the second half of the 1990s, a fact highlighted by the McKinsey Report – "a completely independent analysis of the issues, challenges, and opportunities surrounding the use of information technology in schools, and of the options for policymakers in general" (McKinsey & Co, 1997:iii). The importance of computer networks in schools was finally recognised by the government later that year, with the publication of a consultation document (Department for Education and Employment, 1997).

The period following the publication of this consultation document saw the publication of a new version of the National Curriculum in 1999, in which the word "communication" was introduced into the title of the orders for the first time (Department for Education and Employment, 1999) and in which technologies such as email and the Web were included (although there was still no explicit mention of networked computers). Research commissioned by the government in this period highlighted the rôle that might be played by ICT in raising standards (eg Burghes, 1997; BECTa, 1998; McFarlane, 1999; BECTa, 2001; Harrison et al., 2003; Cox et al., 2004) and the way in which ICT may motivate students (Harrison et al., 2003; Cunningham et al., 2003; Cox et al., 2004). Although all of these studies consider the use of networked

computers in gathering information and in communicating with other people (including students, teachers and experts) there has been little exploration of the way in which networked computers may encourage the development of learning communities within and between schools, something that is given little emphasis in the UK government's recently-published e-learning strategy (Department for Education and Skills, 2003).

Summary

The use of practical work in school science teaching has a strong tradition, promoted by government policy and the subject of considerable research, and there is reason to think that many students enjoy practical work (RSC, 2002). There is also a consensus concerning the need for students to learn about the nature of science; this is an aim of the National Curriculum that has been strengthened in recent years, and a significant amount of research in science education has been conducted into young people's understanding of the nature of science and into ways in which this may be developed. These areas of research – concerning practical work and understanding the nature of science – overlap to the extent that a significant amount of research suggests that appropriately managed discussions of practical work may lead to an increase in understanding of the nature of science. This is an aim for practical work that has formed part of government policy and which has informed the development of the National Curriculum for Science.

While the use of computers in schools has grown during the 1990s and the early part of this century, there are significant differences in the patterns and types of use of computers within the school curriculum and elsewhere. Government policies for the use of computers in schools have been based largely on a rhetoric in which the raising of standards has been seen as paramount, coupled with a desire to produce young people who are the possessors of an appropriate set of ICT skills in

order to equip them for employment. Outside schools – in Higher Education and in Continuing Education in industry – attention has been focused on the use of networked computers and their ability to promote learning among peers which transcends both time and space. This is an aspect of computer use that has been almost entirely absent from the formulation of school policy, except where the Internet has been seen as a means of acquiring and distributing information. At the same time, the growth of personal computers in the home has meant that young people increasingly make use of computer networks for communication purposes. As a result of these developments, the use of networked computers in schools does not reflect their use in other areas of society, and there has been little research conducted into the rôle that CSCL may play in schools.

This chapter began by asking "Can CSCL be used to provide secondary school students with a way of sharing and discussing ideas relating to practical science investigations?" From the perspective of both research and policy, CSCL appears to be a particularly appropriate medium for supporting young people's science education due to the constructivist approach to knowledge that is common to research in both areas and due to the extensive use of networked computers for communication among young people that has yet to be reflected in pedagogical practice within schools. An appropriately developed CSCL environment may be highly suitable for providing students with support as they conduct a science investigation. Such an environment may enable students to collaborate in the construction of ideas related to a science investigation, to share observations and data, and to engage in a critical dialogue about the interpretation of these, provided that suitable expertise in managing the learning process is on hand and that a suitable context for the investigation is chosen. Crucial to the task are that it should motivate students and develop a sense of *shared purpose*. If these conditions can be met, it may be possible for the epistemological dimension of discussions among students to emerge.

The detection of these emerging epistemologies forms the basis of the research questions, which are discussed at the beginning of the next chapter.

Chapter 3

Research questions and methods

The previous chapter concluded that, under the right conditions, a CSCL environment may provide an appropriate medium for supporting students as they share and discuss ideas relating to practical science investigations, in pursuit of explanations for the behaviour of objects in the world. The epistemological dimension of interactions among a community of student scientists collaborating in this way can be thought of in terms of the three *key elements* of understanding the nature of science described by Driver *et al* (1996) and discussed on page 32:

1. *understanding the purposes of scientific work*
2. *understanding the nature and status of scientific knowledge*
3. *understanding science as a social enterprise*

From the perspective of researching this epistemological dimension it is unlikely that any degree of understanding of the *purposes* of scientific work are likely to a emerge from discussions surrounding school science investigations; the purposes of such investigations are largely determined by constraints that lie outside students' control and, to a degree, are outside the control of the teacher too. In order to achieve any discussion concerning the purpose of scientific work it may be necessary to direct students' attention away from students' science and towards scientists' science; this would have the undesirable effect of detracting from the *authenticity* of the discussion of practical work, a critical aspect of the nature of the knowledge building community as was shown in the previous chapter.

However, the other two key elements can provide a framework for examining the epistemological dimension of students' discussions, since these discussions are likely to feature interchanges which focus on knowledge and on knowing (eg "how does x affect y?"; "why do you think that ... ?"). It is therefore possible to maintain students' focus on students' science (ie the investigation in the classroom and the

speculation surrounding it) whilst still addressing issues that are relevant to scientists' science, thus maintaining authenticity.

Two research questions about science knowledge-building in a CSCL environment may therefore be posed; the first of these concerns the nature of scientific knowledge (key element 2), and the second concerns the social nature of science (key element 3). These questions focus on the understandings within the community about scientific knowledge and practice:

Research question 1

When students interact in a CSCL environment as members of a community of student scientists, what do these interactions reveal about the community's understandings which relate to the nature and status of scientific knowledge?

Research question 2

When students interact in a CSCL environment as members of a community of student scientists, what do these interactions reveal about the community's understandings which relate to science as a social enterprise?

The remainder of this chapter is concerned with the methodological approach to answering these two questions and the specific methods used to collect and analyse data; the ethical issues of researching interactions between young people under the age of 18 in an online environment are also discussed.

The nature of the research

The research questions described above concern the exploration of online interactions among a group of student scientists and the social relationships as the group constructs knowledge. Writing about studies involving human subjects, Cohen and Manion describe two contrasting

ways of approaching *conceptions of social reality* (Cohen & Manion, 1989:6). One of these derives from the traditions of the natural sciences which views social reality as external to the individual, and the other takes the view that social reality is the result of individual consciousness. The ontologies (beliefs about the way the world works) that correspond with these two views lead to very different epistemologies (beliefs about knowing), which in turn have implications for the approach to research (methodology).

Researching CSCL

As Oliver and Conole have pointed out, "the kinds of data that are available to e-learning researchers often suggest particular kinds of interpretation" (Oliver & Conole, 2004). This is far from being a problem unique to e-learning researchers, however; Borg & Gall have described the way in which different approaches to data collection have different conceptions of reality and human relations embedded within them, and note that the selection of approach will depend in part upon the research problem to be solved (Borg & Gall, 1989).

Surveying the literature concerned with the collection and analysis of data relating to CMC, McLoughlin suggests that there is "no lack of analytical tools for studying communication patterns" and lists eight major approaches to researching online learning: *survey questionnaire*, *user interview*, *case studies*, *discourse analysis*, *participant structure analysis*, *intermessage reference analysis*, *message act analysis* and *content analysis* (McLoughlin, 1996, see table 3.1). In fact McLoughlin's survey is somewhat broader in scope than communication patterns alone, and concerns techniques used to collect and analyse data relating to learners' responses to CMC (through survey questionnaires and user interviews) in addition to techniques which are intended to provide some insight into learners' online interactions (through case studies, discourse analysis, participant structure analysis, intermessage reference analysis, message act analysis and content analysis). In the

case of those techniques listed by McLoughlin which are directly concerned with studying online interactions, the case study approach (defined as "a detailed examination of a single subject, group or phenomenon" (Borg & Gall, 1989:402)) alone has the potential to produce a rich description of the research subject through interactions between the researcher and the subject over an extended period of time. In contrast, the other techniques adopt an approach in which the relationship between the researcher and the subject is one in which each functions independently of the other, and in which research strategies are intended to minimise the way in which any interaction affects the research outcomes.

Technique	Method	Purpose
Survey questionnaire (Hiltz 1988)	pre and post course questionnaires	to obtain student views on CMC effectiveness
User interview (Burge 1993)	interviews by telephone and face to face	to explore participants' views of online learning
Case studies (Waggoner, 1992)	qualitative and quantitative techniques of participant analysis	to gain insight into processes and outcomes of collaborative learning
Discourse analysis (Graddol 1989)	examination of discourse structure, turn taking and development	to examine the properties of talk that contribute to learning
Participant structure analysis (Levin, King, Riel, 1990)	examination of interactive structures occurring in CMC environments	to compare interactions in different networked environments
Intermessage reference analysis (Levin et al. 1990)	coding of messages to determine reference to previous message	to trace multiple threads or topics
Message act analysis (Levin et al. 1990)	to plot the density of messages per unit time	to show general level of peaks and troughs
Content analysis (Henri 1992)	in depth analysis of message content	to understand the learning process and its social and cognitive dimensions

Table 3.1 – approaches to data collection and analysis (from McLoughlin, 1996)

Implicit in any approach to research is the ontology of the researcher – for example, techniques employing survey questionnaires and content analysis involve the researcher in making sense of data without reference to those from whom it was generated, usually with the intention of producing theories that are generalisable over time and space. Such an approach suggests a *positivist* view of research,

assuming that the "procedures of natural science may be applied directly to the social sciences" (Cohen & Manion, 1989:12) and that with "sufficient research ... every action or effect can be explained by a cause ... that precedes the effect in time" (Borg & Gall, 1989:384). In the context of researching CMC, a positivist perspective implies that it is possible for the researcher to know all that there is to know about an online discussion simply by reading a transcript of it. The attractiveness of such a position is discussed by Lally and De Laat, who note that data deriving from online interactions carries with it "the comforting feeling ... that the transcripts of discussions taking place [online] contain easily accessible and significant evidence of learning among the participants" (Lally & De Laat, 2002).

A positivist approach to the collection and analysis of data from CMC has formed a common approach in the last 15 years (Rourke et al, 2001; Oliver & Conole, 2004), based on the idea that the entire meaning of online interactions is accessible through logfile analysis alone. Rourke et al (2001) list 19 studies that they describe as "influential", all employing some variety of content analysis. The basis for the majority of these is the work of Henri (1991), whose analytical framework for the categorisation of students' electronic contributions to a discussion is based on five dimensions. These classify contributions as:

1. Participative (contributing to the online discussion)
2. Social (unrelated to subject matter of online discussion)
3. Interactive (responding to another message)
4. Cognitive (exhibiting knowledge and skills relating to the discussion)
5. Metacognitive (showing awareness, self-control and self-regulation of learning)

(Henri, 1991:125)

Content analysis can be described as a positivist research method since it is the researcher who is in complete control of determining meaning based on text alone:

> *The first analysis ... allows us to extract from messages the ideas that have been presented, so that what has been said about the subject may be understood.*
>
> (Henri, 1991:123)

> *Our proposal is to divide messages into statements corresponding to units of meaning, and to use these, rather than messages proper ...*
>
> (Henri, 1991:126)

Research which adopts a positivist approach has an epistemology that allows the researcher to make specific claims about the world provided that an appropriate methodology has been employed – the general term for the quality of such research is its *objectivity* (Cohen & Manion, 1989:20-24; Borg & Gall, 1989:247-8). Concerns about the objectivity of content analysis form part of the discussion of the strengths and weaknesses of content analysis by Rourke et al, who argue that "the failure of researchers to adhere to the principles that make quantitative research valid" makes content analysis unreliable (Rourke et al, 2001:21). Other researchers disagree, and contend that the problem with content analysis lies not in the way it is conducted but in its positivist approach *per se*, which attempts to infer the meaning of data out of context (Jones, 1999; Hara, Bonk & Angeli, 2000; Salmon, 2002; Herring, 2004).

Researchers who argue against a positivist methodology propose a more naturalistic form of enquiry in which the study of a setting is more holistic and where the relationship between the researcher and the research subject is one of interaction rather than distance (Borg & Gall, 1989:383-4). For example, McConnell sounds a note of caution about the adoption of positivist approaches to research into CSCL, which seek to "define *how* we look at research data in advance of carrying out the research" (McConnell, 2000:242). He argues for making sense of data from a naturalistic perspective, also described by Salmon as

constructivism, involving "participants ... [exploring] their own thinking and knowledge building processes" (Salmon, 2002). The ontological position of research of this kind rejects the notion of an external, observable reality to which the observer has direct access through objective research methods. The result is an epistemology in which knowledge claims are not intended to reveal ultimate truth but to provide a rich description of the world in order to make sense of it (Cohen & Manion, 1989:27). The implications of this epistemology for the methodology of inquiry into CSCL are the adoption of "research methods that would allow us to explore issues rather than methods which would impose a certain kind of highly structured framework on the research" and in which "we would want to relate our analysis to that of the groups' own analyses ... but we would also be analysing the transcripts [of the CSCL work] in order to examine the ways in which knowledge is negotiated, controlled, understood, etc by the learners and tutors" (McConnell, 2000:242-3). On this theme, Lally & De Laat suggest that a more appropriate approach to data collection and analysis when researching online learning communities is to avoid the use of single methods, and to make use of a multi-method approach in order to "understand a richness of learning beyond the capability of any one of the methods when used by itself" (Lally & De Laat, 2002). Henderson also notes that "when it comes to researching new media, it is becoming clear that a mix of ... methods is necessary to fully understand the nature of online activities" (Henderson, 2004:105).

Summary

A considerable quantity of research into online learning communities has been conducted on the assumption that the entire meaning of online interactions can be captured by the logfiles of online dialogue generated automatically by the computer. Recent work has highlighted the inadequacy of this approach, pointing out that the richness of human interactions, even when computer-mediated, makes them not susceptible to simple textual representation. This work strongly

suggests that the use of more naturalistic approaches are likely to provide a deeper picture of the research setting, leading ultimately to a fuller understanding. Although the use of naturalistic methods may offer advantages in terms of the depth of description, this may be at the expense of an ability to generalise from the findings so as to be able to "search for universal laws which explain and govern the reality being observed" (Cohen & Manion, 1989:8); the adoption of a multi-method approach to data collection and analysis may go some way towards addressing these concerns.

Researching understandings of the nature of science

Whilst the history of teaching about science goes back around one hundred years, the history of research in this area is only just fifty years old (Lederman, 1992). The research methods used in early studies emphasise the use of pencil and paper tests to measure an individual's conception of the nature of science; in many studies this is then compared with the nature of science as determined by "experts" such as scientists, philosophers and science educators (eg Cooley & Klopfer, 1963; Rubba & Andersen, 1978). Such studies emphasise the acquisition of an understanding of the nature of science that can be described as "correct"; some are associated with specific curriculum innovations connected with developing students' understandings of the nature of science:

> *Proportions of student pre-test and post-test responses to three ... items concerning the international character of science are presented ... the changes in student responses were in the direction of the best answers for all three items.*
>
> (Klopfer & Cooley, 1963:79)

Reservations about the use of instruments like these include the difficulty that some students at school level may have in understanding the language used in some of the items (Hukins, 1963) and the evocation of strong affective response in the subject by some items, leading to an measure that is likely to be attitudinal rather than cognitive (Aikenhead, 1973). As with early research analysing online

interactions, these examples of research into conceptions of the nature of science adopt a positivist ontology, laying them open to essentially the same criticism – the entire "meaning" of an individual's response to an item in a questionnaire cannot be encapsulated in a single letter or figure. Even where subjects' responses take the form of complete sentences or paragraphs, the researcher is still placed in a position of needing to interpret these, leading to concerns over the validity of such research (Munby's "doctrine of the immaculate perception", quoted in Aikenhead, Fleming & Ryan, 1987).

For this reason more recent research has moved away from this approach; for example Aikenhead has advocated exploring students' views of the nature of science using methods that are grounded in the responses of students themselves (Aikenhead, 1988), a position supported by Lederman, who cites evidence from various studies which suggest that "the use of interviews to assess students' understandings of the nature of science are essential" (Lederman, 1992:349). A comprehensive study of UK students' conceptions of the nature of science conducted by Driver and co-workers notes the "richness and complexity" of students' understandings; this employed a methodology with instruments based on stimulus material, associated tasks and semi-structured interviews (Driver *et al*, 1996). These developments in methodology reflect changes in ontology and epistemology relating to science studies and described by researchers concerned with the public understanding of science (eg Shapin, 1992), recognising that the nature of science and scientific knowledge is not susceptible to a simple positivist characterisation (Ziman, 1991).

Surveying instruments used to assess understandings of the nature of science, Lederman Wade and Bell catalogue 24 different "nature of science instruments", concluding that "while paper and pencil instruments can reveal something about students' views of the nature of science they cannot tell us everything we would like to know"

(Lederman, Wade, & Bell, 1998:345). They conclude that instruments for assessing understanding of the nature of science with certain characteristics are likely to have poor validity; these characteristics are:

1. largest proportion of the instrument concentrates on a student's ability and skill to engage in the process of science;
2. emphasis on the affective domain (the realm of values and feelings) rather than knowledge;
3. primary emphasis on science as an institution with little or no emphasis upon the epistemological characteristics of the development of scientific knowledge.

(Lederman, Wade, & Bell, 1998:332-3)

Summary

The literatures concerned with researching learning communities interacting through CMC and with methods of probing learners' understanding of the nature of science show considerable similarity. Online interactions between students may be complex and extensive; the analysis of these is more likely to lead to insightful conclusions when a naturalistic approach is adopted which involves the students themselves in making meanings from the textual data. Understanding students' positions concerning the nature of science is a similarly complex process, and is also more likely to be productive when a non-positivistic approach is used.

The analyses of these two different strands of research, each concerned with the research questions in this study, strongly point to a methodological approach in which any initial interpretation of CMC-derived data is followed by further data collection to provide the participants with an opportunity to contribute to the construction of meaning from the original logfiles. In order to provide valid measures of understanding the nature of science, this process should focus on understandings relating to knowledge and knowing rather than on attitudes. The knowledge claims arising from such an approach,

although not necessarily capable of being regarded as widely generalisable, are more likely to provide a full description of the community's understandings of the nature of science present in online discussions.

Studying a knowledge-building community

The effective study of a knowledge-building community is dependent upon a suitable theory being used to frame it. Given the characteristics of the community as described above, such a theory must be capable of taking into account that cognition within the community is *distributed*, emerging in situations "tackled by teams of people and the tools available to them" (Salomon, 1993a:xiii); it must fit with the task-driven nature of the learning; and it must also provide a way of describing how individuals collaborate as they pursue these tasks. *Activity theory* is a longstanding theoretical perspective used to frame studies which involve collaboration in pursuit of a shared task, with a history that goes back to work in the former Soviet Union in the 1920s (Nardi, 1996b:73). Hill et al argue that activity theory is well suited to the study of knowledge-building communities because it "situates activity within particular sociocultural contexts and because it can be used to analyze both individual and collective activity" (Hill, Cummings, & van Aalst, 2003:10). This link is also highlighted in a paper concerning methodological approaches to studying networked learning by De Laat and Lally, who note that "the tension between the conceptual structure or understanding ... of the group or the individuals within it is the driving force for the collective processing of the group" (De Laat & Lally, 2003). The link between individual and collective understanding provided by activity theory suggests that it is likely to be more powerful in framing studies of knowledge-building than sociocultural theories of mediated action such as those of Wertsch (1998). Hill et al also reject frameworks based on situated learning (Lave & Wenger, 1991) for knowledge-building communities in schools, not on the basis of the inability of the teacher to act as an expert

practitioner of research (page 38) but because situated cognition is based upon "the trajectory of community members from the periphery to the centrality of the community" (Hill, Cummings, & van Aalst, 2003:11) and it does not allow for individual members of the community to occupy different positions within the community at different times, something that is to be expected as knowledge-building occurs.

Activity theory

Activity theory draws principally on the work of Leont'ev, Luria and Vygotsky (Hedegaard, Chaiklin, & Jensen, 1999). Its name is somewhat confusing, since it is neither directly concerned with activity *per se*, nor is it a theory in the sense of being a fixed body of accurately defined statements (Kuutti, 1996:25). The description of activity theory that follows is based principally on the work of Cole and Engeström (Cole & Engeström, 1993; Cole, Engeström, & Vasquez, 1997; Engeström, Miettinen, & Punamäki, 1999). At the heart of the theory is the notion that all human experience is rooted in social interactions; but an understanding of the theory must begin with a consideration of the individual and the importance of *tools* and their rôle in mediating human behaviour, the word tool connoting a culturally-derived artefact which may be physical (eg a hammer or a car) or psychological (eg language or a scientific theory).

The basic mediational triangle (figure 3.1) describes the relationship between an individual (or *subject*) and the *object* of some activity. *Natural* or *unmediated* activities are directed along the base of the triangle, while *mediated* activities are those which are subject to the influence of tools of some kind. This then forms the basis of a more complex model, designed to account for the collective nature of human activity. This model is often referred to as the *activity triangle* (figure 3.2).

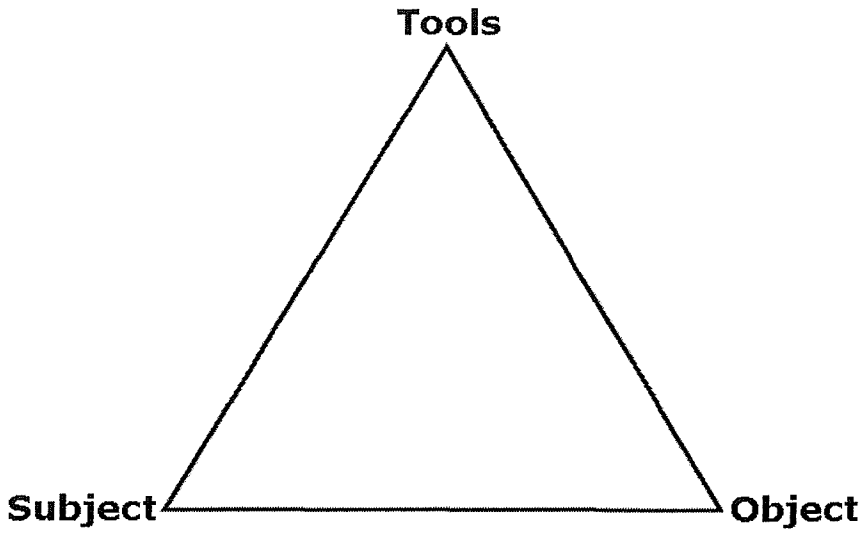


Figure 3.1 – the basic mediational triangle

The activity triangle is concerned with the ways in which individuals cooperate in communities in order to perform some kind of activity directed toward a common goal (or *object*). This object may be tangible (eg a spectrophotometer) or it may be abstract (eg a theory); the one requirement is that it should be something that all members of the community can share for the purposes of manipulation and transformation during the activity, which is directed towards some shared *outcome*. Working together as individuals and as groups, each with their own object and employing a particular set of *tools*, the

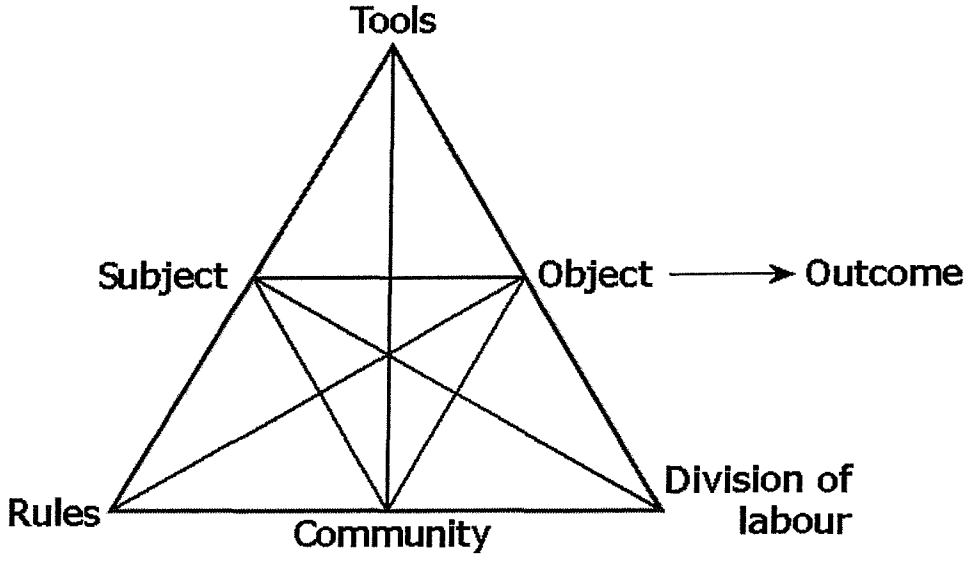


Figure 3.2 – an activity triangle

community will pursue the common outcome of this activity, and in doing so will be subject to a variety of *rules* which govern the conduct of the community (including the relations between the *subjects* making up the community) and the *division of labour* within it.

The epistemic qualities of activity theory

Activity theory can provide a means of unravelling the complex sets of relations between people, mediating influences and objects in the pursuit of a common outcome. It has been employed by researchers examining such diverse situations as scientists undertaking research into enzyme action (Miettinen, 1998), the introduction of new technology in the United States Postal Service (Engeström & Escalante, 1996) and the development of communication skills for networked learning (McAteer et al., 2000). As Nardi observes, the strength of activity theory is that "as a unified approach [it] obviates the need to construct a theoretical apparatus bricoleur fashion, from a multiplicity of smaller frameworks" (Nardi, 1996a:375).

Where the emphasis in situated learning is on activity that is specific to a particular context (the apprentice learning to carry out a task under the instruction of a master), the focus of activity in activity theory is always towards the intended outcome shared by the community, progress towards which is made through the joint efforts of individuals dividing up the activity into discrete "chunks", and making use of knowledge and expertise spread throughout the community. Hutchins illustrates this when he writes about the way in which the expertise needed to carry out certain flying manoeuvres is embodied, not simply within the brain of a single pilot but throughout the pilot/aircraft system:

> *The memory of the cockpit...is not made primarily of pilot memory. A complete theory of individual human memory would not be sufficient to understand that which we wish to understand because so much of the memory function takes place outside the individual.*
>
> (Hutchins, 1995:286)

In this sense activity theory and distributed cognition are closely related – Nardi goes so far as to argue that the two approaches "will mutually inform, and even merge, over time" (Nardi, 1996b:89). In this case, activity theory provides the framework for the entire study, while distributed cognition is an important element which frames the collection and analysis of data, reflecting the emphasis on common understandings within the community, as described in the research questions.

Of particular relevance to both activity theory and to distributed cognition are Popper's three worlds (Popper, 1972): world 1 (W1) consisting of material artefacts, world 2 (W2) of personal ideas and beliefs and world 3 (W3) of conceptual artefacts such as theories and models. W1 and W3 both contain the tools with which the community works in pursuit of the outcome of the collective activity. These two worlds can interact only through W2, that is to say, the personally constructed worlds of each of the members of the community as applied in the particular context. This is not to say that W3 represents a social dimension of the ideas held by individuals in W2; rather, as ideas are developed in W2 they may enter W3 where they take on a life of their own, literally belonging to this world (Hill, Cummings, & van Aalst, 2003).

Applying activity theory

Although activity theory provides a framework which offers a way of describing the complex relationships existing when a community undertakes an activity, any attempt to do this in a holistic way requires the simultaneous consideration of a large number of interdependent variables. In order to apply the theory, what is needed is some way of deciding which are the most important and relevant variables on which to focus – the theory must be 'concretised' (Wells, 2002). Some workers achieve this by adapting and developing the activity triangle to fit the system under study (for example Hedegaard, 1999; Ardichvili,

2003), others consider the areas of interaction between two activity systems (for example the notion of the *common object* in Hakkarainen, 1999 and in Daniels & Cole, 2002), or adopt a grid-based taxonomy of activity elements (Kuutti & Arvonen, 1992). Another approach is to take the activity triangle itself and focus attention on relevant aspects through reference to the two-dimensional properties of the model, which should be regarded as flexible (McAteer & Marsden, 2004). The approach described here is based on the use of *triads*, an approach that developed by Lewis as a means of constraining the number of variables to be considered at any one time (Lewis, 1997). These triads are labelled according to the points in the activity triangle that comprise their vertices. The first triad provides the frame for the study setting, linking relationships between individuals, the community and the intended outcome of collaboration (knowledge-building), the second triad describes the rules used by the community in knowledge-building, while the third triad is concerned with the tools used by the community.

*Triad SCO – **S**ubject : **C**ommunity : **O**bject*

Triad SCO (figure 3.3) describes the relationship between the **S**ubject, the **C**ommunity and the **O**bject; that is, it concerns the intentions of individuals within the community and those of the community as a

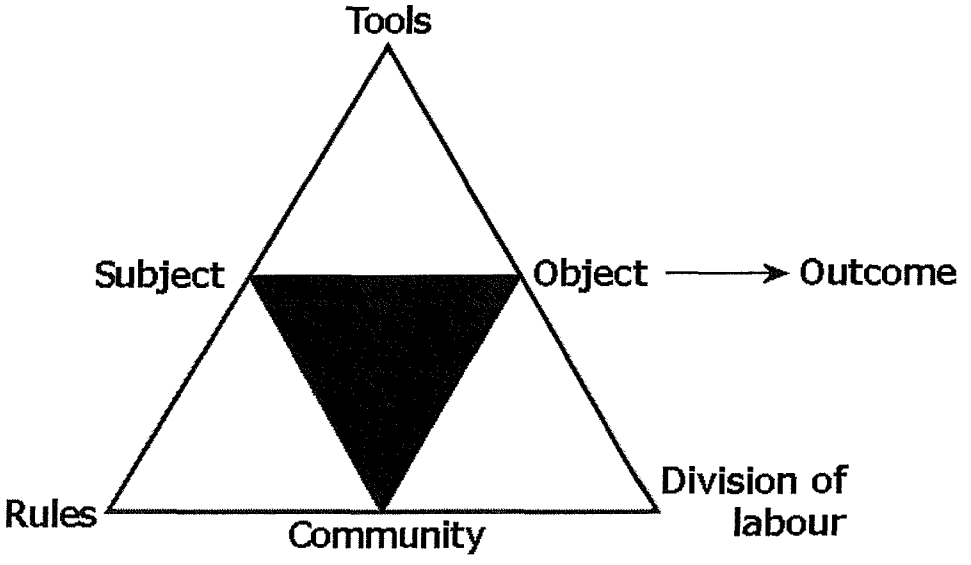


Figure 3.3 – triad SCO (additional lines removed for clarity)

whole. Lewis argues that this triad plays an important rôle in the establishment of a learning community because "there must be space for interpretation, negotiation and the establishment of group ownership of the motive [the object of collaboration]" (Lewis, 1997:214).

This triad provides a way of viewing collaborative knowledge-building discussed in the previous chapter, and in particular the conditions guiding the establishing of knowledge-building communities on page 43. These make clear statements about: the nature of the tasks to be undertaken; the way the community is organised; the nature of the relationships between individuals and the community; and the rôle of the teacher and the student/teacher relationship. Clear understandings of about all of these are required if there is to be collaborative activity directed towards the shared object of producing explanations, encouraging learners "to draw upon the rich potential of each other's ideas and perspectives" (Steeples & Mayes, 1997:219). Table 3.2 shows how the aspects highlighted by the activity theory approach correspond to the conditions required for knowledge-building and, crucially, how the knowledge-building perspective addresses the relationships within the SCO triad.

Activity theory	Conditions needed for knowledge-building
nature of tasks to be undertaken	1. sustained study of topics in depth rather than superficial coverage 2. focus is on problems rather than on categories of knowledge 3. enquiry driven by students' questions 4. explaining is the major challenge 5. day-to-day focus is progress toward collective goals of understanding and judgement
organisation of community	6. students typically work in small groups, each with a different task
nature of the relationships between individuals and the community	7. discourse is taken seriously
rôle of the teacher and the student/teacher relationship	8. teachers can contribute what they know to the discourse, but there are other sources of information; 9. teacher's role shifts to leading it by virtue of being a more expert learner

Table 3.2 – activity theory as related to knowledge-building communities

*Triad RCO – **R**ules : **C**ommunity : **O**bject*

Triad RCO (figure 3.4) is concerned with the way in which the community operates in order to achieve the intended outcome of the activity, and in particular, the rules used by the community as it pursues this outcome; these rules may be described as belonging to one of two classes: *explicit* and *tacit*, depending upon the extent to which they derive from external sources intended to provide behavioural norms or whether they derive from internal interactions within the community. Explicit rules are those which are clearly articulated from the start; they are effectively those that are the rules for joining or participating in a community; in contrast, tacit rules develop as part of the community's social capital through the establishment of social norms (Preece, in press).

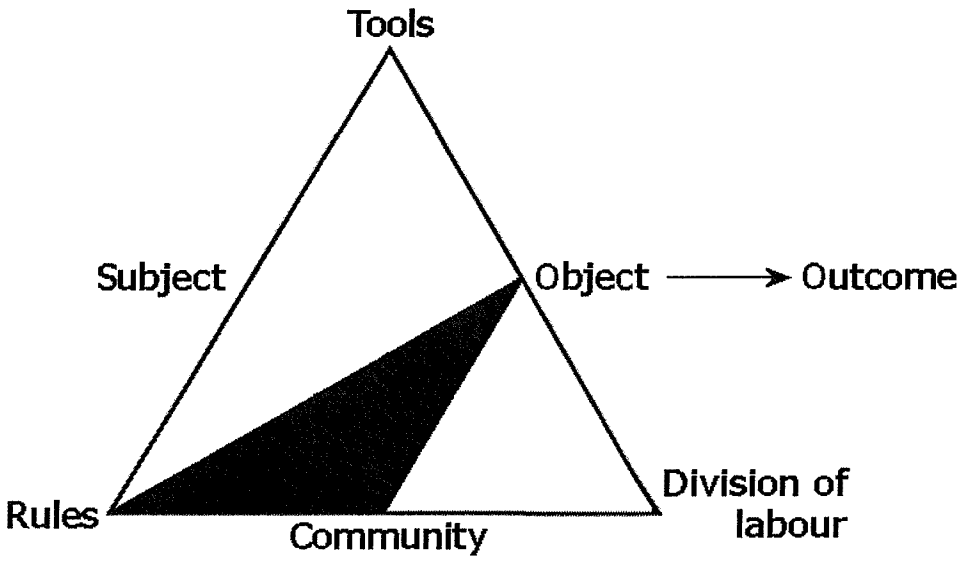


Figure 3.4 – triad RCO (additional lines removed for clarity)

Explicit rules guide and shape behaviour in a community in order that the community can better function. The need for clear rules when seeking to promote discussion in classrooms is made by Edwards and Mercer, who note that such rules normally remain unarticulated, for reasons related to assumptions by teachers that they are self-evident, the desire by teachers to exert control over the educational process and

the idea (held by teachers) that rules should not need articulating (Edwards & Mercer, 1987:59-60). Awareness by teachers of the complexity of classroom interactions and the rules which guide them is also a key point made by Wellington, who argues that such awareness has an important part to play in understanding and improving classroom discussion (Wellington, 1998a). In the light of this, it is important that the teacher(s) (and any other "experts") involved with any knowledge-building community work to produce a set of rules that are made explicit to students, and which are designed to foster and develop the kind of contributions that are likely to prove productive in generating new knowledge, ie "half-formed" ideas. Rules which encourage this kind of speculative thinking support the authenticity of the activity in which the community is engaged, according to recent work in the field of argumentation in science classrooms:

> *... school science predominantly deals in ideas which are perceived to be right or wrong, whereas good discussion requires the participants to propose thoughts that are half-formed or simply flawed. Therefore, teachers need to 'impress on them that it doesn't matter if what they think is wrong'.*
>
> (Newton, Driver & Osborne, 1999:566-7)

Based on a survey of 14 experienced science teachers, Newton, Driver and Osborne list four *constraints* affecting the development of discussion in science lessons: *advanced planning*, *appropriate time slots*, *a prerequisite knowledge base*, and *establishment of clear procedures for running group discussions* (Newton, Driver and Osborne, 1999:566). In the context of online interaction there is also need for an explicit set of rules to guide behaviours, and to link these with behaviours in the "real" world; the process of facilitating and guiding online interaction is sometimes referred to as *e-moderation*. The differences between the online and the "real world" environments mean that e-moderation is somewhat different to teaching in a classroom or managing a discussion in a seminar room, although there are similarities too. Salmon writes:

> *The lack of traditional hierarchies in CMC and its ability to support synthesis of knowledge lead to somewhat different styles of*

> *communication and knowledge sharing, compared to synchronous meetings ... the CMC environment is such that mistakes are rather public and recorded for all to see ... minor complaints can escalate when several individuals in a conference agree with each other and create a visible 'marching about with banners' online.*
>
> (Salmon, 2000:19)

There is thus a need to ensure that, as far as possible, everyone is clear about the kinds of rules that apply in both face-to-face and online settings; furthermore, these rules should be commensurable, since the "social understandings and practices" (Baym, 1998:40) in one clearly influence the other.

In a science knowledge-building community in school, explicit rules can be traced to two sources. One of these is the social milieu within which the community operates, ie the school (school rules will also reflect those of the wider society within which the school itself operates); the other is derived from the perceived way in which scientific discourse is conducted, communicated through the mass media and (especially important in a school context) through text books and curriculum materials, and through teachers themselves, too. (For example, Monk and Dillon describe the image of science presented in the Key Stage 3 curriculum documents as one of *empiricism* tempered (depending upon the teacher's mediating rôle) by the presentation of evidence to support contemporary scientific views (Monk & Dillon, 2000).) The very model of science in the curriculum, in the form of the attainment target known as *Sc1*, itself provides powerful messages, mediated by teachers (the majority of whom have received little formal instruction concerning the history or philosophy of science (Lakin and Wellington, 1994)), about the way in which science as an enterprise is conducted. The unmediated messages contained within the National Curriculum present a picture that conveys science in a way that is consistent with Merton's description of science as being conducted in accordance with four *constitutive norms*. The four norms can be represented by the letters **CUDOS**, which stand for -

> ***C**ommunalism - science is concerned with public knowledge. This norm implies that secrecy has no place in the conduct of science.*
>
> ***U**niversalism - science is a collective activity. This norm implies that the conduct of science depends on scientists being able to express themselves freely, to communicate with each other freely, and to travel freely, without discrimination.*
>
> ***D**isinterestedness - science is emotionally neutral. This norm implies that the conduct of science depends upon the scientist being detached from the object of study.*
>
> ***O**rganised **S**cepticism - science involves rational procedures and reserved judgement. This norm implies that a scientists' work is judged against a set of rational criteria before being accepted into the body of scientific knowledge.*
>
> (Fullick & Ratcliffe, 1996)

Like any normative description, these norms present science in an idealised, quasi-romanticised way; it is questionable whether any human activity could be said to be truly described by such high ideals in which disputes about interpretation of data are conducted with complete emotional neutrality.

Writing in the context of studies of online communities, Preece notes the way in which thriving social groups develop norms for behaviour based on *tacit knowledge*; these rules are communicated and enforced through informal communication in stories, anecdotes, impromptu comments and personal opinions (Preece, in press). Within a community of scientists explicit knowledge (in books, journals etc) appears to be the predominant way in which the community pursues its objects (the production of new scientific knowledge); however, tacit knowledge is also crucial in the conduct of science (Collins, 1974; MacKenzie & Spinardi, 1995; Collins, 2001), playing a rôle in constructing knowledge, in applying it and in validating it (accepting it as "finished").

Collins and Pinch point out that the resolution of "deep disagreements" in science inevitably involve more than experiments; there are social

forces at work which would not normally be thought of as scientific activities (Collins & Pinch, 1994:101). This is because the conduct of experiments is a highly skilled process, and there are no direct measures available to decide whether or not an experiment has been conducted skilfully except getting the "right result" – which is itself the point of contention in the case of the production of new scientific knowledge. (This situation is described by Collins and Pinch as "the experimenter's regress", and was discussed on page 21 in the context of students' science. In students' science the "right result" is available through the textbook or teacher, and therefore provides a measure of skill.) The rules which govern the interactions through which judgements are made about the skilfulness or otherwise of an experimenter are based on tacit knowledge.

Concerning the relationship between knowledge in the process of being made and "finished" knowledge, Collins writes:

> *... when we consider the grounds of knowledge we do it within an environment filled with objects of knowledge which are already established ... it is as though epistemologists are concerned with the characteristics of ships (knowledge) in bottles (validity) while living in a world where all ships are already in bottles with the glue dried and the strings cut.*
>
> (Collins, 1975:205)

Collins is referring here to Popper's *World 1* (or *W1*, which consists of "all the material objects that we normally experience" (Corvi, 1997:87)) and to his *World 3* (or *W3*, containing "all the products of the human mind" (Corvi, 1997:88)). Although, according to Popper, these two worlds are not in contact, each is in contact with World 2 (*W2*), which "encompasses all our psychological experiences both conscious and unconscious, from states of mind to desires, from convictions to memories" (Corvi, 1997:88). The difference between *W2* and *W3* provides a distinction between thought processes themselves and the *outcomes* of thought processes; in making judgements about knowledge claims scientists apply *tacit rules* which determine whether an idea may pass from *W2* into *W3*.

In the context of the knowledge-building community of student scientists, answers to research question 2:

> When students interact in a CSCL environment as members of a community of student scientists, what do these interactions reveal about the community's understandings which relate to science as a social enterprise?

may therefore be sought by examining the criteria (or *tacit rules*) used by the community when knowledge claims are scrutinised in order to decide whether they may pass from *W2* into *W3*.

*Triad TCO – **T**ools : **C**ommunity : **O**bject*

The third triad (figure 3.5) concerns the tools used by the community in addressing the object of the activity – in this case, the joint construction of an explanation for a scientific phenomenon under practical investigation.

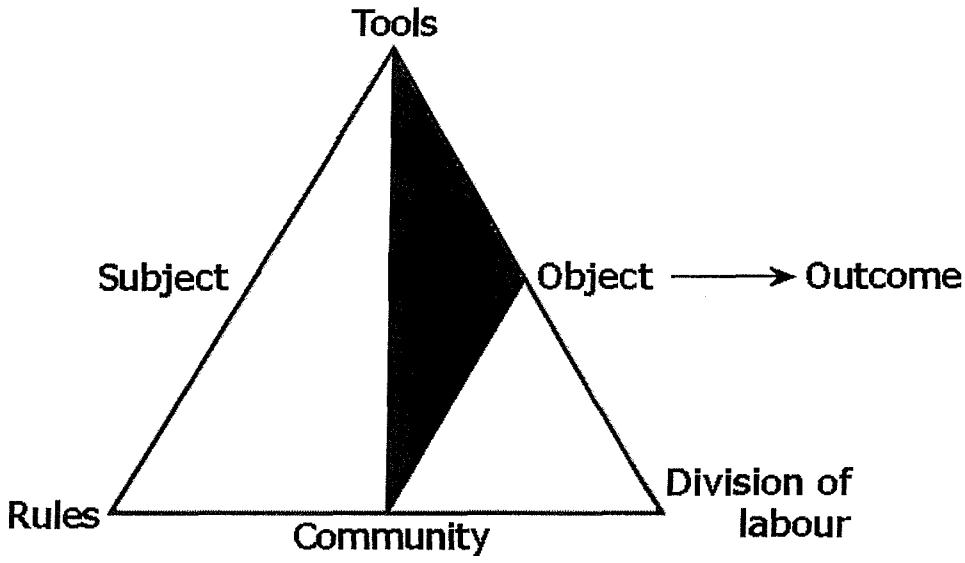


Figure 3.5 – triad TCO (additional lines removed for clarity)

Although the term tools inevitably has connotations with physical artefacts such as hammers and saws, Cole and Engeström make the case that the term includes psychological tools as well, quoting Vygotsky's argument that "what we conventionally call tools and what

we conventionally call symbols are two aspects of the same phenomenon" (Cole & Engeström, 1993:6). The tools employed by the community in this way are *cultural tools* (Hill, Cummings, & van Aalst, 2003); in Popper's terms, they are the *W3* artefacts that the community employs in pursuit of explanations of *W1* phenomena. They are thus represent of the *collective goods* of the community undertaking a shared activity (Rheingold, 2000:xxxviii).

As with the community's use of rules, tools may be classified as *explicit* or *tacit*; again, the classification of a particular tool depends upon the extent to which it is derived from external sources or whether it derives from internal interactions within the community.

The term *explicit tools* relates to those which are applied through general agreement within the community and which are derived very largely from sources within the community of professional scientists. Such tools include science knowledge or 'facts' (eg the atomic mass of sulphur or the density of water) and scientific theories that are regarded as 'proven' (eg Newton's laws of motion or the laws relating to chemical combination of elements). These tools may be acquired by the student knowledge-building community from a variety of authoritative sources which include textbooks, the teacher and the Internet (with especial regard to provenance in the case of the last example). In addition to these tools for thinking, the community also has access to a set of physical tools (laboratory apparatus, computers etc) to assist in making progress towards its object.

The net effect of this dual set of tools is to double, as Cole and Engeström observe, the world in which humans work – through the use of language we have access to meanings and theories in addition to objects (Cole & Engeström, 1993:6).

Tacit tools are operated by the community with little or no discussion about them. The use of these tools is determined by the way in which the community goes about achieving its objects, and what may be termed its *style* or *approach* as it does so. Thus, the tools involved here are those which the community uses as it makes use of the explicit tools described above. As an example, consider a group of student scientists acting collectively to classify some leaves that they have found in the school grounds. The leaves form part of Popper's W1, while the taxonomy produced by the community of student scientists will exist in W3; in order to produce and agree this taxonomy, students first produce personal theories which exist in W2. The relationship between objects in W1 and tentative, pre-formed personal ideas in W2 – which may be held by small groups of individuals as well as by individuals (Salomon, 1993b:121) – depends upon judgements made by students about knowledge and the world, which are in turn influenced (as was seen at the beginning of this chapter) by ontological positions. Discussions about *models*, the *reliability* and *validity* of measurements, the implications of *graphs* and the *mathematical handling* of data are all part of making these judgements, which make use of *tacit tools*. The tools are not the models, measurements and graphs themselves, but are rather the distributed mental structures used by the community in making sense of the world; this is Mercer's *interthinking*, carried on as "joint, co-ordinated intellectual activity" (Mercer, 2000:16) and mediated by language in which "the resources of past experience [are used] to make new, joint, knowledge and understanding" (Mercer, 2000:46). The analysis of the language used in making (shared) meaning thus provides important evidence for the kinds of tacit tools used by the community as knowledge moves between worlds.

Answers to research question 1:

> When students interact in a CSCL environment as members of a community of student scientists, what do these interactions reveal about the community's understandings which relate to the nature and status of scientific knowledge?

may therefore be sought through examination and analysis of students' discussions about the relationship between objects in W1 and knowledge in W2 and W3.

Summary

In this study, activity theory provides a framework for structuring relationships in a knowledge-building community of student scientists, in which individuals collaborate in pursuit of a shared goal (the development of explanations of phenomena). Within the activity triangle, triadic groups highlight important relationships within the community – one of these (triad SCO) frames the conditions needed for knowledge-building and online interactions while two others (triads RCO and TCO) describe the ways in which the community approaches knowledge-building. The activity triangle thus acts as a unifying framework which brings together the theories underpinning the study, as shown in figure 3.6.

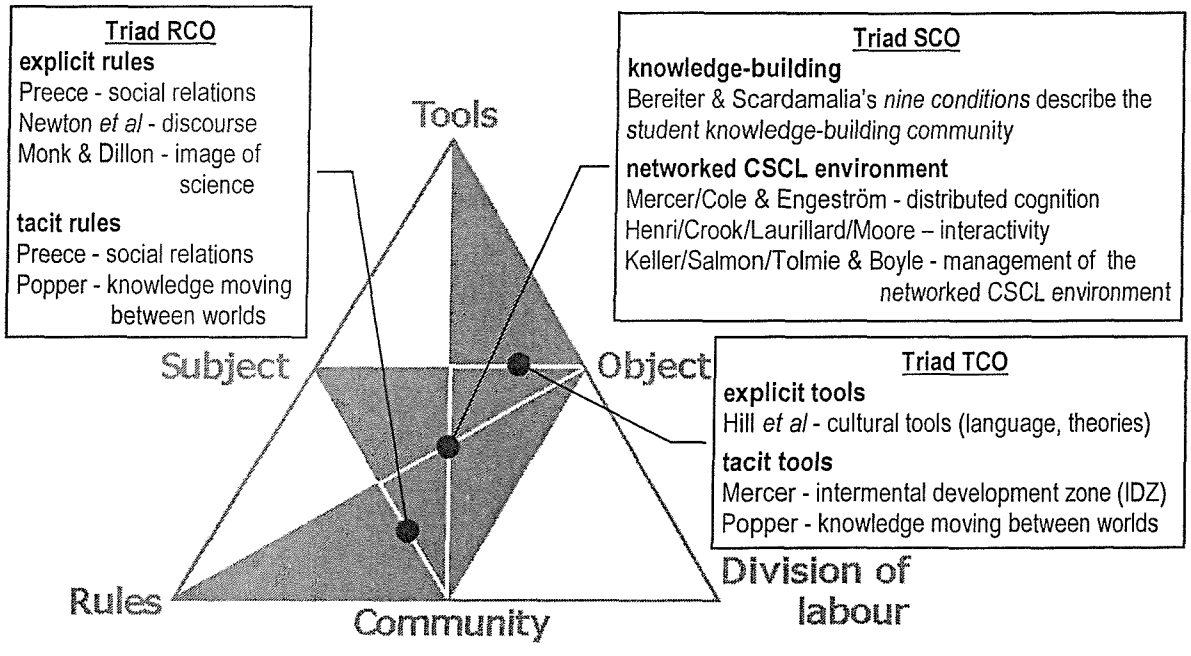


Figure 3.6 – activity theory as the unifying theoretical framework

In this unifying framework, triad SCO describes and frames the setting within which the student scientists interact, both online and offline. In this setting the description of knowledge-building by Bereiter &

Scardamalia (1993) provides a set of conditions (see page 43) which guide the pedagogy to be adopted when creating a knowledge-building community. These conditions are reflected and supplemented by a series of theories which relate to the pedagogical implications of extending knowledge-building into an online environment. These comprise:

- theories describing the way in which knowledge is distributed between members of the community – Mercer (2000), Cole & Engeström (1993)
- theories concerning the management of online communities in order to motivate participants to engage with learning tasks and contribute to discussions – Keller (1983), Salmon (2000, 2004), Tolmie & Boyle (2000)
- theories where the relationship between learners and teachers provide insight into the development of different types of interactivity to promote cognitive development – Henri (1995), Crook (1994), Laurillard (1993), Moore (1993)

Between them, the theories concerned with triad SCO provide a *reflexive accounting for substance* (Altheide & Johnson, 1994) in which each theory is included on the basis of its necessity in relation to one or more aspects of the setting for the enquiry, while the body of theories as a whole is sufficient to frame the enquiry. Within the naturalistic methodology of this study these theories comprise a statement of the researcher's *interpretative paradigm* (Guba & Lincoln, 1994) – the equivalent of which are the controlled variables of the positivistic researcher.

In addition to the theories within triad SCO, concerned with the pedagogical environment experienced by students, triads TCO and RCO frame the *social* context of interactions between students. These interactions are governed by *explicit* tools and rules used by students as they focus on the task(s) required by knowledge-building (the *object* of

their activities). The explicit tools here are described in terms of their cultural context (Hill *et al*, 2003), being the language and theories of scientists' science used in students' science. Explicit rules are also culturally derived, from within the community (Preece, in press), from the educational context in which the community is set (Newton, Driver & Osborne, 1999) and from the (mediated) messages about science imparted by the school science curriculum (Monk & Dillon, 2000).

Finally, *tacit* rules and tools are also a feature of the social interactions between students engaged in knowledge-building. This aspect of interactions is concerned with the way in which knowledge moves between personal and social worlds in order to take on a life of its own (Popper, 1972) – subject to both rules and tools used by the student community – and with the unspoken social rules (Preece, in press) and tools (Mercer, 2000) used by students as they construct and agree new knowledge. It is these tacit rules and tools that form the focus of this enquiry – the next section of this chapter considers the research methods to be used in collecting data relating to them.

Data collection and analysis

The approach to data collection and analysis when studying CSCL communities was discussed at the start of this chapter, and the case was made for the adoption of a naturalistic approach in which research participants are provided with an opportunity to contribute to the interpretation of data relating to online discussions.

Critical incidents

McAteer et al describe a study of CSCL in which this approach was employed, aimed at identifying effective communication practices in CMC. The study used individual interviews with participants to elicit information about interactions and responses to them that was impossible to glean from logfiles (McAteer et al, 2002). These interviews were based on *critical incidents* as an aid to memory, interviewees

being asked to "recall instances where communication was particularly successful and particularly unsuccessful, and to give their reasons why" (McAteer et al, 2002:316). Archives of conferences assisted in this process, which gave an interviewee the opportunity to respond freely with recollections about the conference before more targeted questions were used to focus on key issues highlighted as important by the researchers. McAteer et al consider the interview process a "fundamental part of the research" which provides "a central means of identifying successful and unsuccessful communication events and communications practices" (McAteer et al, 2002:316).

Lally outlines a somewhat similar way of eliciting data of this sort; he describes these data as holding information about the "non-expressed cognitive, affective and social processes of individuals and group" (Lally, 2002); Lally's work is based on *critical event recall*, in which "participants recall include their worries, concerns, motivation, thinking, understanding, plans and intentions, observations and conclusions in relation to the event" (Lally, 2002). Using this technique, Lally worked with participants who had used an e-learning environment some 14 months earlier, asking them to reflect on the e-learning experience with the help of logfiles and various summary tables providing information about the interactions. Discussing the value of this technique in obtaining information from a tutor reflecting on his online interactions with a group of students, Lally observes that "the tutor engaged in many reflective and analytical observations about his own facilitation of the group and the behaviours of individuals within it, yet much of this thinking was not directly observable in the transcripts of the group's work", and concludes that "critical event recall has the potential to access aspects of learning and tutoring processes that are not directly available in group discussion transcripts" (Lally, 2002). He also observes that the use of group recall provides an additional dimension, "enable[ing] the articulation of many previously unexpressed aspects of learning" (Lally, 2002).

From their descriptions there appears to be little difference between the *critical event recall* approach of Lally and the use of *critical incidents* by McAteer et al other than the use of two different terms for the process. Both studies employ an initial summary or distillation of online interactions using criteria based on a review of the literature, and follow this with interviews to elicit further information, supported by documents relating to the online event to promote and stimulate recall. The value of this technique in the context of exploring the interactions within a student knowledge-building community appears to be the ability to focus on certain key aspects of discussions within the community in order to derive data that are much richer in content than those derived from the scrutiny and analysis of logfiles alone. The technique therefore appears to satisfy the desirable characteristics of research into CSCL identified earlier in this chapter, in which analysis draws both on the transcripts of CSCL interactions and on the reflections of those involved in the interactions themselves (see page 74).

In further discussions of this approach, the term *critical incidents* will be used to describe the parts of the logfiles chosen to be the focus of discussion in interviews; the term *critical incident recall* will be used to describe the technique itself.

Identifying and classifying critical incidents

In order to apply an approach in which critical incidents form the basis of interviews with students from the knowledge-building community, some means of classifying the data from logfiles is required. Consistent with the two research questions, this classification process should provide some insight into the epistemological aspects of knowledge-building, relating to the *tacit rules* and *tacit tools* being employed by the community in knowledge-building discussions. The following section describes the development of two taxonomic frameworks designed to

scaffold the identification of critical incidents and the analysis of subsequent discussions.

Framework 1 – tacit rules

Tacit rules are those used by the knowledge-building community when discussing claims for new knowledge (page 89). Following extensive interviews with scientists concerning the resolution of a controversial claim about the detection of gravitational radiation, Collins and Pinch (1994) list a range of non-technical reasons stated by scientists as grounds for believing or disbelieving the results of a scientific experiment and the resulting knowledge claim; Collins and Pinch note that these extend "beyond what [is] usually thought of as science" and that "the scientific and social aspects of this process [of evaluating knowledge claims] are inextricable" (Collins & Pinch, 1994:100-1). These stated reasons are the *tacit rules* used in scientists' science when evaluating a controversial knowledge claim which lies well outside the boundaries of "finished science". The left-hand column of table 3.3 lists these tacit rules, with a corresponding set of rules in the right-hand column developed from these to apply to students' science in this study.

For the purpose of analysing the rules applied in students' science, the eleven statements from the work of Collins and Pinch are translated into five rules (the right-hand column in table 3.3) that have relevance to discussions in students' science where claims about new knowledge are made. This process conflates some of the rules in scientists' science into a single rule in students' science; in addition, two rules applied by scientists seem irrelevant to students (both of these rules relate to institutional affiliation). For completeness in classifying the rules of students' science a further, non-tacit rule must be added to the list; this relates to technical aspects of knowledge claims.

Tacit rules applied to knowledge claims	
Scientists' science – belief based on:	**Students' science – belief based on:**
Faith in a scientist's experimental capabilities and honesty, based on a previous working partnership. A scientist's reputation gained in running a huge lab. A scientist's previous history of failures.	Reputation Personal reputation for ability in science practical work and integrity.
The personality and intelligence of a scientist.	Personal qualities Personality and intelligence.
Whether or not a scientist worked in industry or academia.	Not relevant
'Inside information'.	Private information Information divulged outside the (formal) online environment.
A scientist's style and presentation of results. A scientist's 'psychological approach' to experiment.	Presentation Presentation of results and report of investigation.
The size and prestige of a scientist's university of origin.	Not relevant
A scientist's degree of integration into various scientific networks. A scientist's nationality.	Social Social reasons unrelated to science classroom or online environment.
-	Technical Technical aspects (relating to science knowledge) in presentation of knowledge claim (non-tacit rule).

Table 3.3 – arguments relating to knowledge claims (based on Collins & Pinch, 1994:101)

In order to employ this taxonomy, further development of these rules and their definitions is needed in order to produce indicators that define the nature of the critical incident that suggests the application of a particular rule. An indicator may be thought of as an attribute, or set of attributes, that defines the concept behind a rule (Borg & Gall, 1989:827) – the indicator(s) for each rule are shown in table 3.4. (The process of developing indicators for tacit rules is similar to that used in Henri's approach to content analysis (Henri, 1991), the difference here being that indicators are, through interview, subject to negotiation and revision rather than being fixed and immutable means of classifying interactions in logfiles.) In this way, a discussion containing a reference to (for example) the layout of a report suggests that a rule is being applied which results in a judgement being made based on criteria

based on *presentation*; reference to a personal relationship suggests a rule based on *social* arguments, and so on. The application of indicators to logfiles provides a structured way of searching for critical incidents; the same indicators may then be applied to the transcripts of interviews conducted as part of critical incident recall, in which students have contributed to understanding and explicating the meaning behind these events.

Rule		Definition	Indicator(s)
reputation	(r)	Personal reputation for ability in science practical work and integrity.	• reference to practical ability • reference to integrity / trustworthiness
personal qualities	(q)	Personality and intelligence.	• reference to personal characteristics having a bearing on science practical work • reference to intelligence / ability
private information	(i)	Information divulged outside the (formal) online environment.	• reference to information relevant to investigation relayed by another means (eg word of mouth, or via another online channel)
presentation	(p)	Presentation of results and report of investigation.	• reference to appearance, layout, clarity etc of investigation report
social	(s)	Social reasons unrelated to science classroom or online environment.	• reference to personal relationship(s) or qualities with no direct bearing on science practical work
technical	(t)	Technical aspects in presentation of knowledge claim.	• direct reference to scientific theory ("finished science") connected with knowledge claim

Table 3.4 – indicators associated with rules and their definitions

Framework 2 – tacit tools

Tacit tools are those used by the community when making new knowledge and in the discussions surrounding this process. Language used in these discussions as students draw on shared experiences provides insight into these tools, and the extent to which the community regards the construction of knowledge as an unproblematic process in which observations of objects in W1 lead in a straightforward way to theories in W3 through meaning-making in W2.

The problem of assessing individuals' conceptions of the nature of science was discussed earlier in this chapter where it was noted that positivist methodologies have been largely replaced in the last fifteen

years or so by more naturalistic enquiries, a shift that reflects changing perceptions of the nature of science itself (Abd-El-Khalik and Lederman, 2000:666). This fluidity makes any attempt to make a direct measurement of students' understanding of the nature of science a extremely difficult task, since the methods of science are far removed from what Shapin refers to as "the fables of 'the scientific method' so beloved of textbook writers" (Shapin, 1992:28). Nott & Wellington have argued that attempts to categorise research subjects' conceptions of the nature of science in terms such as "correct" or "good" are problematic given changing definitions of the nature of science which "themselves may be the subject of academic criticism" (Nott & Wellington, 1996:283).

Despite these concerns, there is some agreement about what may constitute an understanding of the nature of science that can be characterised as inadequate – for example, criticisms of Process Science rest in part upon the naïve inductivist account of science on which these teaching schemes are based (see page 8). Based on philosophical and sociological considerations of science, and in particular the work of Kuhn (1970), Nadeau and Desautels describe a conception of science that they argue is deficient in five key respects, an epistemological position which they term *naïve scientism* (Nadeau & Desautels, 1984). They argue that this way of viewing science "sees it not only as an activity Involving special knowledge ... but [also] as one with a cognitive basis that is beyond criticism ... [that] alone can establish the soundness of our claims to knowledge ...by accumulating progressively ... definitive answers to questions that human beings pose" (Nadeau & Desautels, 1984:13). The model of naïve scientism that Nadeau and Desautels propose has five characteristics, which broadly reflect the description of science given in Curtis's *Baconian Narrative* (page 34):

Naïve realism
Scientific knowledge is the reflection of things as they actually are
Blissful empiricism
All scientific knowledge derives directly and exclusively from observation of phenomena
Credulous experimentalism
Experimentation makes possible the conclusive verification of hypotheses
Blind idealism
The scientist is a completely disinterested, objective being
Excessive rationalism
Science brings us gradually nearer the truth

These characteristics may be regarded as descriptions of a set of tacit tools used in handling knowledge which exhibit an extreme of naivety. Thus, a discussion in which reference is made to (for example) "carrying out an experiment to see whose idea is right" suggests that a tacit tool characterised by *credulous experimentalism* is being employed as a means of framing the relationship between experiment and theory; a statement in which (for example) students suggest "measure it and see if you're right" implies a tool exhibiting *naïve realism*.

In considering the tools used to handle knowledge in students' science the characteristics of *blind idealism* and *excessive rationalism* should be excluded, for the reasons that the former is concerned with *motivation* (which is part of the SCO triad, and is very different for students' science as compared with scientists' science) and the latter is closely concerned with science as an enterprise involving experts (and it has been shown already that students' science is not characterised in this way (page 38). The simplified framework that results from this contains three tacit tools; as with the framework for identifying tacit rules, each tool has its own definition and indicators, shown in table 3.5. As in the case of the indicators relating to tacit rules, the indicators for tacit tools provide a method of searching for critical incidents in logfiles and of analysing the transcripts of interviews from critical incident recall.

Tool		Definition	Indicators
naïve realism	(nr)	Scientific knowledge is the reflection of things as they actually are	• statements relating to the relationships between the entities in scientific theories and models (eg atoms, taxonomic groups) and their existence in the real world
blissful empiricism	(be)	All scientific knowledge derives directly and exclusively from observation of phenomena	• statements relating experimental outcomes and conclusions
credulous experimentalism	(ce)	Experimentation makes possible the conclusive verification of hypotheses	• statements relating to hypothesis testing

Table 3.5 – indicators associated with tools and their definitions

Summary

Critical incidents identified in logfiles provide a way of identifying where tacit rules and tools are being used by the community in building knowledge. These critical incidents may be explored through group interviews. The two taxonomic frameworks described here describe the tacit rules and tacit tools which provide the means of identifying critical incidents and for analysing the outcomes of the interview process. Figure 3.6 shows a model of this process, including the influences of research and policy acting on the research setting and the processes of data collection and analysis.

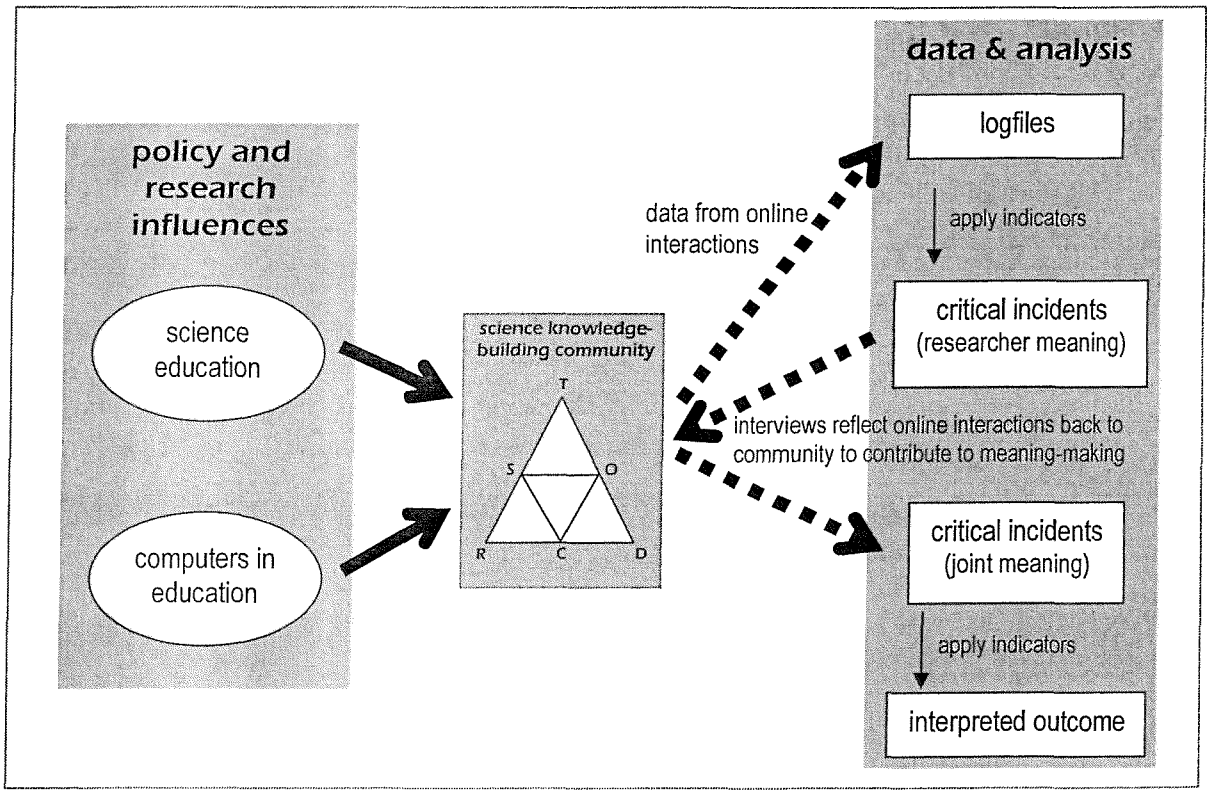


Figure 3.7 – the model for the research

Ethical considerations

The need to conduct any piece of research in accordance with relevant ethical guidelines is highlighted by Borg and Gall, who write:

> *In conducting an educational research project one must never lose sight of the special requirements and problems involved in working with people ... [this] is particularly important when the project is carried out in ... schools.*
>
> (Borg & Gall, 1989:83)

For the purpose of producing an ethical framework for this study the ethical guidelines of the British Educational Research Association (BERA, 2004) are relevant, together with checklists in Bell (1993:58-9) and Hopkins (1993:221-3) and the guidelines produced by the Association of Internet Researchers (Ess & AoIR ethics committee, 2002). The framework is shown in table 3.6.

	Principle	Rationale	Action
1	At all times, the best interests of the child(ren) involved are the primary consideration	UN Convention on the Rights of the Child, article 3.	No aspect of the study should prejudice the safety of any student(s) involved, nor should students' access to any aspects of the school curriculum be impeded.
2	The study should be conducted on the basis of *obtaining informed consent* from all interested parties.	BERA ethical guidelines UN Convention on the Rights of the Child, article 12	Informed consent for the study should be obtained from school management, staff directly involved, students and their parents/carers. Students should have all aspects of the study fully explained to them, and be allowed to express concerns or to withdraw from the study at any time.
3	Confidentiality	BERA ethical guidelines	Access to collected data to be limited to researcher. All individuals to be protected from identification in any subsequent written reports.

Table 3.6 – ethical framework

In view of the online nature of the proposed research, principles 1 and 2 require special care in protecting students from inappropriate communications, and in seeking informed consent from them and their parents/carers.

The ethical conduct of work in which children's online interactions are studied therefore requires, first and foremost, the construction of an online environment in which children are safe from intrusion from anyone outside the research group. Further, in view of the opportunities

for inappropriate interactions to occur *within* the student community, some kind of moderation needs to be operated in order that such interactions can be controlled. Given a safe environment, informed consent for the study should be obtained from all involved, under the understanding that the interests of children will be put first at all times, and that any child has the right to withdraw at any time without the need to provide any reason. Finally, ethical conduct of the research also requires students to have equality of opportunity to participate, recognising that not all households have access to computers connected to the Internet. Any issues concerning equality of access should be addressed through the provision of access to computers after school.

Chapter 4

Trial study

The previous three chapters have set the scene for the study of an online learning environment as an extension of a school science classroom involving the discussion of shared practical work; a *science knowledge-building community*.

Before conducting a full-scale study of a science knowledge-building community, a small-scale study was conducted in order to ascertain the technical feasibility of research on a larger scale. The importance of a preliminary trial of this sort is noted by Borg and Gall (1989:77-8) as an important prerequisite in planning the main study; particularly important in this case given the lack of similar studies involving students of this age. The initial study was conducted in order to explore the feasibility of using a CSCL environment to support students building knowledge through a science investigation. Specifically, this study sought answers to the question: assuming that students make use of the CSCL environment provided for them, does the extent and nature of their online interactions suggest that there is an epistemological dimension of these discussions that is likely to be possible to research?

In addition, assuming that a positive answer to this question was received, it was desirable that this study should also provide some insight into the way in which the online discussion forum might be refined and developed for a second stage of the study, in order to trial the use of *critical incident recall*.

The trial study

In choosing a suitable setting for studying CSCL in science knowledge-building it was necessary to gain access to a suitable group of students with a teacher who would be happy to participate in the study, and who would be willing to do so in a manner that was consistent with the

principles for supporting a knowledge-building community (page 42). These same principles made it unlikely that a Key Stage 4 (aged 14-16) class would be suitable for the study, since the nature of GCSE practical assessment with its focus on particular assessment outcomes would be unlikely to be consistent with the more task-focused nature of knowledge-building. This therefore limited the choice of students to those in Key Stage 3 (aged 11 to 14).

The school, teacher and students

Within the constraints of the Key Stage just described, the choice of setting for the initial study was made largely due to the enthusiasm of one particular teacher, the Head of Science at Pynebrook School[3] located in South East England. This section provides some contextual information about the school, about the teacher, and about the class.

Pynebrook School is situated in a mixed area of housing, with some 850 students on roll. Results in tests at the end of Key Stage 3 (students aged 13/14 years) for the school year 2002-03 are shown in table 4.1; these show that the achievement of students at Pynebrook School at the end of Key Stage 3 is comparable with the LEA average and above average for England as a whole. In this sense the school may be judged as being fairly representative of schools in this region.

	English	Mathematics	Science
students achieving level 5 or above	70%	76%	73%
LEA average	74%	76%	76%
England average	69%	71%	68%

Table 4.1 – key stage 3 test results for Pynebrook School (2002-03)

The Head of Science at Pynebrook School had been known to the researcher for several years through teacher-training contacts; he was a keen user of ICT in his science teaching and he was keen to explore the use of CSCL as part of this. At the time of this study he was in his

[3] The names of all schools and individuals involved in this research have been changed to protect their identities.

seventh year of teaching, having spent some 12 years before this as a laboratory technician in both FE and HE, and then trained as a teacher at a local university. He had a suitable class which he was willing to volunteer for the study and who met the criteria described above. The class consisted of 28 students aged 13/14 years who made up one of two, parallel, "top ability" groups, setting being based on results from National Curriculum tests, tests using recognised protocols to measure such things as cognitive aptitude, and by school science tests.

Planning

Planning for the trial study took into account the conditions required to support *knowledge-building* (page 43) and *argumentation* (page 86) in order to provide an environment in which students would be encouraged to see *explaining as the major challenge* (condition 4 for knowledge-building, page 43) and where they would feel comfortable in proposing "thoughts that [were] half-formed or simply flawed" (Newton, Driver and Osborne, 1999:566-7). The investigation and the online environment were also the subject of careful thought and discussion, and planning included preparation for monitoring and moderating the online interactions. These preparatory aspects of the initial study are described below.

The CSCL environment

Bearing in mind the limited scope of this initial study, a simple solution to producing a CSCL environment was sought; it was decided that this solution should support asynchronous CMC. This decision was taken since asynchronous discussion tends to promote in-depth analysis and response as opposed to the quicker, more spontaneous nature of synchronous CMC (CAP, 2004). In addition, the need for students to be online at the same time for synchronous CMC was felt likely to reduce the opportunities for interaction out of school.

Based on the class teacher's insights into his students' proficiency in using the Internet it was decided that Web-based asynchronous CMC would produce an environment which all students would be able to use with relatively little difficulty. Other important criteria for the choice of software to produce this environment included:

- the ability of the software to provide logfiles of online interactions in a form that was easily exported into a spreadsheet (in order that analysis could be carried out);
- cost; and
- ease of set-up and use.

These considerations led to the choice of the opensource software *Hypermail 2.0*, freely available for downloading under the GNU public licence (www.hypermail.org). This program was judged particularly suitable for the purpose of the initial study since it enabled the production of a hyperlinked, Web-based forum that would have a familiar "look and feel" for students, and which could be integrated easily with a custom-produced environment written in HTML. Hypermail is an example of unstructured groupware (McConnell, 2000:33); in the context of supporting a knowledge-building community such software is preferable to structured groupware (McConnell, 2000:29) since it does not impose any particular boundaries on collaboration within the group. Being text-based it also has low bandwidth requirements, meaning that students without fast Internet access were unlikely to be disadvantaged in comparison with other students when seeking access to the environment outside school.

The Hypermail software was hosted on a Web server at Southampton University which also hosts the website of *ScI-Journal* (www.sci-journal.org, appendix 1). Founded in 1995, *ScI-Journal* consists of a collection of reports of science investigations written by science students from the UK and around the world, with associated sources of help for students conducting science investigations. The investigations in the journal are published in the form that they are

received – including any errors that the student author may have made. The idea behind the journal is that such errors will form the basis of discussion among student scientists, thus subjecting students' work to a form of 'peer review'.

Hosting the Hypermail software on the same server enabled the discussion forum to be easily associated with the collection of *SciJournal* reports, producing a sense of a science knowledge-building community through the presence of a "community database" (Bereiter & Scardamalia, 1993:212) existing even before any interaction between students had begun. The CSCL environment thus consisted of two elements – a database of reports of science investigations coupled with an asynchronous CMC medium. A screenshot of this is shown in appendix 2.

Due to the possible effects of differences in local software, security policies and Internet filtering, extensive trials of the online discussion forum were carried out in Pynebrook School and via two Internet Service Providers (ISPs), using a range of Web browsers including Internet Explorer and Netscape to ensure as far as possible that the software would work effectively in a range of environments.

The science investigation

So as not to disrupt the flow of the science work carried out by the class, the study was planned alongside a science investigation that formed part of the school's scheme of work. This investigation related to the *physical processes* programme of study in the National Curriculum:

> *Pupils should be taught:*
> ...
> c *that unbalanced forces change the speed or direction of movement of objects and that balanced forces produce no change in the movement of an object*
> d *ways in which frictional forces, including air resistance, affect motion*
>
> (DFEE, 1999:34)

By definition, the investigation also related closely to that part of the programme of study that is concerned with investigations (DFEE, 1999:28-9). This investigation concerned the frictional force acting on a block of wood pulled at constant velocity across a horizontal plane surface and its relationship with other variables such as area of the block in contact with the surface, the nature of the surfaces in contact or the mass of the block (and hence the normal reaction force of the surface acting upwards on the block). Six types of investigation are described by the AKSIS project (Watson & Wood-Robinson, 1998:89):

- fair testing
- classifying and identifying
- pattern seeking
- exploring
- making things or developing systems
- investigating models

This investigation is an example of a "fair test", in which a single variable is controlled (eg the nature of the surfaces in contact or the mass of the block) and another (causally-related) variable is measured (Watson & Wood-Robinson, 1998:89). The investigation required students to generate a hypothesis linking the frictional force acting on the block of wood to some other variable (eg the mass of the block, linking this to their previous knowledge and experience. They were then required to devise a plan which would enable them to collect data which could be used to test the hypothesis, to analyse these, and then to draw suitable conclusions. A written report covering all of these stages was required to be submitted a short while after the end of the investigation.

Two reports written by students who had previously conducted a similar investigation were available online on the *ScI-Journal* website. The opportunity to make use of these as part of investigation provided a part of the "community database" (Bereiter & Scardamalia, 1993:212) that was immediately relevant to students using the CSCL environment.

Timing

The availability of appropriate time is identified by Newton, Driver and Osborne as one of the four constraints influencing the quality of discussion work in school science (Newton, Driver and Osborne, 1999). The use of a CSCL environment in this context was intended to expand the time potentially available for discussion (page 86) by encouraging students to log on outside school hours. It was thought important that the length of time during which online discussion was expected should be long enough to allow discussion to become established (Salmon, 2004:64) without being so long that interactions were likely to peter out. In the absence of information from any similar studies about suitable time periods for interaction the last three weeks of the autumn term of 2002 were allocated to the science investigation, with the intention of using the CSCL environment to support the final two weeks. With a two week timetable, the class had eleven one hour lessons in this time period plus several timetabled homework periods.

The programme for these three weeks was designed to enable the students to gain a good grasp of the practical investigation and to obtain some results from practical work before being introduced to the online discussion forum in the second week; appropriate support was provided by the teacher as the students did this, based on the first four stages of the nine-stage AKSIS lesson structure: *focusing, defining the problem, planning and obtaining evidence* (Watson & Wood-Robinson, 1998:88). The delay in introducing students to the forum was planned in order to ensure that students were sufficiently familiar with the investigation to feel confident in contributing to the online discussion from the beginning, following advice to "structure the discussions, so that there are specific activities for [students] ... [these] are most effective if they gradually introduce participants to the forum" (CAP, 2004:4). This approach is also consistent with Salmon's model for e-moderation (Salmon, 2004:29); see figure 2.3 on page 51, and was intended to maximise opportunities for establishing student motivation

(stage 1), online socialisation (stage 2) and information exchange (stage 3) prior to knowledge-building (stage 4). As was conventional with this class, practical work was planned to be conducted in groups of the students' own choosing, with group size and constitution being managed by the class teacher where necessary. Table 4.2 shows the structure of the planned sessions during the three week period – during homework periods during weeks 2 and 3, students were instructed to log on to the CSCL environment in order to read and contribute to discussions.

	Monday	Tuesday	Wednesday	Thursday	Friday
w/c Dec 2	Students introduced to investigation (T)	Students browse *Scl-Journal* website (T)	Discussion of factors involved in investigation (T+R)	Practical work (T)	No lesson
w/c Dec 9	No lesson	Practical work (T)	Students introduced to online forum (T+R)	Practical work (T)	No lesson
w/c Dec 16	Practical work (T)	Practical work (T)	Practical work and writing up (T)	Practical work and writing up (T+R)	No lesson (school term ends)

Table 4.2 – class timetable for initial study (T = lesson with teacher alone, T+R = lesson with teacher and researcher)

The introduction to the online forum (Wednesday December 11) was conducted in an "ICT room" containing sufficient networked computers for students to have access to one each. The focus of this session was the examination and critique of the two *ScI-Journal* reports relating to the investigation, with instructions (projected onto a whiteboard at the front of the room) as follows:

> *You are going to use the discussion board to share your ideas about the two science reports. Be critical about them (politely!) and include your own ideas. Don't just make comments about which is better – really think about the science in the report, and how the investigation was done.*

Moderating and monitoring the online discussions

Online discussions between students as members of a knowledge-building community require moderation for three reasons:

1. the teacher plays a crucial rôle as an expert in managing learning in such a community;
2. members of online communities often require support in order to feel confident to participate in discussions;
3. an online community of students brought together for research purposes is owed a duty of care by the researcher under the ethical guidelines for research.

The bases for these three aspects of moderation have been discussed in earlier chapters – the rôle of the teacher as "master" (Henri, 1995) and as manager of learning (Bereiter & Scardamalia, 1993); the need for support (Salmon, 2004) and motivation (Tolmie and Boyle, 2000) for members of online communities; and the primary ethical concern for the well-being of students (page 104). Moderation for all three purposes was agreed between the school and the researcher to be the joint responsibility of the researcher and the teacher, both of whom agreed to log on to the CSCL environment at regular intervals (at least daily) and to monitor events. Responses to students' postings were agreed prior to the establishment of online discussions within a general set of guidelines:

1. any student abusing the system in any way (defamatory postings, links to inappropriate websites etc) would be the subject of immediate sanction – access to the CSCL environment to be at least temporarily withdrawn;
2. postings to be carefully monitored for "personal" comments which could cause distress;
3. all students to have access to personal email addresses of both researcher and teacher in order that complaints about another student's behaviour could be made privately;
4. "expert" interactions with students to be guided by Bereiter and Scardamalia's conditions relating to the establishment and management of knowledge-building communities (page 43) and by

Newton, Driver and Osborne's constraints affecting argumentation (page 86).

Guidance about online behaviour was also planned for students, with an introduction to the CSCL environment for the first time during the science lesson of the second week of the three week period. This briefing concerned the need for appropriate online behaviour and responsible use, reflecting the tone of the school's rules for behaviour in the "offline" world which particularly emphasised the need for mutual respect (appendix 3). Responsible use was also defined in terms of non-disclosure of access passwords and usernames, since such disclosure could potentially jeopardise the safety online of other students.

Ethics

Ethical conduct of the study was guided by the principles described at the end of the previous chapter. Consent from parents/carers was sought by means of a letter, written and signed by a member of the school's senior management team and sent home with students in the ten day period prior to the study. This letter provided a brief explanation of the study and sought permission from the student's parent(s)/carer(s) for them to participate in the study; this was documented by the return of a tear-off slip. Parent(s)/carer(s) who had any questions about the nature of the study were invited to contact the school to discuss these with the teacher involved in the study in his capacity of Head of Science. Consent from students was also sought verbally, with the option to withdraw from the study at any point made clear during the first lesson with the researcher present; the consent obtained extended to the use of quoted material in publications, with the assurance of anonymity. Similar consent was sought from the teacher.

Equality of access to the CSCL environment out of school hours (page 105) was addressed by ensuring that networked computers

within the science department were available after school hours with suitable supervision for the period of the study. Although initial discussions with both staff and students prior to the study indicated that the students in the class chosen for the research were active and experienced Internet users and that most had easy access to computers at home, it was appropriate to gauge students' access to the Internet from home at an early stage in order to ensure that these impressions were not misleading. The method used to collect data relating to this is described in the next section of this chapter.

Collecting data

A *multi-method* approach to data collection and analysis (Lally, 2002) was adopted in order to provide a range of information from the trial study to assist in making decisions about subsequent work – as a trial study, this offered a good balance between obtaining information about the study quickly and ensuring that as much data as possible was available. In addition to the logfile recording online discussions, data concerning students' Internet access was collected by means of a short questionnaire administered to all students participating in the trial study (appendix 4). A preliminary trial of a version of this was trialled with a small sample of students (N=4) of similar age to those in the class, as a result of which some small changes were made to the order of questions and their wording. The final questionnaire was administered in a class session, when both teacher and researcher were on hand to provide students with any assistance needed (for example, explanation of terms like "network" and "broadband"). Further qualitative data was obtained through email and interviews.

The nature and extent of students' online interactions was investigated through a process of content analysis of the logfiles recording online interactions. This was based on a simplified version of Henri's model (Henri, 1991) described below. Concerns about the positivistic nature of content analysis and its inability to provide deep insights into online

interactions have already been raised (page 72). In the context of a simple trial study of this sort however, content analysis is a very suitable method for making judgements about interactions since it can provide *pragmatic* guidance for the main parts of the study that followed. As Thomas notes, the question is not "*whether one method is superior to another but, rather, whether the method a researcher employs can yield convincing answers to the questions that the investigation is intended to settle*" (Thomas, 2003:7). In this case, content analysis of the online logs offered a quantitative perspective on the qualitative aspects of students' online interactions in the discussion forum, providing information about the proportion of messages likely to yield useful information in any further study at a level of detail which was sufficient to guide decisions about whether the study should proceed.

While Henri's model for content analysis has five dimensions (participative, social, interactive, cognitive and metacognitive – previously discussed on page 72) the simplified model used here has only three – social, technical and cognitive (table 4.3). This adaptation was made in order to provide a simple analysis which would provide sufficient information about the nature of the posts, particularly those related to the science investigation which appeared to provide some insight into the students' thinking.

Social posts are part of the "glue" that holds the fabric of any community together, including greetings and personal comments. The need for such posts is increased by the fact that there is no possibility for body language or other social cues in a text-based communication system, and makes such postings very important in finding 'roots' (Salmon, 2004:34). Also included in this group of postings are those concerned with managing the discussion and keeping it on-topic, whether by teacher / researcher or by students as another important aspect of online socialisation.

Technical posts are concerned with using the discussion forum software or with ICT-related aspects of the investigation (eg downloading an image for inclusion into a report). There were occasions where issues needed to be explained to students, and where the *purpose* of the forum needed further explanation (in response to a posting like "remind me what we're supposed to be doing, please", for example). Postings from teacher / researcher providing additional instructions were also included in this category.

Cognitive posts relate to the science investigation linked to the discussion. This relationship may be very direct and obvious (concerned with a method of measuring force, or of making fair comparisons, for example) or it may be quite indirect (related to some science knowledge that may have a bearing on the investigation, for example).

Dimension	Definition	Indicators
social (s)	posting unconnected to content of science investigation	• greetings • verbal support • social conversations
technical (t)	posting related to use of forum or other aspect of networked computers	• questions about using the forum • responses to such questions
cognitive (c)	posting (exhibiting knowledge and/or skills) related to science investigation	• comments / questions about investigation, conclusion, methods etc • comments / questions relating to science connected with investigation

Table 4.3 – content analysis dimensions used for the initial study

Qualitative feedback concerning the experience of using the Hypermail discussion forum was obtained using an email survey consisting of a series of short questions posted to students towards the end of the period of online interaction. This was followed by a group interview with students including a sample from those responding by email. An individual interview with the class teacher was also conducted in order to obtain his views about the experience of acting as expert in the knowledge-building community. Interviews took place a few weeks after the end of the online interactions. The elapsed time between the experience of participating online and discussing the experience was intended to promote the process of *reflection*, allowing participants to

comment on their participation from a distance and with the benefit of hindsight (Collier, 1999).

Outcomes

In response to the letter sent home by the school seeking permission for students to participate in the study, 21 completed slips had been returned out of a possible 28 by the start of the first lesson. So far as it was possible to ascertain, the unreturned slips were due to a lack of motivation or organisation on the part of students rather than any expressed wish not to be involved on the part of them or their parent(s)/carer(s). Those students who had not returned slips were not permitted to participate in the study, and were transferred for its duration to another science class of similar ability who were carrying out the same investigation.

Internet access

Detailed results from the Internet access questionnaire are given in appendix 5 – responses from all of the students in the trial study were received (N = 21). Only 2 students in the trial study did not have a computer at home, meaning that 90% had access to at least one computer at home. This figure is slightly higher than that which would be expected based on comparable data collected as part of a national survey conducted at the same time as this initial study (Hayward et al., 2003:2); this found that 81% of households with children at school had access to a personal or laptop computer at home. Of the remaining 19 students in the trial study, 14 had more than one computer at home (average across all students = 1.8 computers/student) and one student reported having more than three computers at home. There were four students who had two or more computers that were networked, and one student who had a computer at home which had no Internet access. Of the 18 students with Internet access at home, 10 had one computer with Internet access, the other 8 having access via two or more computers; 8 students accessed the Internet by means of a

broadband connection. The majority of students (13 out of 18) reported no control over their Internet access, while 4 reported that their access was controlled by adult supervision; the access of one single student was controlled by means of software installed on their home computer.

Every student in the survey claimed to have made use of the Internet in the two weeks prior to completing the questionnaire; figures 4.1 and 4.2 illustrate the nature and extent of this use.

Students reported a significant amount of Internet use (figure 4.1), with more than two-thirds spending more than two hours a week using the Internet. Although students were not asked to provide information about the proportion of this Internet use which occurred in school lessons, given the extent and nature (figure 4.2) of this use it is not unreasonable to infer that the majority of this access takes place outside lessons. This reflects the conclusions of the ImpaCT2 study, which found that:

> *For most pupils the amount of time spent on ICT at home greatly exceeds the time spent on ICT at school.*
>
> (Harrison et al., 2003:7)

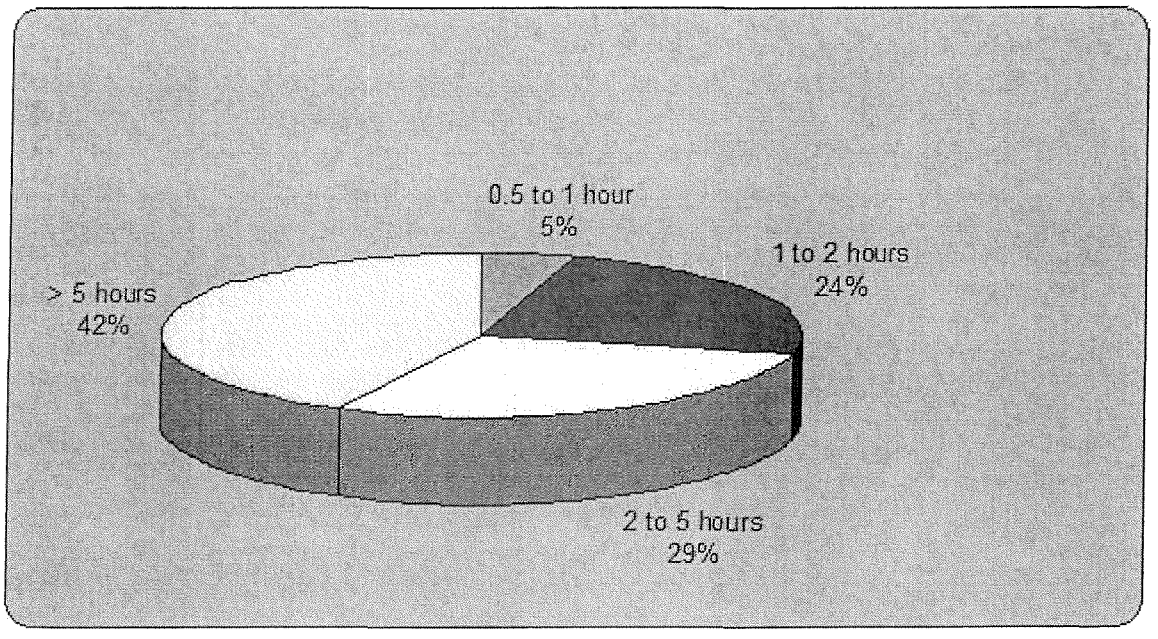


Figure 4.1 – students' self-reported weekly Internet use

Interestingly, lack of Internet access from home did not appear to hamper students, since 2 students in this category reported weekly Internet use in excess of 5 hours, and the third reported use of between 2 and 5 hours, access being via computers at school.

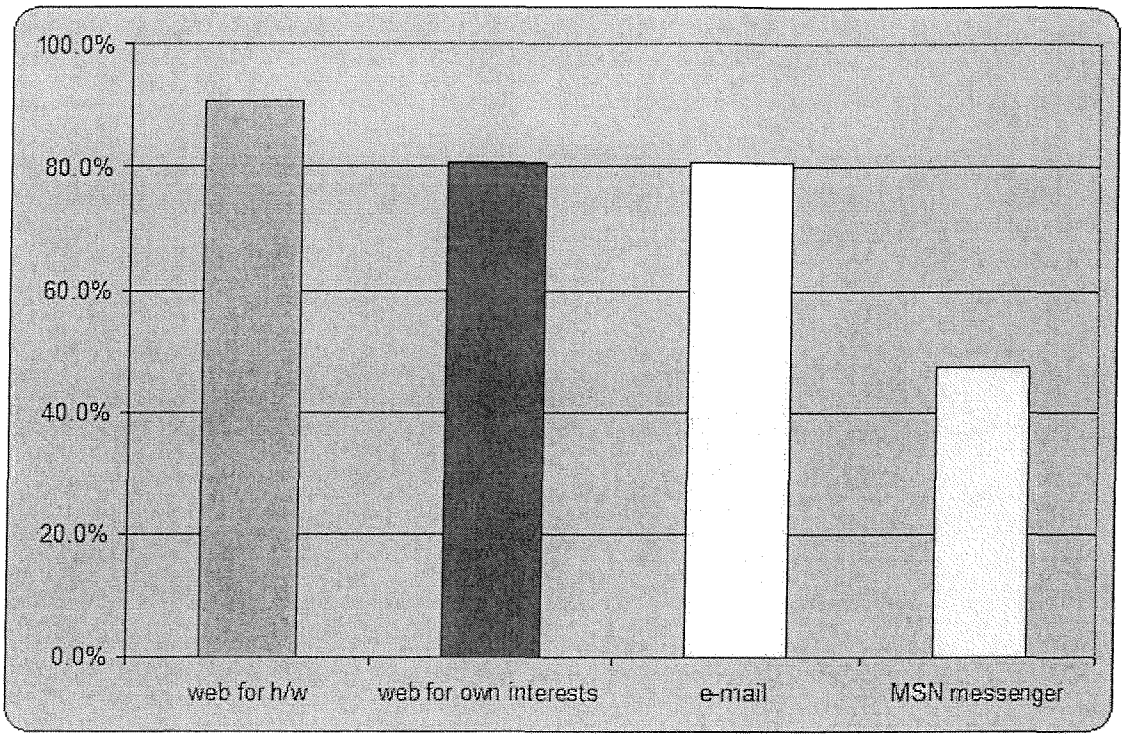


Figure 4.2 – students' self-reported use of the Internet

Six possible Internet-based activities were listed in the questionnaire, and students were asked to identify in which of these they had been engaged in the two weeks prior to completing the questionnaire. Of these, all students reported use of the Web, *either* for personal use *or* related to schoolwork; 15 students had made use of the Web for *both* personal and homework-related reasons. Communication also formed an important aspect of the majority (17) of students' Internet activity, with all of these reporting use of e-mail, and 10 reporting use of MSN Messenger. No students reported the use of Internet chat rooms – subsequent (informal and unrecorded) conversations with students within this group showed that awareness of the significant dangers of this form of contact was well-recognised by the youngsters, who said that they liked the ability provided by programs like MSN Messenger to "block" unwanted contacts.

The findings from the questionnaire suggest that Internet access for students in the study group, even where access was not available at home, was not an issue; there is no evidence to suggest that access for members of this group is characterised by "pervasive social inequalities" (Aurigi & Graham, 1998:62). What is more, the extent and nature of Internet use reported by these students suggests that they are well able to make use of networked resources to acquire and to communicate information; this confirmed the class teacher's impressions of their capability as a group, as noted earlier (page 109).

Online discussions

The automatically generated logfile from the discussion forum was imported into a spreadsheet where 339 posts from individuals were available for analysis; these were composed as follows (table 4.4):

posts in school	205	163 during introductory lesson in ICT room (Dec 11) 36 during second lesson in ICT room (Dec 17)
posts out of school	134	over half of these (72) submitted on evenings of Dec 11, 12 and 14
total	339	

Table 4.4 – contributions to the discussion forum

As table 4.4 shows, the large number of posts during school-based sessions mainly consists of those made during the introductory session on December 11, during which students were using the Hypermail forum for the first time. In addition to these school-based posts, there are also many out-of-school posts, with use of the online forum running right the way through the Christmas holiday period into the New Year. Of the total 339 posts, 17 were from the teacher and 3 from the researcher, leaving a total of 319 posts from students.

One easily obtained measure of the extent of *discussion activity* in any discussion forum is related to the numerical size of messages as a measure of the extent to which discussion is occurring (Wiley, 2002:2). Wiley provides a useful way of computing discussion activity in CMC by measuring the extent to which contributions fall into threads and sub-

threads. Wiley argues that the structure of threaded discussions contains much information about the extent to which students are interacting (as opposed to posting individual, discrete messages). Unfortunately the Hypermail software does not permit threading of this sort, and the situation is further complicated by the fact that all of the text fields on the message submission form were editable, leading to occasional problems in cross-threading when key fields were changed (deliberately or accidentally) by contributors. Therefore, any calculations based on threading would involve an attribution of messages to particular threads, the validity of which would be difficult to check. Because of this, an initial measure of discussion activity in the Hypermail forum was taken simply as the number of words in posts (abbreviated as "word length", table 4.5), on the basis that longer messages can reasonably be regarded as containing a greater depth of analysis and reflection than short messages (Dietrich, Grear, & Ruth, 2002).

	Average word length of contributions
posts in school	12.4
posts out of school	30.3
all posts	19.5

Table 4.5 – word length of contributions to the discussion forum

On the basis of word length it appears that there is more depth to the interactions between students when interacting outside school than in school. This is unsurprising since when using the discussion forum in school students are all online together. This tends to give interactions more of a synchronous quality as students rush to reply to each others' postings; it is well known that the length of contributions in synchronous CMC exchanges is less than those in asynchronous exchanges, which promote "in-depth analysis and response" (CAP, 2004:2).

The analysis of interactions based on the number of postings and their word length suggests that the *extent* of discussion forum use by

students, with significant periods of interaction out of school on evenings in which "online homework" was set (Dec 11, 12 and 14). Further information about the *nature* of the interactions was obtained through content analysis of the logfile from the forum in which each message was assigned to one of the three dimensions described in table 4.3. In order to increase the reliability of this coding, all messages were coded in a single session by the researcher, who reviewed the coding of a random sample of 10% of the messages at the end of the procedure. This review process showed that messages were reliably being assigned to the same dimension on each occasion. The proportion of postings assigned to each dimension is shown in table 4.6 (total ≠ 100% due to rounding). The fact that a significant proportion (over one third) of messages fall into the *cognitive* dimension (ie they are directly related to discussion of the science investigation) provides encouraging evidence that students made good use of the forum to support their investigative work.

Dimension	Proportion of all posts (*N* = 339)
social (s)	57%
technical (t)	9%
cognitive (c)	35%

Table 4.6 – dimensions of posts to the discussion forum

Further analysis of the percentage of postings within different ranges of word length word in each dimension is shown in table 4.7.

	Word length range								
Dimension	1-5	6-10	11-15	16-20	21-25	26-50	51-100	101-200	>200
social (s)	87.3	67.2	65.8	29.0	30.0	23.7	7.1	0	0
technical (t)	1.8	8.2	2.6	6.5	5.0	18.6	28.6	66.7	33.3
cognitive (c)	10.9	24.6	31.6	64.5	65.0	57.6	64.3	33.3	66.7

Table 4.7 – relationship of word length to dimension for postings

The content analysis shows that, whilst social content forms the majority of posts with lengths of 15 words or fewer, the great majority of longer posts are within the cognitive dimension; for posting lengths greater than 15 words, cognitive posts outnumber social posts by nearly

3:1 (cognitive posts = 89, social posts = 30). Although posting length *per se* cannot be taken as a measure of students' active engagement in discussions concerning the investigation within the discussion forum, the fact that cognitive posts predominate in postings of 16 words or more strongly supports the idea that students were engaged in qualitatively rich discussions which related to the practical science investigation they were conducting (see discussion below).

Email survey

Qualitative feedback concerning students' experience of using the Hypermail discussion forum was sought through emails from students, who were invited to respond to a posting in the forum consisting of a series of short questions about their experience (appendix 6). Six students (out of 21) responded to the questions posted in the forum; these responses are shown in appendix 7.

None of the students had ever used online discussion as part of schoolwork before; all found the software straightforward to use. Two students wrote positively about the opportunity for students to help each other online, whilst two others felt that online discussions could be easier than their face-to-face counterparts, especially where students were less confident. The opportunity to communicate in a "safe" place, where students knew who they would encounter was also seen as important. One (female) student felt that the behaviour of some of the boys online had been a little off-putting ("some of the boys messed about and that didtn [sic] help"); another student felt that the configuration of the forum meant that information about who was online was lacking, while a third thought that the existence of so many messages on the list was potentially difficult ("every single message is still on there from the beginning so it can get a bit confusing"); there were no other negative comments. There were two suggestions for changes to the forum, involving the ability for students to see who was online at the same time, and monitoring of the forum to prevent

inappropriate messages (such monitoring had been in place; the exact nature of the inappropriate messages raised by this student was unclear).

Overall, there was a general feeling among students that they had benefited from the experience of discussing their work online. Three students mentioned online discussion as being potentially easier than face-to-face discussion, whilst increased understanding was also reported by three students; a fourth student had already posted something to this effect in the forum ("I am pleased with my results and would like to say that some messages on here have helped me write this"). Only one student felt that there had been no personal benefit for her, saying that she had not wanted to be confused by the ideas of other students; however, this student reported positive feelings from others in the class ("a lot of my friends find it easier to discuss things with people of they [sic] ability so they can understand each other").

Interview with students

A group of students was selected to take part in a group interview conducted during the term following the initial study. This interview was conducted so as to amplify the findings from the Internet access questionnaire and the feelings reported by the six students responding by email. The composition of the group was arrived at with the help of the class teacher; it consisted of the six students responding to the forum posting plus three others selected in order to make the feedback given by the group as representative as possible of the class as a whole. The group interview was highly appropriate to fulfil this rôle, because its use with a set of people who have undergone a shared experience is intended to "treat the outcomes as communal views and to represent them as artefacts of a shared encounter" (Watts & Ebbutt, 1987:30). In this context, although the participants are known to each other, the intention is similar to that of a focus group, where

perceptions and feelings are sought and where the production of quantitative data is not required (Krueger, 1994:19). The nature of the interview in this case is probably best described as a *focused [group] interview* (Cohen & Manion, 1989:326), an *interview guide* identifying the major *areas of enquiry* being used to explore the experiences and feelings of the subjects in respect of their shared experience. These major areas of enquiry included the students':

- use of and access to the Internet
- understanding of the Internet as a communication medium
- perceptions of discussing the science investigation online
- attitude to conducting a similar study with an expanded group of students
- ideas for improving the online discussion environment

The transcript of this interview is provided in appendix 8.

As in the online survey, students reported extensive use of the Internet out of school, with one reporting use of up to 6.5 hours each weekday after school (3:30pm to 10:00pm, lines 21-22). The interview confirmed the general nature of unregulated Internet access, although one student was subject to a time restriction in Internet use (lines 78-94). There was general agreement about the superiority of broadband Internet access over dialup, not least because of the flat rate nature of the charging structure. Discussion about the nature of online communication (lines 153-211) showed that students had a good understanding of the various communication modes possible on the Internet (MSN messenger, chat, e-mail, discussion boards), the differences between them – both in technical terms and in terms of the quality of communication – and the associated aspects of personal safety.

The group were positive about the discussion of the science investigation online, and there was general agreement that it could be easier to participate in online discussions than to do so face-to-face.

The positive aspect of being able to offer help and support (and to receive it) were widely mentioned, as was the fact that it felt safe because of the closed nature of the community (lines 126-133). There was also mention of the positive effect of having a teacher involved, providing clear support for Henri's assertion of the importance of the rôle of *experts* and *animateurs* (Henri, 1995).

In terms of continuing the research, students were happy to consider an increase in the size of the group (lines 254-260), and were not worried that they might be the object of laughter if they posted a contribution (lines 307-313) in any expanded group. However they were concerned that other students involved should be of a similar ability range if there was to be mutual benefit and trust (lines 314-318). Suggested improvements to the online environment included the ability to swap files (lines 209-210), to see who was online at any time (lines 214-5, 227-230) and the provision of a chat room in order to have somewhere to interact where the discussion could be more like a "flowing conversation" (lines 216-225).

Interview with teacher

As a final source of data, an interview was conducted with the class teacher to provide his perspective on the online discussion and the class response to it. This was particularly important as continuing with the work to the next stage required his support; it was also essential to obtain a school view of the value of the research. Once again, this was conducted as a focused interview, the major areas of enquiry including his:

- background and experience
- reasons for agreeing to become involved in the study
- insight into the nature of the group of students and their interactions
- approach to teaching science and carrying out science investigations with this group

- perceptions of the group as they interacted online
- thoughts about further research with this group

The transcript of this interview is provided in appendix 9. In the description that follows he is referred to as *Dan*.

It was Dan's interest in ICT that led him to become involved in the research study, having had some responsibility for promoting the use of ICT in the science department when he first joined the school (not as head of department at that point) (lines 35-42). This involvement was also stimulated by interest in developing his students' experience of science investigations (lines 45-59).

Dan's description of his approach to teaching the group and his description of them (lines 114-145) emphasises the collaborative nature of learning in his classroom, and the importance of social interactions. He describes the way in which they work as a group, and the effect that this has on their attainment. He prefers to allow individuals within the group to have a high degree of autonomy as far as their learning is concerned, provided always that behaviour and classroom management does not become an issue. He describes how "little cohorts" have emerged as the group have got to know each other, and how each of these has an "academic achiever" who "is actually helping the others" (lines 115-118). This description is striking, inasmuch as it corresponds to the kind of stance advocated for the teacher in a knowledge-building community as described by Bereiter and Scardamalia (1993:210-211).

Discussing the class's response to participating in the study, Dan confirms that the experience seems to have been a positive one. Considering individuals in the group (lines 146 *et seq*) he lists a number who have participated particularly strongly. From this description it is clear that the contributions made by individuals within the online community are often similar in nature to those within the face-to-face community (for example lines 189-209). However this is not unfailingly

the case, and Dan's description suggests that some students may respond very differently, the examples given providing evidence for the online discussion providing the impetus to direct the energy of certain students (lines 186-188), providing confidence (lines 222-225) and inspiring others to contribute online in a way that would not be expected in class (lines 242-255).

Conclusions

This chapter has described the initial, small-scale study conducted in order to gauge the extent and nature of students' interactions in the CSCL environment and to assess whether such interactions are likely to feature an epistemological dimension that can be the subject of research. In addition, the study provides valuable information about students' access to the CSCL environment and their response to it.

Access and response

The outcomes of this study provide clear evidence that the students involved were able to make good use of the online discussion forum in respect of both the quantity and quality of their posts as measured through content analysis and analysis of the length of posts. The degree of use of the discussion forum outside school was particularly encouraging, and contributions were received from all students, including those who had no Internet access at home. Students confirmed that access to the CSCL environment was not problematic.

Students' responses to the experience of using the forum were very positive; particularly encouraging was the disclosure that for many students the online environment provides a place where confidence-building occurs, and where discussion is found easier than in classroom situations. Students clearly took seriously the responsibility of managing their online learning environment for the benefit of all, citing the ability to give support and to receive support themselves as particularly welcome. This outcome is particularly encouraging in that

such an environment is more likely to engender "risk taking" (McConnell, 2000:125) which may lead to the advancement of more creative and imaginative explanations for the phenomena under investigation. An environment in which risk taking is more likely is therefore one in which knowledge-building is more likely to thrive.

These outcomes are reflected in the comments from the class teacher, who confirmed the worthwhile nature of the students' experience, and who, in describing his observations of students' participation, provided insight into the way in which the online discussions had motivated and focused students' learning.

In view of their perceptions of the worthwhile nature of the experience, both students and class teacher confirmed that they were happy to contemplate continuing the study, and to expand the number of students involved (in order to produce a larger community with a potentially richer set of interactions).

Nature of the community and interactions

The evidence from the initial study provides a picture of the knowledge-building community that is encouraging in terms both of the relationships between students and in the rôle of the teacher. Email responses and students' responses in the group interview show that collaboration in online construction of knowledge emerged as one of the strengths of the forum as perceived by students and by their class teacher. The perspectives of the collaborative experience clearly reflect the characteristics of a knowledge-building community described in the previous chapter (page 43), especially (crucially) the *driving of enquiry by students' questions*, the *focus on progress towards collective goals of understanding*, the way in which *student discourse is taken seriously* and the *teacher functioning as a guide to the learning process*.

Although the content analysis of the online interactions provides a picture only of the extent to which interactions reflected the content of the science investigation, the proportion of responses of this type and their word length is indicative of discussion with some degree of depth (Veerman & Veldhuis-Diermanse, 2001). This is suggestive of an environment in which metacognition may be present (Shimamura, 1994) and which may therefore involve students in discussion which involve "knowing about knowing". To this extent, the trial study supports the idea that there may be an epistemological dimension to interactions between students which may be the subject of research.

Development of the CSCL environment

Students' suggestions for the development of the CSCL environment included provision of a facility for sharing files, a facility existing in instant messaging programs like MSN Messenger. Some students also felt that it would have been helpful to be able to have some indication of which students were logged on to the discussion forum at any one time. Other changes to the discussion forum suggested included improvements to the way in which messages were displayed/threaded, and the provision of opportunities for synchronous communication ("chat") in addition to the asynchronous forum.

Chapter 5

The second study

The initial study described in the previous chapter established that, given an online discussion environment in which to conduct discussions related to their science practical investigations, it can reasonably be expected that students will make use of this environment in a way that involves the pursuit of shared knowledge – "knowledge-building". Before moving to a study in which students' online interactions were subject to analysis in depth, it was necessary to trial the taxonomic frameworks proposed for the identification and analysis of *critical events* in order to ascertain whether the frameworks as constructed were fit for this task. In this respect, this second study was concerned with whether the frameworks would prove effective in

1. identifying critical incidents from logfiles; and
2. analysing critical incidents following critical incident recall.

As such, the study seeks to establish that the proposed approach to the research (employing critical incidents followed by subsequent critical incident recall) is a viable one.

As a further aspect of this study, the opportunity was also taken to refine and develop the online environment as a result of the evidence from the trial study.

The context

Writing for an audience of researchers in educational communications and technology, Savenye and Robinson caution that qualitative studies are neither easy nor quick to design and conduct, and that researchers should be prepared to adapt and refine methods of data collection during such studies (Savenye & Robinson, 1996). Although the initial study indicated the viability of studying students' online interactions relating to practical work, it was necessary to carry out some development work related to the online environment and to trial the

proposed methods of data collection and analysis outlined in chapter 3 – in addition, careful thought had to be given to the nature of the practical investigation to be undertaken by students, in particular its *authenticity*. This section describes changes made to the investigation and to the CSCL environment resulting from the outcomes of the initial study. The research methods are the subject of description and discussion later in the chapter.

The school, teachers and students

This study was conducted with two parallel classes of Year 9 students in the same school as the initial study; these classes are identified here simply as 9A1 and 9B1. The two classes consisted of the class from which the students in the initial study were drawn, plus the other "top" ability class in the year. The times at which these two classes were taught science did not always coincide since the year group was divided into two halves for the purposes of timetabling. Nevertheless, there were sufficient opportunities for briefing students and conducting whole group activities afforded by the single period overlap in timetables for the two classes, and the ability to work with classes individually facilitated easier access to computer facilities when needed in school. Table 5.1 shows the timetables of the two classes.

		Monday	Tuesday	Wednesday	Thursday	Friday
Week A	9A1	period 5	period 2	period 1	period 4	-
	9A1	-	period 5	-	period 4	period 2
Week B	9B1	-	period 3	period 3	period 5	-
	9B1	period 1	period 5	period 4	-	period 3

Table 5.1 – the timetables for classes 9A1 and 9B1

The number of students taking part in this study was increased in order to facilitate a richer source of data with which to undertake the trial of the methods of data collection and analysis. The total number of students in the expanded group was 58, with the consent of students and parents/carers being sought through a letter sent home by the school, as in the trial study. In a group interview, a sample of students from the group in the trial study had indicated their willingness to take

part in a further study with a group of increased size – the recruitment of the second class parallel in ability to that containing the group in the first study addressed the concerns of these students, who wished any expansion in the size of the group to involve students of similar ability (see appendix 8, lines 314-318).

The teacher of the class who had not been involved in the trial study had been an interested observer during the period of this work. Although not a particularly experienced user of computers for anything other than basic word-processing, she was keen to be involved in the research, and was happy to undertake a (limited) amount of online interaction with students, while being very supportive of the use of the CSCL environment as part of investigative practical work. Guidance from both the researcher and from her head of department was arranged so as to ensure that she was induced to the philosophical basis of the research, with the intention that the climate in both classes would reflect the ideals of knowledge-building and argumentation. The process of planning the study around these ideals is described in the following section.

Planning

Planning for the second study emphasised the processes of *knowledge-building* and *argumentation* in the same way as the first study, using the elements of activity theory described in chapter 3 to structure and supporting these processes. As well as considering the specific conditions needed to foster knowledge-building, preliminary planning for this study also addressed the changes and developments needed to the CSCL environment, the science investigation to be used and the data to be collected. All these aspects are discussed in this section of the chapter, beginning with the use of Activity Theory.

Framing the community and its activities

Activity theory was described in chapter 3, where it was shown how different triads focus attention on different parts of the knowledge-building community and their relationships. For the purposes of planning this study, the three triads were important in guiding the way in which the knowledge-building community was established and run and governing relations between students, teachers and researcher. The three sub-sections that follow describe the influence of the three triads on planning; respectively they are:

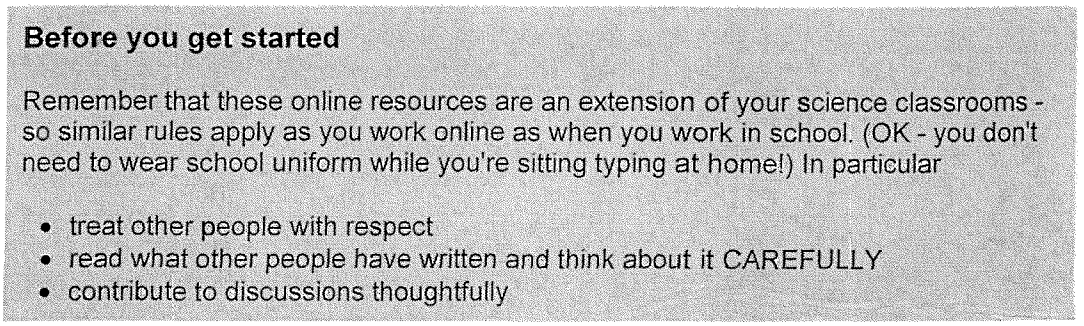
- triad SCO – guiding the constitution and motivation of the community and the guidance given to students in order to promote knowledge-building (see table 3.2, page 84);
- triad RCO – establishing the *explicit rules* for discourse within the community so as to accord with those rules identified in chapter 3 and so as to ensure that any rules applied in the online setting reflected rules applicable offline;
- triad TCO – clarifying the *explicit tools* that students were expected to use during the investigation.

Triad SCO – the community

The community in this study consisted of the student members of the two classes together with the two teachers and the researcher. It was intended that this community would function as a *knowledge-building community*, pursuing new knowledge (new, that is, to the students) through interactions with the teachers and the researcher as "expert learners" (page 43) both in the classroom and online.

In designing the activity and the framework to support knowledge-building both in the classroom and in the CSCL environment, attention was paid to Bereiter and Scardamalia's criteria for a knowledge-building community (page 43) and to the important aspects of communication and discourse described on page 86. The outcome of this was a simple framework of guidelines to support interactions both online and offline;

this reflected the school's own ideals as described in the school's homework diaries issued to students (appendix 3) and was also designed to promote knowledge-building. The web page seen by students as they logged into the online resources home page was one aspect of this, intended to encourage *progress toward collective goals of understanding and judgement* (page 43, criterion 5) and to foster a climate in which *discourse is taken seriously* (page 43, criterion 7):



Before you get started

Remember that these online resources are an extension of your science classrooms - so similar rules apply as you work online as when you work in school. (OK - you don't need to wear school uniform while you're sitting typing at home!) In particular

- treat other people with respect
- read what other people have written and think about it CAREFULLY
- contribute to discussions thoughtfully

The other aspect was the nature of the interactions between teachers/researcher and students, where it was agreed that:

- questions from students relating to the investigation (other than simple, mechanistic questions about, say, the location of a particular resource or whether a particular piece of equipment was available) would be reflected back to them, with suggestions about possible ways in which answers might be sought;
  (This emphasised *problems rather than categories of knowledge*, where *enquiry [is] driven by students' questions*, in a context where *teachers can contribute what they know to the discourse, but there are other sources of information* and where the teacher leads *by virtue of being a more expert learner* (page 43 criteria 2, 3, 8 and 9).)
- students would be expected to seek possible explanations for phenomena and to discuss their emerging ideas with other members of the community.
  (This emphasised both *explaining [as] the major challenge* and the idea that *discourse is taken seriously* (page 43 criteria 4 and 7).)

Triad RCO – the (explicit) rules

Consistent with the description given above, the rules for the general conduct of the community were drawn carefully so as to reflect not only the ideals of a knowledge-building community but also the rules of the real world of school as actually constituted. The framework also reflects the explicit aspect of the conduct of science investigations as described by Merton's constitutive norms (page 88) of *communalism* and *universalism*, ("treat other people with respect") *disinterestedness* ("read what other people have written and think about it CAREFULLY") and *organised scepticism* ("contribute to discussions thoughtfully"). These norms were further mediated by the agreed rôle of both teachers and the researcher as they engaged with students on and offline, countering the idea that students' science exists simply as a body of "finished" knowledge (page 21).

Triad TCO – the (explicit) tools

As discussed in chapter 3, the explicit tools used by the community in pursuing its object include scientific facts and theories and the physical paraphernalia found in school laboratories. In planning this investigation, consideration was given to the areas of knowledge covered by the Key Stage 3 National Curriculum in order to ensure that students were likely to have access to the relevant cognitive tools. Special care was taken to select an investigation which would relate to science theories that students had already studied; this was made easier by the timing of the investigation, taking place at the end of Key Stage 3 when the entire Programme of Study had been completed. Students were encouraged from the outset to make use of a wide range of electronic resources (and to share these with other students) to provide them with the necessary knowledge tools.

The CSCL environment

Following the first study, some significant changes were made to the online support available to students. First, both students and researcher

had noted the shortcomings of the Hypermail discussion forum software, largely relating to its inability to provide for effective threading of messages in the context of students having the facility to amend information in certain fields prior to submitting messages following on from other postings, but also relating to the difficulty in "tidying up" the large numbers of messages visible once the forum had been in use for some time. (Similar complaints had been made by pre-service teaching students when the software had been used in their course the previous year, supporting this view of the software (J. Basma, 2001, personal communication, 10 Oct). Second (as reported at the end of the last chapter), students had asked that there might be an opportunity for synchronous interactions and file-sharing. With these issues in mind, the changes described below were made to the online environment.

Discussion forum (asynchronous)

The hypermail software was replaced by another open source package, phpBB ...

> *... a high powered, fully scalable, and highly customisable open-source bulletin board package [with] a user-friendly interface, simple and straightforward administration panel, and helpful FAQ.*
>
> (www.phpbb.com)

The Web-based interface of phpBB provided an attractive front end for the discussion forum, with an administrative function providing a significant degree of flexibility and customisation without imposing a large overhead in terms of bandwidth. The choice of this software allowed the forum to be given a much enhanced visual interface, and provided facilities for managing discussions much more effectively. Students who had used the Hypermail software previously commented on their favourable impression of the phpBB software in comparison to Hypermail. Appendix 10 provides a screenshot of part of the phpBB forum for this study.

File-sharing

Students were provided with access to software with a Web-based interface for file-sharing (appendix 11) to facilitate the exchange of such things as spreadsheets, word-processed documents and images.

Chatroom

To allow synchronous interaction to take place a chatroom was made available to students at certain times, agreed with students and teachers in advance. The reason for limiting the times at which the chatroom could be accessed was based firstly on the need to provide moderation of interactions, and secondly on the desire to ensure that there was a "critical mass" of students online to interact. (The logs for the Hypermail forum in the initial study indicated that there were 19 posts (5.6% of the total of 339 posts) from students with the general enquiry "is there anybody here?", indicating a desire or an intention to communicate synchronously.)

The chatroom (appendix 12) was based on the NFC Chat software package freely available under the GNU Library General Public Licence at http://sourceforge.net/projects/nfcchat/, providing all the facilities needed for students to be able to interact online in a Web-based environment in real time.

As with the Hypermail software, both phpBB and the chatroom are examples of *unstructured groupware* (McConnell, 2000:33).

Software implementation

As in the initial study, all of the software was hosted on the *SciJournal* server. Students accessed the CSCL environment via a simple url, entering a username and password common to all students in the study but different to those used in the initial study. This method of providing a secure environment had proved successful in the initial study, and both teachers and researcher felt that it was again likely to be the most

suitable approach. Once again, initial briefing of the students by teachers and researcher stressed to students that, in the light of the need to provide a safe online environment, any evidence of such disclosure would be treated as a serious matter.

Both the phpBB forum and the chatroom generated logfiles of usage, recording details of names, times, and dates of contributions in a format that, after some manipulation, could be imported into a spreadsheet for scrutiny and analysis.

Student identification

Many young people of the age of those in this study feel comfortable online and make use of the Internet to continue their "offline" relationships and to develop new relationships online that may be fluid in terms of personal identity, geography and social context (appendix 8 lines 273-285; Holloway & Valentine, 2003:127-152). For the purposes of researching the online interactions in this study, it was important that students had a visible identity that was stable over time so that others might have some clear idea who it was they were interacting with in order to make appropriate links with the students they were working with in school. For this purpose, all students were assigned online names that consisted of their first (given) name followed by an underscore character (_) and the first letter of their second (family) name. Thus, John Smith would have an online name of John_S and Helen Jones one of Helen_J. In the rare case where identical online names existed, the name was followed by a number 1 or 2, as appropriate; ie Lisa_T1 and Lisa_T2.

The science investigation

A somewhat longer period was allocated to this investigation, following the statutory tests for Year 9 in May 2003, consistent with the condition that knowledge-building should occur through *sustained study of topics in depth rather than superficial coverage* (page 43 criterion 1). A

session to introduce each class to the online discussion area and associated resources was run in the week commencing May 12, the investigation having been introduced in the final lesson of the previous week. As in the initial study, the object of the first familiarisation with the online environment was to ensure that students felt sufficiently confident in using the online resources to be able to contribute to discussions right from the start of the investigation. Less time for *focusing, defining the problem, planning and obtaining evidence* (Watson & Wood-Robinson, 1998:88) was provided for this investigation, since it was intended that the online discussions should reflect this stage of the investigation.

The initial study had made use of an investigation which formed part of the standard scheme of work used by the school. As noted previously, this investigation was typical of those conducted within the Sc1 framework, consisting of an activity concerning the control and measurement of variables typical of the "intellectual uniformity" noted by Donnelly et al in their earlier review of National Curriculum science investigations (Donnelly *et al*, 1996:129). Furthermore, the nature of this type of investigation makes it much more of a search for evidence to exemplify or illustrate laws relating to friction than to provide an opportunity for students to construct scientific meanings as part of a conceptually challenging piece of practical work. This limiting is referred to by Bereiter and Scardamalia, who describe a "commonsense" epistemology of schooling, constrained by a curriculum which provides simply:

1. a list of facts and principles to be learned;
2. a list of skills to be developed - sometimes labelled as "processes";
3. a catalogue of suggested activities

(Bereiter & Scardamalia, 1993:189).

With the intention of producing an environment in which students would be encouraged to participate in building new (to them) knowledge, such

an investigation was clearly likely to constrain rather than support and encourage such a process, and an investigation of a much broader nature was sought, although this was to be linked to the requirements of the National Curriculum.

Following discussions with the science teachers involved, an investigation was selected which was felt likely to provide students with the opportunity to think creatively about the science behind the practical situation. The investigation was based on an activity in a published scheme of work (Fullick *et al*, 1996a:40-42), extended somewhat to provide the necessary scope for students to be challenged to produce creative explanations which could be the subject of discussion with other students. Students were provided with a briefing sheet at the start of the investigation (appendix 13), and were encouraged by their teachers to consider the science theories and knowledge that might have a bearing on the investigation, which involved exploring the relationship between the extension of a rubber band and the height to which a prototype of a child's jumping toy might jump. The "real-life" setting of this practical problem-solving task was chosen in order to provide students with an opportunity to practise *authentic science*, described by Woolnough as being "important in developing the student's personal knowledge of scientific phenomena and the way a scientist works" (Woolnough, 1998: 116). Prior discussion between teachers and researcher resulted in a consensus as to the possible ways in which students might proceed in tackling this task; it was thought likely that a shared understanding of this between teachers and researcher would be much more conducive to an environment in which produced a "real meeting of minds, and not just unassociated pieces of text" (McConnell, 2000:139). It was agreed between teachers and researcher that this shared understanding should extend to an acceptable scientific explanation for the behaviour of the prototype toy ("Jumping Jiminy") in order that students should not receive conflicting advice concerning their investigations. Based on

considerations of the properties of elastic bands and on the conservation of energy, it was judged that a plausible set of observations would lead to the plotting of a roughly sigmoid curve when height was plotted against extension of the rubber band. It was also thought that the ablest students in the group might be able to find a qualitative explanation for this in terms of the tensile properties of rubber. Given the age of the students and the science curriculum they had covered it was thought unlikely that any deeper explanation would be forthcoming from students; the quantitative relationship between force and work do not form part of the Key Stage 3 National Curriculum for science.

Timing

Three full weeks were allocated to the investigation, with the asynchronous discussion forum running continuously and the chat room open on four, previously agreed and publicised, occasions for up to two hours on each occasion. Table 5.2 shows the overall timings. As in the initial study, students worked in friendship groups for the practical work, group size and composition being largely determined by students, with teachers managing this where necessary (page 43 criterion 6). This structure was chosen since it was the manner in which the students were used to working in these classes, and both teachers and researcher agreed that to impose a significant change for this study could have proved disruptive. This reflects the ecology of the knowledge-building classroom, in which

> *There is little schoolwork of the conventional kind, where the students are working individually but all doing the same thing. More typically, students work in small groups; each group has a different task related to the central topic and plans how to distribute work among its members.*
>
> (Bereiter & Scardamalia, 1993:211)

w/c May 5	Classes introduced to investigation and begin planning.
w/c May 12	Classes introduced to online environment. First chat room session May 14.
w/c May 19	Classes continue investigation. Chat room session May 21.
w/c May 26	Half-term week. Chat room session May 29.
w/c June 2	Classes continue investigation. Chat room session June 5.
w/c June 9	Final week of practical work.
w/c June 16	Written reports handed in.

Table 5.2 – the timing of the investigation

Once students had handed in their investigations a further stage of online discussions were held in which two groups of students (selected by teachers and researcher together in order to obtain a cross-section of students across working groups) debated among themselves the various merits of the reports by two of their number. These discussions took place in the final two weeks of the term, from June 30 onwards.

Ethics

In the initial study, access to the Internet had not been an issue for any students, even those with no Internet connection at home, and all students had contributed to the online discussion. In view of this, the teachers of each class spoke informally to their students to determine whether any of them might need access to the Internet at school in order to participate in the research. In addition, students were encouraged to make arrangements for Internet access via friends' computers; as a result, both teaching staff and the researcher were satisfied that no student was likely to be excluded from participating in the study as a result of not having Internet access at home.

Permission for students to participate in the study was obtained in exactly the same way as the initial study, by means of a letter sent home from the school explaining all aspects of the study. The purpose and nature of the study was explained carefully to students in each class by the researcher; consent was sought from students at this stage and at the commencement of all interviews conducted with students.

Collecting data

In chapter 3 the argument was made for a naturalistic approach to researching knowledge-building in a CSCL environment, in which meaning is held not to reside in the logfiles of online interactions alone. In order to gain access to the multiple meanings possible in any online exchange, it is therefore necessary for the researcher to engage in discussion with the research subjects after the event; this is the purpose of the technique of *critical incident recall*.

Data collection in this study was concerned with trialling this technique, employing the taxonomic frameworks developed as a means of identifying critical incidents and classifying the kinds of *tacit rules* and *tacit tools* used by the community in knowledge-building. The process of data collection and analysis is shown in figure 3.7 on page 103, and involves the logfiles from online interactions and the interview data collected subsequently, following the identification of critical incidents.

Outcomes

In response to the letter sent home by the school seeking permission for students to participate in the study all of the students returned their permission letters. The study was thus able to proceed with all 58 students from the two classes participating. No concerns were raised by parent(s)/carer(s) concerning any aspect of the study, and students indicated that they were content to proceed.

Number and nature of online contributions

More than 1,500 contributions to the discussion forum were recorded, totalling nearly 24,000 words. Three chatroom sessions were run (14 May, 21 May and 5 June), during which over 5,000 contributions were recorded; these amounted to nearly 25,000 words. Table 5.3 shows the data relating to contributions to both forum and chatroom.

	Forum	Chatroom
contributions	1,523	5,051
total words	23,971	24,866
average word length	15.7	4.9

Table 5.3 – contributions to the forum and chatroom

The greater length in the average word length of contributions in asynchronous interactions compared to synchronous interactions is consistent with observations by Veerman & Veldhuise-Diermanse (2001). Although the word length of contributions was markedly different, and to some extent reflected the different characterisations of asynchronous and synchronous interactions described on page 47, the identification of 11 critical incidents during chat room sessions (see table 5.4) out of 34 critical incidents identified in total is indicative of a significant degree of interactions involving knowledge-building in the chatroom environment, and confirms the fact that reflection and elaboration on the posts of others is not limited to asynchronous interaction.

Identifying critical incidents

The approach to identifying critical incidents involved the application of the taxonomic frameworks relating to the two triads RCO and TCO according to the research model (figure 3.7, page 103), using the indicators associated with the dimensions in tables 3.4 (page 100) and 3.5 (page 103). This was carried out as a continuous process throughout the period of the online interactions between students (see table 5.2), logfiles from both chatroom and forum being split and sorted into a series of different spreadsheets, amounting to a total of some 8500 lines. The result of this process was a set of 34 critical incidents consisting of one or more lines of text, each associated with one dimension in the taxonomic frameworks. These critical incidents are documented in appendices 14 to 20; no critical incidents were identified for two of the dimensions in triad RCO (table 5.3); this is discussed later in this chapter. In all logfile references ch = chatroom and fo = forum. Extracts from chatroom logfiles are further identified by date (eg jn05 = June 5) followed by a line reference after the underscore character. A complete reference is in the form chjn05_319. Extracts from forum logfiles are further identified by a reference to a worksheet (eg lg25) followed by a line reference after the underscore

character. A complete reference is in the form folg11_013. The division of forum posts into different worksheets reflects the way in which the posts to the forum exist in threads – each thread was assigned to a new worksheet.

Certain critical incidents were selected for further exploration through critical incident recall, using three group interviews with students. The basis for this selection was the extent to which the critical incident was judged likely to form the basis for a successful group interview, and resulted in 11 critical incidents being selected for follow up (table 5.4). Those critical incidents selected are noted with a tick mark (✓) in the appendices.

triad	dimension	total number of critical incidents		number of critical incidents selected for CI recall	location
		forum	chat		
RCO	r – *reputation*	0	0	-	n/a
RCO	q – *personal qualities*	4	2	2	Appendix 14
RCO	i – *private information*	0	0	-	n/a
RCO	p – *presentation*	4	0	2	Appendix 15
RCO	s – *social*	4	0	0	Appendix 16
RCO	t – *technical*	1	0	1	Appendix 17
TCO	nr – *naïve realism*	2	1	2	Appendix 18
TCO	be – *blissful empiricism*	5	4	1	Appendix 19
TCO	ce – *credulous experimentalism*	3	4	3	Appendix 20

Table 5.4 – critical incidents selected for critical incident recall

Transcripts of the three group interviews are given in appendices 21 to 23, in which a total of 19 students were interviewed. These students were those who had contributed in some way to the critical incident (whether through a chatroom session or a posting to the phpBB forum), the purpose of the interview being to elicit the collective understanding of the critical incident and so uncover the tacit rules / tools underlying the interaction(s). The transcripts were scrutinised carefully in order to identify part(s) that related to the dimensions within the framework by applying the indicators in tables 3.4 and 3.5 (pages 100 and 103). This

process resulted in a set of cross-references between critical incidents as identified in the logfiles and to portions of the interview transcripts. This process of cross-referencing thus provides access to students' meanings of critical incidents; the cross-references are described in table 5.5.

triad	dimension	critical incident number	critical incident recall – data reference
RCO	q	1	Teacher interview (appendix 9) lines 228-232
RCO	q	5	Student group interview 1 (appendix 21) lines 27-57
RCO	p	3	Student group interview 1 (appendix 21) lines 7-22, 67-71
RCO	p	4	Student group interview 2 (appendix 22) lines 1-15, 36-51 Student group interview 3 (appendix 23) lines 8-52
RCO	t	1	Student group interview 1 (appendix 21) lines 108-129
TCO	nr	1	Student group interview 2 (appendix 22) lines 36-61
TCO	nr	2	
TCO	be	1	Student group interview 1 (appendix 21) lines 41-55, 83-100
TCO	ce	2	Student group interview 1 (appendix 21) lines 81-86, 162-8
TCO	ce	3	Student group interview 3 (appendix 23) lines 98-105
TCO	ce	6	Student group interview 3 (appendix 23) lines 53-77

Table 5.5 – critical incident recall – cross-references between logfiles and transcripts of group interviews

The discussion that follows is structured around these critical incidents as they relate to the triads RCO and TCO, with reference to the transcripts of the three group interviews conducted. References to critical incidents is in the form CI[number][dimension], where [number] is the number of the critical incident as given in the relevant appendix.

Triad RCO – tacit rules

This triad is concerned with the tacit rules used by students when advancing a knowledge claim with which they are associated or when critiquing a knowledge claim made by another student (or group of students). The taxonomic framework relating to this triad consists of six dimensions: *reputation*, *personal qualities*, *private information*, *presentation*, *social* and *technical* (table 3.4, page 100).

As the logfile analysis proceeded, it became clear that there were no interactions that could unambiguously be assigned to the dimension *reputation* (r), relating to practical ability and trustworthiness; this resulted in no critical incidents being identified under this heading. However, some contributions in the logfiles suggest that this dimension lies close to the dimension *personal qualities* (q); for example, this contribution in an interaction where one student is bolstering another student's opinions of her own abilities in carrying out practical work:

> *[name], I dnt think that u repeated things 2 much, i didnt even think that u did, until u mentioned it but still didnt think that, i am always concious of that in my reports, but i just think its you worrying! Ne way, theres no harm in it, ur just putting ur point across.*
>
> (folg43_012)

There were also no interactions in the logfiles that could be coded as *private information* (i). Careful analysis of the logfiles indicates that this is not because such interactions did not occur but rather that there had not been any opportunity to record them as they occurred *outside* the CSCL environment:

> *ill try to get thru 2 ya on ur msn [name].*
>
> (folg06_174)
>
> *[name] need 2 talk 2 u in msn*
>
> (chjn05_1493)
>
> *shes jst connecting ...*
> *shes on msn ...*
> *so she shud b on this soon*
>
> (chmy14_1881)

Although these dimensions appeared to be absent from the logfiles, and this did not themselves give rise to any critical incidents, they were not at this stage excluded in the analysis of critical incident recall associated with other dimensions. This was to provide a further opportunity for interactions associated with them to emerge.

Dimension q – personal qualities (appendix 14)

Analysis of the logfiles identified six critical incidents associated with this dimension, of which two were selected for critical incident recall (CI1q and CI5q). Four of the critical incidents (CI1q-CI4q and CI6q) identified made reference to other students' abilities to provide answers to questions (eg "lol yeah i guess she prob would no" (folg11_013); "[name] ur a bit of a boff outside of school aren't you" (folg06_089)), while critical incident number 5 was associated with the rhetorical style used in interactions regarding a knowledge claim.

CI5q was discussed by the students involved during interview 1, where those concerned with developing the particular measurement technique (in which a video camera was used) were given the opportunity to describe it. This description shows the confidence of the group in the superiority of their method: "...we'd play it back a few times until we could tell which [measurement] was right, definitely" (appendix 21, lines 46-7). This confidence is associated with the manner in which those associated with this technique argue for the superiority of the outcomes of their investigations, in which the technical merit of the knowledge claim becomes secondary to the perceived superiority of the those responsible for the technique. This is therefore an example of a knowledge claim which is being advanced by individuals who are making reference to themselves as a means of bolstering support for it. Whilst scientists are not supposed to operate in such a way (Merton's norm of *disinterestedness*), there is evidence that they do, as Collins and Pinch have shown in their description of the claims surrounding cold fusion (Collins & Pinch, 1994).

The other critical incident associated with this dimension (CI1q) comes from a private interaction outside the chatroom which was invisible to others in the chatroom (although recorded by the software). Further information about this incident comes from the class teacher rather than the students; this is the only critical incident where such

information was found to be useful. The teacher describes the student referred to in this critical incident as "probably the brightest kid I've ever taught" (appendix 9, lines 155-6), and notes that "I think that sometimes Andrea does the talking for [her friends]" (appendix 9, lines 230-1). The rôle played by such students when knowledge claims are discussed in the community appears to be noticed by other students, for whom understanding the behaviour of their peers is an aspect of developing scientific knowledge that is at least as important as understanding the behaviour of the objects they are investigating.

Dimension p – presentation (appendix 15)

The explicit rules of students' science give presentation an important rôle:

> *Listen to your teacher who may give you special instructions and remember to:*
>
> - *Underline titles and subtitles*
> - *Always write in ink and as neatly as possible*
> - *Draw in pencil*
> - *Check correct spelling and punctuation*
> - *Leave a margin on the left*
> - *Add the date*
> - *Add titles or labels to any diagrams and illustrations*
> - *Keep work clean*
> - *Keep the outside of your exercise book free of graffiti*
>
> (Pynebrook School student organiser)

The extracts in appendix 15 suggest that judgements about presentation feature when students present their results and when other students come to judge the quality of their work. Some incidents show that correct technical terminology and the "style" of presentation is seen as important by students (CI3p and CI4p), while the correct use of technical terminology is also important (CI2p). This is an aspect of learning science that students encounter from the very earliest years of secondary education, the use of which appears to lend (to students' minds) an authenticity to the voice of the author based on their teachers' use of words (Wellington, 1994:173-4).

Critical incident recall, in which students reflected on why they found some students' accounts of their work more compelling than others, indicates that the inclusion in a report of *detail* may be important, partly for its own sake:

> *[researcher] why are you convinced by what Jill's written ... ?*
>
> *She's presented it better.*
>
> *There was a lot of detail and everything.*
>
> (Appendix 23, lines 8-10)

and as an important aspect of the report as a rhetorical device:

> *Yeah, but when you look at a book or something you always look at the front cover first ...*
>
> *... and that's presentation! [pause] And the order's got to make sense as well.*
>
> (Appendix 23, lines 26-9)

CI3p also implies that *detail* may provide evidence that the writer understands the subject matter:

> *I think he could have also put more detail in ova parts of the work and shoul dhave showed his understanding more??*
>
> (folg44_005)

The richness of students' ideas about the importance of presentation is an indication of the importance it plays when students consider each others' reports. The discussion of presentation based on CI3p and CI4p features such factors as the importance of an author's *explanations* (eg appendix 21, line 15; appendix 22 lines 14, 44-5, 47, 51) in indicating the extent to which they *understand* what the outcome of their investigation implies (appendix 21, line 7). These explanations are also seen as important in bringing about understanding in the reader (appendix 21, lines 18-22; appendix 22 line 43).

Dimension t – technical (appendix 17)

This dimension concerns students making "direct reference to scientific theory ("finished science")" in connection with a knowledge claim. In applying this indicator to the logfiles and interview data it was found

that only one set of interactions could be characterised in this way, relating to Hooke's law. Students discussing this subsequently (appendix 21 lines 108-129) were clearly unfamiliar with the detail of this law, which is unsurprising given that it does not form part of the curriculum that students of this age are expected to have studied. No other direct references to "finished science" in relation to knowledge claims were made at any point in the logfiles.

Discussion of framework relating to triad RCO

Application of the framework relating to this triad to the logfiles resulted in the identification of 15 critical incidents, five of which were subject to critical incident recall in order to provide a deeper understanding of the incidents and the tacit rules underlying the interactions (table 5.4). From the six dimensions of the framework (table 3.4), only *presentation* (p) appears to provide an unproblematic set of indicators that enable the identification of critical incidents and subsequent analysis of the outcomes of critical incident recall.

The lack of critical incidents in the logfiles (and in the recall of other critical incidents) relating to *reputation* (r) suggests that this dimension does not provide a useful characterisation of tacit rules. However, the observed closeness of this dimension to that of *personal qualities* (q) leads to the conclusion that, rather than abandon the indicators associated with *reputation* altogether, it is useful to incorporate these into a revised set of indicators for *personal qualities* which also reflect those of *reputation* – see table 5.6.

Dimension		Definition	Indicators
personal qualities	(q)	personality and intelligence, personal reputation	• reference to personal characteristics having a bearing on science practical work • reference to intelligence / ability • reference to integrity / trustworthiness

Table 5.6 – revised dimension of *personal qualities* (q)

In the same way as *reputation*, the dimension relating to *private information* led to the identification of no critical incidents in logfiles.

However, the implication of this (discussed above) is that interactions of this nature may be occurring outside the CSCL environment rather than simply not happening. In view of this, changes to the indicators for this dimension do not seem appropriate as a result of this study. Changes to the indicators for interactions with underlying *social* tacit rules are also not suggested by this study, since critical incidents can be identified using the indicators for this dimension; the limited time available for critical event recall in this study did not allow this dimension to be explored, and discussion of other critical events did not produce any evidence relating to this dimension.

The single critical incident relating to the *technical* dimension is surprising, since it might reasonably be expected that any discussion about a science investigation would inevitably include references to established scientific theories. The critical incidents indicate that there was considerable concern among students about the best way in which to measure the height to which the Jumping Jiminy rose (this topic of discussion occurs in all critical incidents for the RCO triad), but the established scientific theories needed to understand this behaviour fully were not widely available. However, it may also be the case that the indicator for this dimension ("direct reference to scientific theory ('finished science') connected with knowledge claim") is unnecessarily restrictive in requiring "direct" reference to a scientific theory; inspection of the logfiles suggests that a slight broadening of this indicator would have led to other examples of critical incidents relating to this dimension; the revision to the indicator is shown in table 5.7.

Dimension		Definition	Indicators
technical	(t)	technical aspects with reference to knowledge claim	• reference to scientific or technical issues connected with new knowledge, ie scientific "fact" or theory as found in text books or other authoritative source

Table 5.7 – revised *technical* dimension (t)

Incorporating the amended indicators in the taxonomic framework relating to triad RCO leads to the revised framework to be used in the

identification and analysis of critical incidents in the final study, shown in table 5.8.

Dimension		Definition	Indicators
personal qualities	(q)	personality and intelligence	• reference to personal characteristics having a bearing on science practical work • reference to intelligence / ability • reference to integrity / trustworthiness
private information	(i)	information divulged outside the (formal) online environment	• reference to information relevant to investigation relayed by another means (eg word of mouth, or via another online channel)
presentation	(p)	presentation of results and report of investigation	• reference to appearance, layout, clarity etc of investigation report
social	(s)	social reasons unrelated to science classroom or online environment	• reference to personal relationship(s) or qualities with no direct bearing on science practical work
technical	(t)	technical aspects in presentation of knowledge claim	• reference to scientific or technical issues connected with knowledge claim, ie scientific "fact" or theory as found in text books or other authoritative source

Table 5.8 – revised taxonomic framework for the RCO triad

Triad TCO – tacit tools

This triad is associated with the tacit tools used by students as they engage in the co-construction of knowledge and as they advance and examine knowledge claims. The taxonomic framework associated with this triad consists of three dimensions – *naïve realism*, *blind empiricism* and *credulous experimentalism* (table 3.5, page 103).

Dimension nr – naïve realism (appendix 18)

This dimension is concerned with the nature of scientific knowledge, and as such is a measure of the extent to which students regard scientific theories as the product of human agency taking place against a background of a community sharing tacit knowledge (O'Hear, 1989:207) as opposed to (naively) viewing the emergence of theories as being the result of a process of theory-independent induction. This appendix contains three critical incidents, two of which (CI1nr and CI2nr) were the subject of critical incident recall. In C1nr, three students had been discussing the interpretation of their results in the

chatroom, having reached a stage in their investigation where they had drawn some preliminary graphs based on their data.

For these students, graphs appear to represent a way of seeing what is happening in the investigation, as if opening a window into the data to see the patterns emerging underneath without the encumbrance of preconceived ideas; Chalmers terms this attitude *naïve inductivism*, and describes it as "dangerously misleading" (Chalmers, 1982b:2). This view of these students' approach to the use of graphs is supported by the reflection on this process during critical incident recall in which students were asked why they those chose to plot graphs. They responded:

> *So it looked easier so we could work it out.*
> *So it's easier to have a look at and understand - easier to interpret than writing.*
>
> (Appendix 22, lines 39-40)

Other members of the group (CI2nr) also appear to see the construction of a graph in terms of theory-independence, with the drawing of a "line of best fit" being guided solely by the placing of points on a page, apparently uninformed by any kind of preconceptions ("make sure there is the same amount of results on each side of the line" (folg25_020)).

Contrasting with this naïve view of the use of graphs, one contribution during this critical incident suggests that there may be some theory applied to the construction of a graph, with the statement "by the way make sure the line of best fit begins at the oragin [sic]" (folg25_022). A similarly non-naïve view of graph plotting is also evident in the critical incident recall of this discussion, where students noted that the line drawn through a set of points on a graph may be the outcome of some quite subjective judgements:

James	*He's done a line of best fit, but ...*
Andrea	*No, but he could have made it the same shape, it's just that they've done it differently ...*
Int	*... why did you draw a straight line through it, Tim?*

Tim *I just thought it'd be easier to look at it like that rather than a curved line.*

(Appendix 22, line 51-61)

The final critical incident relating to this dimension (CI3nr) has no corresponding recall, but also suggests a non-naïve approach, in this case to the writing of reports. The incident (involving an interchange between two students) is contextualised by a previous discussion involving a total of 7 students considering how they might write up their work. Coming near the end of this thread, two students discuss report writing and come to different conclusions:

student 1 *u could think back 2 wot u did and then write in word or sumthing ya know. or u could (ahem) bend the truth slightly if u cant remember.*

student 2 *good point but thaere wouldnt be much evidence to mtch it if i bend the trut*

(Appendix 18, CI3nr)

Although the author of the first statement appears to be advocating some kind of scientific sleight of hand, the second student has reservations. This suggests that some students at least may see the report of an investigation less as a realistic account of what they have done, and more as "fraud" (Medawar, 1963).

Application of the indicators for this dimension suggests that the indicator would be clearer if phrased in terms of (a) the relationship of scientific theories to real-world entities and (b) the way in which observation statements relate to real-world quantities. These changes are detailed in table 5.9.

Dimension		Definition	Indicators
Naïve realism	(nr)	Scientific knowledge is the reflection of *things as they actually are*	• statements relating to the relationships between the entities in scientific theories and models (eg atoms, taxonomic groups) and their existence *in the real world* • statements relating to techniques used in making and recording observation statements

Table 5.9 – revised dimension of naïve realism (nr)

Dimension be - blissful empiricism (appendix 19)

This dimension concerns the way in which students approach the experimental process, in particular the way in which experimental observations are made and interpreted, at one (naïve) end viewing observations as being completely free of any kind of guiding theory while at the other displaying (for example) some appreciation of the way in which observation changes with perceptual experience (Polanyi, 1958).

The appendix provides many examples of critical incidents in which students discuss their concerns about making "accurate measurements" of the height to which the Jumping Jiminy rises. There is little doubt that these students regard the process of measurement as involving the determination of a quantity which may be known precisely – the use of the word "accuracy" in this context appear to imply the extent to which the measurement made corresponds to this (unknowable) value:

> *i know that it will be very difficult 2 b accurate*
> *its dodgy to get accurate results on this expirment*
> (CI3be, chmy14_434; CI4be, chmy21_191)

For some students, there is an answer to this problem:

> *i think that measuring this was really hard, we should have been given height measurers to attach to them that automaticall tell us*
> *we should have thouse electronic height measurers to attack to them*
> (CI2be, chjn05_1699; CI4be, chmy21_1226)

There is a clear implication here that these students regard measuring instruments as a way of finding the "real" value of a quantity without

the observer getting in the way, and completely independent of any kind of theory.

Some students made measurements based on videotaped recordings, and one of these was the subject of critical incident recall (CI9be). In their reflections on making their measurements the students using this technique were at pains to stress the way in which its use led to results that were "right", by playing the video back until those watching could agree on an outcome:

> *Yes, until we could definitely say which one was right.*
> (Appendix 21, line 50)

Although there is an acknowledgement in this case of the need to negotiate an interpretation of the measurement outcomes, there is still a somewhat naïve implication that the outcome of this process is something that corresponds to a "real" value. By way of contrast, during the same critical incident recall a student from another group appears to have some insight into the rôle played by instruments in the process of making and interpreting observations based on digital imaging, and the enlargement of these images:

> *Oh no, I was thinking differently, I thought that they were plugging it into the computer and reading it off the screen ... cos if you go into the computer it gets like blurrier as it gets bigger.*
> (Appendix 21, lines 91-4)

This student saw the importance of understanding the way in which such images were enlarged, either by using the optical zoom function on the camera (which retains the sharpness of the image) or through the use of digital image manipulation software on a computer (using which the image becomes blurred as it is enlarged). In this case, the student appears to understand that instruments do not provide a way of making absolute measurements (ie that a "height measurer" does not exist) and that care is needed in interpreting observations made with instruments in the same way as observations made with human faculties in conjunction with simple instruments such as rulers.

The application of the indicator in this dimension suggests that greater emphasis needs to be placed on the interpretation of practical measurements rather than the original emphasis on the outcomes of (whole) experiments – see table 5.10.

Dimension		Definition	Indicators
Blissful empiricism	(BE)	All scientific knowledge derives directly and exclusively from observation of phenomena	• statements concerning the making and interpretation of individual practical measurements and observations

Table 5.10 – revised dimension of *blissful empiricism* (be)

Dimension ce – credulous experimentalism (appendix 20)

The third and final dimension relating to the tools used by the knowledge-building community describes the use of experiments in testing hypotheses. In particular, it describes the way in which experiment alone is not enough to resolve claims between competing hypotheses (Collins & Pinch, 1994:106-7). The critical incidents in appendix 20 can be classified into two groups – one concerned with the number of experiments conducted, the other concerned with the treatment of unexpected results:

> *ive decided that im going to do 12 graphs* (CI1ce, chjn05_1256)
> *[teacher] but how can you make results clearer? Anyone? lets have some discussion about it?*
> *do it more times ...* (CI2ce, chmy14_948, 954)
> *i am gonna try as many tests as i can* (CI5ce, folg06_059)
> *but [name] it doesn't matter if u can't double check it because u have to test it more times anyway* (CI7ce, folg58_011)

> *[researcher] Hi guys - one thing that interests me is why you repeat your results 3 times ...*
> *thats to get an average result for each one*
> *so we can get a mean*
> *[researcher] Ok - but why three ...?*
> *yeah*
> *seems like the right amount*
> *2 is too less*
> *and 4 will take too long*
> *cause it will give us a reasonable answer* (CE3ce, chmy21_172-180)
> *... take other peoples results and compare them with yours*
> *yea use averages*
> *no don do that , that wud b unfair*
> *[teacher] ... why unfair?*

bcoz its a hole differnet jimini, dif elastic band etc (chmy14_966-80)

In the first set of critical incidents students appear to be arguing that the more tests that can be made, the more likely there will be some certainty to the result. Repeating measurements is something stressed by the curriculum in the context of the reliability of evidence:

> *Pupils should be taught to*
> *make sufficient relevant observations and measurements to reduce error and obtain reliable evidence*
> Key Stage 3 programme of Study for Sc1 (DFEE, 1999:28)

This emphasis inevitably makes its way into the instructions for practical investigations and the mark schemes for them; it is therefore unsurprising that students see the number of observations made as a crucial aspect in constructing a procedure for an investigation. This extends to attempts to test multiple hypotheses through the use of multiple tests, as here.

The second set of extracts show how students find it difficult to treat multiple observations, especially where anomalous data exist; the use of simple arithmetic averages in an uncritical manner is common, and students do not appear to be able to describe why they make the number of measurements that they do. Where one student suggests comparing datasets between investigators, another student views this with concern ("that wud b unfair [sic]") on the basis that "it's a hole differnet jiminy [sic]". For this student, the outcomes of the investigation are locally rather than generally valid (Millar, 1989a:43), a naïve position; possibly the result of limited experience involving only certain kinds of science investigations, as discussed earlier in chapter 3.

The confusion of students about what may constitute *valid* and *reliable* observations is apparent in the critical incident recalls associated with this dimension, for example:

> *Linda* *It's more reliable.*
> *Int* *Oh, it's more reliable [emphasis]? Now what does that mean, Linda?*

Linda *Well, it's like – I don't know ... Valerie and Karen said they were marking it by the eye, and like the camera can like never lie, so ...*
Int *Right, OK, so because they used a camera you think that's going to make it ...*
Linda *It's gonna like be more accurate, accurate.*
(appendix 21, lines 81-6)

Another student sees reliability in a very different way:

> *... it means the results aren't always the same, so if you put a mathematical formula on it, it won't work ...*
> *... it won't be continuous ... like, they're not following the line of best fit.*
> (appendix 23, lines 99-102)

This diversity of ideas about the relationship between hypothesis, observations and conclusions brought out by the indicators associated with this dimension suggests that changes to the indicators are unnecessary.

Discussion of the framework relating to triad TCO

Application of the framework to the logfiles produced 19 critical incidents, of which 6 were the subject of critical incident recall (table 5.4). The indicators for these dimensions as initially formulated were less problematic than those for the RCO triad, with the result that critical incidents for all three dimensions were identified, and critical incident recall based on these provided insights into the tacit tools being used by students in knowledge-building. Changes to the indicators in order to clarify them lead to the revised framework shown in table 5.11.

Dimension		Definition	Indicators
Naïve realism	(NR)	Scientific knowledge is the reflection of things as they actually are	• statements relating to the relationships between the entities in scientific theories and models (eg atoms, taxonomic groups) and their existence in the real world • statements relating to techniques used in making and recording observation statements
Blissful empiricism	(BE)	All scientific knowledge derives directly and exclusively from observation of phenomena	• statements concerning the making and interpretation of individual practical measurements and observations
Credulous experimentalism	(CE)	Experimentation makes possible the conclusive verification of hypotheses	• statements concerning the way in which data-gathering is planned to support hypothesis-testing • statements relating to the interpretation of sets of experimental results

Table 5.11 – revised taxonomic framework for the TCO triad

Conclusions

The primary object of this second study was to trial the two taxonomic frameworks for identifying critical incidents and analysing the outcome of subsequent critical incident recall. The study also provides information about the nature of the CSCL environment and the science investigation.

CSCL environment

Students' access to the CSCL environment was monitored by teachers during the study, who reported that arrangements for students to have Internet access after school through the school and through friends with Internet access at home had not been reported as problematic by any students. This is supported by records from logfiles which show contributions from these students.

Although no formal feedback was sought from students, occasional postings (especially near the start of the study) indicated general approval of the revised environment:

> *This website is 8)* (folg38_003)
>
> *Hiya [name] The site is brill 8)* (folg38_004)
>
> *i think the site is good* (folg38_006)

As in the initial study, students appeared to take the responsibility of using the environment very seriously.

Both asynchronous and synchronous CMC environments gave rise to critical incidents, and were the location of interactions in which students actively engaged in building new knowledge and where tentative ideas were the subject of discussion. The introduction of a synchronous environment proved popular with students, even though it was used sparingly due to the need for continuous moderation by teachers and researcher; over three chat sessions 32 student log-ons were recorded, during which the total number of words contributed exceeded the number of words posted in the forum. The file-sharing area was used by a minority of students, and there were only 12 distinct references in the chatroom or forum to files being uploaded. Despite the relatively low use of this area, the facility to share files in this way should be retained in any further study, since this is easily provided and there is no reason to think that the provision of a file-sharing area has any adverse influence on students' online interactions in the forum or chatroom.

The success of the CSCL environment in generating interactions in which critical incidents relating to knowledge-building were observed is supportive of the implementation of the environment in a similar form in the final study.

Science investigation

The investigation proved successful in generating a large number of online interactions between students in which knowledge-building played a significant rôle. This suggests that the *authentic* nature of the task presented to students proved to be motivating, and engaged them both in the practical work and also discussions surrounding it. The varied nature of these discussions reflects the diversity of activity in a knowledge-building environment, based around small groups of students (Bereiter & Scardamalia, 1993:210-11). However, the

investigation as conceived proved problematic in two respects: science knowledge and making measurements.

Whilst care was taken in selecting an investigative task (which was adapted from a published scheme of work for students of this age), the problem of explaining the behaviour of a jumping toy in any depth required the use of knowledge tools (specifically, Hooke's law) which no students had met formally. This inevitably meant that few students made reference to formal, established scientific knowledge in their discussions, and discussions tended to focus more on the specific behaviour of particular prototype toys than on generalisable explanations.

Taxonomic frameworks

Application of the two taxonomic frameworks to the logfiles of online interactions produced a range of critical incidents from both the forum and the chatroom. Nearly one third of these incidents were suitable for further study through critical incident recall, analysis of the transcripts of this process being conducted through further application of the frameworks.

The process of applying the taxonomic frameworks in this way, accompanied by reflection on the extent to which the indicators provided useful descriptions of tacit rules and tools being used by the community, is consistent with Borg & Gall's description of *analytic induction*, in which a research method is subject to validation through "searching for propositions that apply to all cases of the problem under analysis", and in which a description of a phenomenon (in this case, the indicator associated with each dimension of the frameworks) is subject to redefinition and reformulation until there can be reasonable confidence that it is generalisable (Borg & Gall, 1989:404-5). As described in this chapter, analytic induction as applied to the taxonomic frameworks indicates that the revised frameworks may reasonably be

expected to yield a set of critical incidents when applied to the logfiles of online interactions, and that their application in the analysis of the outcomes of critical incident recall are capable of yielding an understanding of these incidents that relates to the rules and tools in use within the knowledge-building community. There is some reason to believe that a lengthy time between the occurrence of a critical incident and its recall (eg appendix 22, line 68) may not promote the best quality of recall due to problems with memory, and that a shorter period may be helpful.

Chapter 6

The main study

The second study, described in the previous chapter, established the revised taxonomic framework for identifying critical incidents within the chatroom and forum logfiles, and identified those areas where changes to the methods used in the second study were required. The first part of this chapter describes the context and planning of the main study, while the second part describes the results of that study, intended to address directly the two research questions:

Research question 1

When students interact in a CSCL environment as members of a community of student scientists, what do these interactions reveal about the community's understandings which relate to the nature and status of scientific knowledge?

Research question 2

When students interact in a CSCL environment as members of a community of student scientists, what do these interactions reveal about the community's understandings which relate to science as a social enterprise?

The context

The structure and context of the main study was similar to that for the second study, with the continued involvement of Pynebrook School (with the same head of department) as that concerned with the first two studies. This continuity meant that establishing the main study within the school was much more straightforward than would have been the case had a new school been chosen, although new students and a new teacher were involved in this study, and a decision to involve a second school was also taken. The final study was carried out during the autumn of 2003, involving students from the same school year

(Year 9, 13-14 year-olds) as before; this was a different cohort of students, entering Year 9 at the start of the new school year in September.

The schools, teachers and students

As in the second study, the main study involved two parallel "top ability" classes at Pynebrook School, in two different halves of the year group, resulting in the timetable shown in table 6.1. As before, these two classes were identified as 9A2 and 9B2.

		Monday	Tuesday	Wednesday	Thursday	Friday
Week	9A2	-	-	period 5	period 4	period 2
A	9A2	period 4	-	period 5	period 4	period 2
Week	9B2	-	period 2	period 1	period 4	-
B	9B2	-	period 2	period 1	-	period 5

Table 6.1 – the timetables for 9A2 and 9B2

The coincidence of all but one period for each class meant that, although this study involved a teacher new to the research, it was possible for this teacher to work closely with his head of department and with the researcher. In the second study the teacher new to the research was induced through discussion with both head of department and researcher, in order that the climate in both classes should support the processes of knowledge-building and argumentation.

In addition to these two classes from Pynebrook School (N = 54), it was decided to recruit a third class from a second school to join this study (N = 28). The principal reason for doing this was to expand the number of students involved to help to provide an even richer supply of data than that found in the previous study. As a third class of similar ability was not available at Pynebrook School, a second school (Castleford School) was recruited through personal contact which had been maintained by the researcher with an ex-student teacher; the recruitment of this school into the study was negotiated and agreed in full with the staff and Headteacher of Pynebrook School.

Castleford School is a 13-18 Upper School in southern England, situated in a mixed area of housing in a semi-rural setting. There are some 1250 students on roll. Results in tests at the end of Key Stage 3 (students aged 13/14 years) for the school year 2002-03 are shown in table 6.2.

	English	Mathematics	Science
students achieving level 5 or above	70%	71%	74%
LEA average	65%	68%	69%
England average	69%	71%	68%

Table 6.2 – key stage 3 test results (2002-03)

These data show Castleford School to be comparable with Pynebrook School in terms of student achievement. The class selected for the study was comparable in year position to those in Pynebrook School, being one of two parallel groups at the top of the year. In total, 82 students were involved in the study. As with Pynebrook School, Castleford School follows a two-week timetable. Science lessons for the class in the study followed the pattern shown in table 6.3, lessons being shared between two teachers.

	Monday	Tuesday	Wednesday	Thursday	Friday
Week A	periods 1 & 2	period 5	period 1	period 2	-
Week B	-	period 5	-	-	-

Table 6.3 – the timetable for the class at Castleford School

The two class teachers from Castleford School were both experienced users of ICT in their teaching, and were keenly supportive of the research. They were induced into the research in the same way as new teachers at Pynebrook School, working closely with the researcher so as to develop an understanding of knowledge-building and argumentation. Most importantly as far as the research was concerned, all teachers involved in the study were keen to see the research proceed, and had the support of their schools' senior management. (Bell notes the need to plan access to classrooms thoroughly, providing a checklist of 12 aspects in negotiating access (Bell, 1993:58-9); this list was used in seeking access to classes in this final study, as the section on ethics describes later.)

Planning

As with the second study, planning for the final study was based on emphasising *knowledge-building* and *argumentation*, activity theory providing the organising framework for the knowledge-building community. As in the previous chapter, this section begins with a consideration of this, before proceeding to discuss the CSCL environment and other aspects of the final study.

Framing the community

Since the second study had established a viable approach in which students were able to engage in knowledge-building and argumentation, the framework of guidelines to support online and offline interactions in the final study was based on that used in the second study, and described on pages 136-8. As before, planning the study involved consideration of the three activity theory triads SCO (guiding the constitution and motivation of the community and the guidance given to students in order to promote knowledge-building), RCO (establishing the *explicit rules* for discourse within the community) and TCO (clarifying the *explicit tools* that students were expected to use during the investigation).

Triad SCO – the community

Discussion at an early stage of planning the third study, which involved all teachers in the two schools interested in the research, indicated that the homepage of the CSCL environment that had been used in the second study provided guidance to students that was consistent with the aims of the study and with the ideals of both schools as reflected in documents such as homework diaries. It was also agreed that interactions between teachers/researcher and students would be managed in a similar way to their management in the second study, emphasising reflection of questions back to students and encouraging them to see *explaining as their major challenge* (page 137). Further guidance was developed for teachers relating to managing online

interactions, based on Salmon's five stage model for e-moderation; the written guidelines developed and discussed with teachers are shown in appendix 24. In addition, a technical briefing sheet providing guidance about the CSCL environment was also prepared for students (appendix 25), in order to emphasise the key aspects of the framework for online interactions.

Triad RCO – the (explicit) rules

Consistent with both the description above and the rules developed for the second study, the explicit rules for the community in the third study reflect knowledge-building ideals, the world of school as experienced by students in both schools, and the conduct of school science investigations. As in the second study, teachers/researcher interactions with students were planned to counter notions of science knowledge as simply "finished" (Milne, Sutton, & Martin, 2002).

Triad TCO – the (explicit) tools

The second study showed that the ready availability of explicit tools in the form of scientific knowledge played an important rôle in enabling students to focus on key elements of the investigation. Although the investigation used in the second study had proved successful in motivating students to collect data and to pose possible explanations for the behaviour of the prototype toy, the teachers involved in the second study felt that the focus on measurement (and especially the difficulties that students had in measuring the height to which the toy jumped) had caused students to focus on this aspect of the investigation possibly at the expense of others, including thinking about the shape of the graph (page 166). An investigation for the third study was therefore sought which would be accessible to students through the application of knowledge tools already available to them through previous study at school.

The CSCL environment

The online environment used to support knowledge-building in the second study was identical to that used in the second study, with facilities for synchronous and asynchronous communication (NFC Chat and phpBB software respectively) and for file-sharing.

Software implementation

The software for this study was again hosted on the *SciJournal* web server, accessed via a url and controlled by usernames and passwords. In this study each student was allocated a unique username and password; together, these controlled access privileges to the file-sharing environment, enabling students to have read/write access to their own file-sharing area but read-only access to other students' files. These usernames and passwords were also used when students logged into the phpBB discussion forum, providing control over student access, with the ability to set up different discussion areas for students and teachers, and even (at the latter stages of the investigation) for different groups of students to discuss different reports. All online interactions generated logfiles which could be downloaded for research purposes.

Student identification

Usernames were allocated to students in such a way as to identify them uniquely to other students, and so as to provide a cue to show the school from which the student came. All students were assigned online names consisting of their first (given) name followed by an underscore character (_) and then the first and last letters of their second (family) name. Thus, John Smith from Pynebrook School would have the username john_shp, while the username of Helen Jones from Castleford School would be helen_jsc. This method provided a form of identity that was clear and unambiguous (there were no potentially duplicate usernames) and which was stable over time, enabling all involved to have a clear idea about who it was that they were interacting with.

Passwords issued to students were six (lowercase) letters long, generated so as to be (moderately) easy to remember but hard to guess. Students were not permitted to alter their passwords. Lost or forgotten usernames/passwords were dealt with through e-mail correspondence, with a link from the entry popup page providing a prompt to remind students about the procedure for lost passwords (appendix 26).

The first and second studies had already shown that students used the online environment as a channel for social interaction. Although it would have been possible to discourage this in the third study (encouraging or even requiring students to use their existing programs such as MSN messenger instead), there are two very good reasons for not choosing to do this. First, the research relied on students logging into the environment on a regular basis to check messages and to engage with other students; discouraging this just because there was social interaction involved could well mean that, rather than log on, a student would choose to do something else. Second, the first two studies show that there may sometimes be a fine boundary between interactions that are social and those that are of interest from the point of view of research. To ban all social conversations (or conversations that students perceive to be social) from the CSCL environment could discourage students from using it at all. The decision was therefore taken to provide different areas of the discussion forum for different purposes: a social area (or "café") for social interactions, together with a technical area where it was possible to "practise" sending messages to the forum, and of course, an area for discussion of the investigation. This is an approach commended by Salmon (2004:34). Appendix 27 shows the phpBB forum set up for discussion, with the area for knowledge-building interactions ("Investigation discussion"), the social area ("Cafe") and the area for practice postings ("Test area"). In addition, an area for teacher discussions is also visible here – this area was invisible to students logged on to the forum.

The science investigation

The period allocated to the investigation ran from mid-October to mid-November 2003, a period encompassing four teaching weeks plus one week's school vacation (half-term holiday). A session to introduce each class to the online discussion area and associated resources was run in Pynebrook School during the week commencing October 6, a similar session being run in Castleford School during the following week. Unlike the second study, this initial session included an introduction to the investigation (conducted through both teachers and researcher working with the classes), with the intention of laying further emphasis on the need for students to engage in focusing and defining the problem posed by the investigation. As in the two previous studies, the object of the initial familiarisation with the online environment was to ensure that students felt sufficiently confident in using the online resources to be able to contribute to discussions right from the start of the investigation.

In the light of issues concerning the ready availability of knowledge tools for students tackling the investigation in the second study (discussed at the end of the previous chapter and earlier in this chapter) another investigation was sought with which students would be able to engage through knowledge tools already available to them. After considerable discussion between all four teachers and the researcher, an investigation exploring the effect of solutions containing biological or non-biological washing powders on (boiled) egg white was chosen. All students in the study had been introduced to ideas about proteins and enzymes as part of their school science work in the previous year. In the opinion of the science teachers, it was thought reasonable to expect these students to collect several sets of results to provide data for testing predictions about the behaviour of egg white in washing powder, and to draw conclusions about the effects of biological and non-biological washing powders based on scientific theories.

The egg white/washing powder investigation had been used as a GCE Advanced Level investigation by one of the teachers at Castleford School in previous years. It had been shown to yield interesting results, the enzymes in biological washing powder digesting the protein in the egg white leading to a decrease in its mass. Based on this prior experience, and after some simple trials to determine appropriate concentrations of washing powder, the briefing sheet for the investigation shown in appendix 28 was produced. This briefing adopted a similar approach to that used in the second study, casting students in the rôle of consultants to a commercial company; the outcomes from the second study suggested that the *authenticity* of a task like this is an effective way of engaging students with the investigation and is one that encourages knowledge-building (Bereiter & Scardamalia, 1993:204-9).

In order to provide some structure to the investigation each student was allocated to one of three groups – numbered 1, 2 or 3 – each group of students being allocated a specific task related to "researching" the scientific background. Division of tasks like this is one of the characteristics of knowledge-building described by Bereiter & Scardamalia (Bereiter & Scardamalia, 1993:210-11). These tasks were explained on a set of Web pages, an example of which is given in appendix 29.

Timing

During the five weeks in which students were engaged in the investigation the asynchronous discussion forum ran continuously and the chat room was open on five, previously agreed and publicised, occasions. Table 6.4 shows the overall timings, from which it can be seen that the two schools ran the investigation slightly out of step. This was because the group in Castleford School were timetabled for a single lesson only during the week that students in Pynebrook School began the investigation, making it impractical for them to begin the

investigation that week. Equally, it was impractical to begin the investigation in Pynebrook School a week later, since to do so would have provided a large discontinuity in their science lessons. The fact that students in the two schools were at different stages in the investigation at different times was not judged to be crucial, and is in many ways reflective of the situation in scientists' science; as Bereiter and Scardamalia note:

> *... adult scientists and scholars do not spend all their time advancing the frontiers of knowledge ... They spend a great deal of their time trying to make sense of what others have found or proposed, and that is not fundamentally different from what we have reported school children to be doing.*
>
> (Bereiter & Scardamalia, 1993:215)

As in the previous studies, students worked in friendship groups for the practical work, group size and composition being largely determined by students, with teachers managing this where necessary; students in both schools were accustomed to working in this way, which was the preferred method of grouping used by all four teachers. Being consistent with the way in which the task was structured in the second study, this timing and organisation is strongly reflective of knowledge-building (Bereiter & Scardamalia, 1993).

	Pynebrook School	Castleford School
w/c Oct 6	Students introduced to online environment and to investigation. Proceed to preliminary practical work.	Students complete previous work.
w/c Oct 13	Practical work continues. Two chat room sessions.	Students introduced to online environment and to investigation. Proceed to preliminary practical work.
w/c Oct 20	Practical work continues. Two chat room sessions.	Practical work continues. Two chat room sessions.
w/c Oct 27	Half-term week. Discussion forum continues – no chat sessions.	Half-term week. Discussion forum continues – no chat sessions.
w/c Nov 3	Students produce reports of investigations. One chat room session.	Practical work continues. One chat room session.
w/c Nov 10	Students move to new topic.	Students produce reports of investigations.

Table 6.4 – the timing of the investigation in the two schools

The structure of the introductory phase of the investigation ran as follows:

Lesson 1

- Researcher introduces idea of carrying out an investigation with online support to students. Shows examples of work carried out in previous study (~ 5 minutes).
- Researcher and teachers introduce science investigation to students – set context based on students' work in earlier years. Investigation briefing sheet is distributed (~10 minutes).
- Each student is allocated to one of the three groups for the introductory activity. Technical briefing sheet distributed.
- Students move to computers, log on to *SciI-Journal* site and explore site. Locate web page with guidance relating to "researching" science background.

Lesson 2 onwards

Students move to planning investigation, continuing with research and carrying out practical work.

Consistent with the second study, some four weeks after students had handed in their reports a further stage of asynchronous online discussions were held in which two groups of students (selected by teachers and researcher together in order to obtain a cross-section of students across working groups and between schools) debated among themselves the various merits of the reports written by three members of that group. These discussions took place in the first two weeks of December, and consisted of an "opening statement" written by each report author, providing them with the opportunity to argue the case for his/her own report; this was followed by an open discussion about the reports within each group of students (see table 6.5 for details of the groups). Briefing sheets for authors and discussants are shown in appendices 30 and 31.

Group 1	Group 2
Authors: elena_hec, sara_grp, charlie_nmc	**Authors:** alan_gnc, chrissie_slp, connor_hlp
Discussants: annie_sdp, billie_flp, carl_cep, darren_bsp, hayley_wnc, jamie_pyc, sarah_rfc	**Discussants:** alana_mtc, andy_agp, alison_brc, david_brp, mary_lrp, nadine_lnp, richard_mnc

Table 6.5 – student groups for discussing the reports

Internet access for students was explored through an informal survey conducted by the teachers. Access for all students in this group was unproblematic, and both teaching staff and the researcher were satisfied that no students were likely to be excluded from participating in the study as a result of not having Internet access at home.

Ethics

As in the second study, equality of Internet access for students was assessed by teachers, who spoke informally to students before the start of the study in order to judge whether any students would need Internet access to be arranged after school in order to participate in the study. Once again students were also encouraged where necessary to make arrangements for Internet access via friends' computers. Teaching staff at both schools together with the researcher were satisfied that no student was likely to be excluded from participating in the study as a result of not having Internet access at home.

Permission for students to participate in the study was obtained using a similar letter to that sent to parents/carers in the second study. The purpose and nature of the study was explained carefully to students in each class by the researcher; consent was sought from students at this stage and at the commencement of all interviews conducted with students.

Collecting data

Following the validation of the use of *critical incidents* identified from logfiles followed by *critical incident recall*, logfiles from online interactions in this study were scrutinised using the modified taxonomic frameworks (tables 5.8 and 5.11) in order to identify critical incidents. These incidents were then explored through group interviews (critical incident recall). These interviews were conducted with a much smaller time delay between the critical incident itself and the recall of it, one of the concerns identified in the second study (page 166).

Outcomes

All letters sent home to parents/carers were returned with permission granted for students to take part in the research – the study proceeded with 82 students participating. At no stage in the study were any concerns about the research raised by any parent/carer, and all students were happy to participate fully in the research.

Number and nature of online contributions

The total number of contributions to all discussion forums totalled more than 2700; 470 of these contributions were directly related to the science investigation (these were posted in areas of the forum intended for this purpose, rather than the social area), totalling some 13000 words. Five chatroom sessions were run (15 October, 16 October, 21 October, 6 November and 11 December), resulting in more than 4000 contributions totalling over 18000 words. Together, these forum and chatroom contributions comprised the corpus of text used as the source of critical incidents for critical incident recall. These figures are summarised in table 6.6.

	Forum	Chatroom
contributions	470	4,027
total words	13,089	18,152
average word length	27.9	4.5

Table 6.6 – contributions to the forum and chatroom

Comparison of these figures with those relating to the previous study (table 5.3 on page 146) shows that the total corpus of text available for identification of critical incidents in the final study was a little less than two thirds of that available in the second study (approximately 31000 words compared to 49000 words). Part of this reduction (around 6000 words) is attributable to a reduced number of chatroom contributions in the final study (despite more chatroom sessions and a greater number of students participating in the study), but the greater part of the reduction (of around 11000 words) is due to the fact that splitting the forum into areas related and unrelated to discussion of the science

investigation makes it possible to eliminate irrelevant contributions from the corpus.

Identification of critical incidents

The corpus was scrutinised for critical incidents using the general process described in the previous chapter and using the revised indicators set out in tables 5.8 and 5.11 (pages 156 and 164). After identification, critical incident recall was undertaken as soon as possible after each critical incident, using group interviews. This is in contrast with the second study, where all recall took place some considerable time after the critical incidents had occurred; this delay had led to some students articulating problems in remembering what had happened during critical incidents (page 167). The critical incidents identified for recall in the final study varied in length from very short interchanges in the discussion forum to lengthy interchanges in the chat room. Altogether, eleven critical incidents were identified. In order to maximise the opportunity to subject these incidents to recall by students, two of the group interviews were not limited to the discussion of single critical incidents during practical work; exchanges between students discussing reports at the end of the study were also treated in this way. This approach also had the advantage of providing insight into the perspectives of students not directly involved in a particular critical incident, thus contributing to the construction of a picture of the community's *intermental development zone* (Mercer, 2000:141). Table 6.7 identifies the various critical incidents and the triads / dimensions associated with them at the time of critical incident identification (ie *before* critical incident recall).

critical incident number	appendix	triad	dimensions identified for recall	critical incident recall
1	32	TCO	ce be	CIR1 (appendix 43) CIR3 (appendix 45)
2	33	TCO	be	CIR2 (appendix 44)
3	34	RCO	s	
4	35	TCO	uncertain	
5	36	TCO	be	
6	37	TCO RCO	be q	
7	38	TCO	be	CIR3 (appendix 45)
8	39	TCO	uncertain	
9	40	TCO	be	
10	41	TCO RCO	nr s	CIR4 (appendix 46) CIR5 (appendix 47)
11	42	RCO	q, p, s, t	CIR6 (appendix 48) CIR7 (appendix 49)

Table 6.7 – critical incidents / critical incident recall (CIR)

Critical incidents and critical incident recall

The following reports of critical incidents and the subsequent recall of these are structured around the critical incidents themselves. The transcript of each critical incident is located within its own appendix – the reference to this is given in the subtitle of each section. All references to parts of the critical incident refer to this appendix. The references to transcripts of critical incident recall take the form CIRn/mm_xxx where n is the number of the group interview in which critical incident recall occurred, mm is the appendix number where the transcript of this recall is located and xxx refers to the relevant line number(s) within this transcript. (A range of line numbers is indicated by xxx-yyy etc.) Extracts from online interactions are generally quoted verbatim in this section, except where slight editing (indicated by [square brackets]) is necessary in order to make sense of the extract. Brief conclusions from each session of critical incident recall are given after the description of each incident and its associated recall session – these conclusions are summarised at the end of this chapter, and a series of common *tacit tools* and *tacit rules* are identified based on the

outcomes of critical incident recall. The results are discussed in the theoretical context of other work in the next chapter.

Critical incident recall – critical incident 1 (appendix 32)

Critical incident 1 consists of a set of interactions in the chatroom taking place on 15 October. These involve three students from Pynebrook and one student from Castleford, with contributions from the researcher as moderator. This critical incident occurred during the first chat session, held in the first week in which Castleford students were involved, when Pynebrook students had already begun their practical work. It was identified as a critical incident since it involved the discussion and classification of preliminary outcomes of practical work, and the interactions contained statements consistent with the indicators relating to *blissful empiricism (be)* and *credulous experimentalism (ce)* in table 5.8 (page 156).

The critical incident began with a discussion of preliminary results obtained by students in choct15_150 to choct15_165, where Naomi and Alana report that the eggs lose mass. Alana notes that her results "arent very good" (choct15_154), but does not elaborate on this even when prompted to do so by the researcher (choct_156). Carl appears unsurprised that Alana rates her results in this way ("oh i guesed dat" - choct15_155). Discussion about the chatroom and practical techniques follows, during which Naomi notes (choct15_187) that the mass of egg white used by different people varies widely. Prompted about whether this matters, she says (choct15_190) "i dunno i guess dey will hav 2 test it and find out", and Carl replies (choct15_191) "I've got another 16 experements 2 do after dat were goin to work out the best experiment".

The discussions about preliminary results appear to indicate that students here are being quite critical of the outcomes of their practical work, although the basis for Alana classing her results as "not very

good" is unclear from the discussion. Since Pynebrook students were ahead of Castleford students at this point it is possible that Carl's lack of surprise about this is due to his greater experience in carrying out this practical work. This brief interchange appears consistent with the application of a tacit tool (triad TCO) with the dimension of *blissful empiricism (be)* since it relates to *making and interpreting individual practical measurements and observations*. Since the students appear to be making judgements about their measurements and observations it is possible that this part of the critical incident could indicate a non-naïve view of scientific knowledge on the part of students.

In contrast, in their comments about the practical work they and others are planning Naomi and Carl appear to view experiment as a means of obtaining information about competing hypotheses in an unproblematic way, consistent with the use of a tacit tool with the dimension of *credulous experimentalism (ce) – statements concerning the way in which data-gathering is planned to support hypothesis-testing*. This is suggestive of a naïve view of scientific knowledge.

The first recall relating to this critical incident was carried out one week after the critical incident (22 October) in a group interview with Carl, Paula and Naomi at Pynebrook School. This recall focused on:
a) the number of experiments planned by Carl; and
b) what students might mean when they describe results as "good".
In addition, clarification of Carl's comment in choct15_155 was also sought.

Alana from Castleford School was subsequently also interviewed about this incident, on 4 November. This interview took place with four other students, and focused on what students might mean when they describe results as "good".

a) Carl's experiments

Carl and Paula discuss their experiments in CIR1/43_016-026, and they return to this topic later, at the invitation of the researcher in CIR1/43_109 onwards. The number of experiments described by Carl in the interview has increased from the 16 mentioned in the chatroom to a total of 72 (CIR1/43_016), related to the number of variables that his group perceive it necessary to test. Pamela and Naomi (who are working together) have much more modest plans (CIR1/43_023-4). Carl appears to see the quality of the work, measured by the degree of certainty that results, as directly related to the number of tests (experiments) that can be carried out. This is confirmed by his final comment: "the best ... situation with the washing powders might be the one we haven't done, so we don't really know" (CIR1/43_118-9). This echoes Naomi's chatroom comment about "testing it to find out" noted earlier.

b) "Good" results

A discussion with Pynebrook students of what might be meant by "good" results (CIR1/43_055-071) followed the disclosure by the students (CIR1/43_046-054) that some results indicated that the eggs gained mass rather than lost mass. The students were clearly unhappy about results like this ("We're going to do that test again to check it, because ... it might be wrong" – CIR1/43_052), but were reluctant to discard such results since "they're still their results from an experiment" (CIR1/43_062). This discussion shows some confusion about how the quality of results might be assessed; although students are concerned to get "good" results, they are unclear about what constitutes a "good" set of results, and cannot articulate clearly what criteria might be used in this or any other investigation (CIR1/43_067-71). There is some conviction (CIR1/43_057) that the more mass lost the better.

In the context of judgements about results, the interview shows that Carl's comment in choct15_155, where he appears to be unsurprised

about Alana's results is in fact "replying to something else" (CIR1/43_034). This interaction is therefore excluded from any further consideration.

One further section of the interview is notable (CIR1/43_087-108), emerging unprompted from discussion of the practical work immediately before. In this section, the students indicate that they consider that an essential part of the investigation involves *simulating* the behaviour of a washing machine, through the use of different temperatures and through stirring/mixing. For this to be the case, the students make conditions in the test tube containing the washing powder/egg white mixture as similar to those inside a washing machine as possible – as Paula puts it "Mixing it up so it's ... like turning around like in a washing machine." (CIR1/43_106 & CIR1/43_108).

Prompted to describe what they might mean by results that were "not very good" (CIR3/45_008), Alana and other students at Castleford showed similar concern to Pynebrook students in terms of the changes in mass of the egg white recorded:

Jamie You've got things messed up ... got the weights wrong ... I did that – it went up.
...
Jamie It went up, it went up – I don't think we washed them properly.
Elena Yeah, we did that.
...
Alison Yeah, so did ours.
Elena Yeah, we didn't wash them.

(CIR3/45_021-7)

These students seem quite clear that the quality of results is embodied within the result itself, but – like the Pynebrook students – they do not articulate any criteria for deciding whether a result is "good" or not. However, they are quite clear that the egg white should reduce in mass, and that whether this outcome is obtained depends upon the technique used in the practical work. The number of tests carried out is also a crucial factor in deciding how to interpret results: "I don't think we'd

done very many tests ... so we couldn't really say what had happened" (CIR3/45_009-010).

Conclusions from critical incident recall 1

Students see exhaustive tests as being necessary to identify which hypothesis is correct from a wide range of hypotheses. This is consistent with a naïve position in respect of *credulous experimentalism (ce)*, where experiments are seen as being a way of deciding absolutely and conclusively between competing hypotheses.

Students describe the outcomes of practical tests as "good" or "bad" but are unable to articulate clearly the criteria that may be used to arrive at these descriptions, and make no reference to any kind of guiding theory. Instead, "good" or "bad" results are judged on the basis of cues from other sources, including the results obtained by other students and comments by teachers. This is consistent with a naïve position in respect of *blissful empiricism* (triad TCO) in which scientific knowledge emerges in a direct and unproblematic way from observation uninformed by theory.

Rather than considering tests on washing powder from the standpoint of *modelling* the conditions inside a washing machine, students make reference to "simulating" the behaviour of a washing machine (CIR1/43_099) so that the conditions are "like in a washing machine" (CIR1/43_108). Conceptualising the testing in this way is consistent with a naïve position in respect of *naïve realism (nr)* where scientific knowledge is a reflection of things as they actually are.

Critical incident recall – critical incident 2 (appendix 33)

The interview in which this recall occurred involved six students from Pynebrooke school, and was used to explore a total of five critical incidents (numbered 2 to 6 respectively) each of which involved one or more of these students. These incidents all took place in the period

between 16 and 22 October; one set of interactions took place in the chatroom, while the other four sets of interactions took place in the forum.

Critical incident 2 consists of a series of interactions in the chatroom between Leila, Andy and Connor from Pynebrook School concerning their results from the initial part of their investigations. The students seem clear that the investigation should lead to observations in which the egg white loses mass; Leila articulates a simple theory for this: "egg gets smaller coz of protiease that react wid proteins" (choct21_334); by implication therefore, "better" washing powders appear to cause a greater decrease in mass (choct21_431 to choct21_437). Throughout these interactions (from choct21_328 to choct21_441) students appear to be making judgements about the results that they have obtained – eg Andy's response "not[h]ing unneggspected" (choct21_420) to the teacher's enquiry "get some good results?" (choct21_411) which echoes his earlier response (choct21_331) to a similar query from the researcher.

Coming nearly one week later than the interactions in the first critical incident, students in this incident appear to be clear in their expectations of the practical work and its outcomes. As in critical incident 1, a tacit tool (triad TCO) within the dimension of *blissful empiricism* (be), relating to *making and interpreting individual practical measurements and observations* appears to be relevant to these interactions, including those in which Connor, Andy and Leila discuss the outcomes of their practical work in terms of the "best" washing powder.

Critical incident recall was conducted on 24 October (three days after the incident). In order to provide elucidation of students' ideas about collecting and interpreting data, the interview focused on:

a) the way in which the students set about collecting data relating to their investigation;
b) the way in which they made judgements about the data they collected; and
c) the extent to which they felt that such judgements enabled them to be certain (or not) about the interpretation of the results (ie how they might argue about which washing powder was "best").

a) Planning data collection

The early part of the interview (CIR2/44_001-062) shows a range of approaches outlined by students as they attempt to describe how they went about the task of initial data collection. Despite the carefully-structured nature of the preliminary work (involving the use of online resources with information about enzymes and washing powder, described earlier on page 178) the students make no reference to information obtained from this work as an element in their planning for their practical work. Leila maintains that "seeing all the ingredients" and "seeing how you could use them" (CIR2/44_006-7) provided the stimulus for planning, given that "we all knew what we were trying to find out ... what it was that made the egg whites get smaller" (CIR2/44_022 and CIR2/44_024). Andy describes a stimulus based on "thinking about all the variables" (CIR2/44_012), and is similarly clear that known outcomes are being sought when he says "we knew what we were aiming for" (CIR2/44_023). Both Leila and Andy link the investigation to work they have done before: "we've done some stuff before ... so we kind of knew what we could use" (CIR2/44_015-16); "we had an idea 'cos of this work we've done before" (CIR2/44_050-1). However, other students argue that initial work is much more haphazard: "Guesswork, I'd have said ..." (David, CIR2/44_003); "Trying things out" (Mary, CIR2/44_021). Later in the interview, even Andy appears willing to admit that the apparently organised approach he describes earlier may be subject to serendipity: "we just stumbled

along blindly until we came across something that worked" (CIR2/44_046-7).

b) Making judgements about data collected

As in the first critical incident, students make judgements about the data collected, noting that none of the results are "unexpected" (choct21_331, choct21_420) and that the work has gone "really wel" (choct21_429). When asked to describe what they mean by a "good result", students find it difficult to articulate any criteria that they may use in classifying their results, other than whether these results are "expected" or not: "we just got the results we expected to get ... 'cos everyone's done it before and knows what it should come out like" (Andy, CIR2/44_144-5). When results do not conform to these expectations, they are quickly discarded: "our experiment, we've done two now and they just don't work" (Lisa, CIR2/44_146).

c) Judgements and certainty

Once sets of results are available for discussion, and where these results are felt by students to be "expected" and therefore "good", debate then begins about which washing powder is "best" (eg choct21_431 to choct21_438). Different groups of students have different opinions about this:

Lisa	Well, we only did our experiment after other people had sort of done theirs and then everyone else sort of figured out that ASDA Smartprice one [washing powder] was the best one, decreased ...
Others	No it wasn't!
Mary	Ours has gone completely different!
David	Just normal ASDA!

(CIR2/44_031-6)

Students find it difficult to cope with this kind of disagreement, since the normal protocol of school science practical work is bound up with its use as a *warrant for belief* (Driver *et al*, 1996:64) and there is therefore the expectation that all groups should obtain similar results. When asked (CIR2/44_204-5) to suggest explanations for these different results, students focus on differences in variables such as the time the

egg is left in the washing powder solution, temperature and quantity of washing powder used. Two students agree that similar conditions should lead to similar results:

Andy But, if we were to use exactly the same everything our results would be pretty much exactly the same.
David Probably be quite similar, yeah.

(CIR2/44_211-3)

Despite this, students see problems in making a firm knowledge claim based on test results:

Researcher If we tested all the washing powders using this test could you say "this is the best washing powder"?
Andy You could say that all signs point towards it but you could never be certain or sure about it because anything could have been changed.
Leila 'Cos they're always bringing out new stuff, aren't they.

(CIR2/44_238-43)

This leads to the suggestion that, rather than using a test which models the behaviour of a washing machine, the use of a real washing machine to test the powders would be preferable: "... the easiest way probably ... would be to get some egg white and ... put some washing powder on some actual clothes and see if you notice a difference once it's actually been in a washing machine" (David, CIR2/44_244-7). (David had previously introduced this idea earlier in the interview – CIR2/44_066-073.)

Conclusions from critical incident recall 2

Students draw on prior knowledge, including that gained in researching the background to an investigation, in a non-systematic way. This approach is consistent with a naïve position in respect of *blissful empiricism* (triad TCO), reflecting the idea that the development of scientific knowledge proceeds principally through inductive reasoning.

Students make judgements about the data that they collect, but are unable to articulate clearly the criteria they use to do this. As with critical incident 1, this is consistent with a naïve position in respect of *blissful empiricism* (triad TCO).

Students regard it as difficult to express certainty regarding conclusions drawn from practical work due to the variability in outcomes from apparently identical situations. They recognise that this may be due to small differences in the control of variables, but do not appear to believe that it may be possible to correct for these. In order to obtain certain knowledge, students resort to references relating to "real" rather than "model" situations – this is consistent with a naïve position in respect of *naïve realism* (triad TCO), and was also found in critical incident 1.

Critical incident recall – critical incident 3 (appendix 34)

This recall was conducted as part of the group interview conducted on 24 October.

This incident has as its basis a posting to the discussion forum on 21 October by David from Pynebrook School. Having uploaded a spreadsheet file to the file sharing area David then seeks to bring this to the attention of other students. He does this by choosing an eye-catching subject for his message: "sex sex sex" (folg55_001, appendix 34), although he is quick to point out what he has done in the content of the message: "NO PORN HERE!!! now ive got ure attention!!!! IVE DONE THE EXPERIMENT AND MY RESULTS ARE IN THE FILE UPLOAD AREA TYPE THE LINK BELOW." (folg55_001). The incident was identified on the basis of the cues provided by David to the other students relating to his knowledge claim. Rather than seeking to draw attention to his claim by reference to its qualities, he chooses instead to make reference to "qualities" with no direct bearing on science practical work, an action consistent with the *social* dimension of triad RCO.

Discussing the upload of these results in the interview (CIR2/44_063-090), a majority of the students indicate that they are aware of this posting, although only two actually respond to it; Leila confirms the eye-catching nature of the subject line when she says "it just caught my

eye when I was looking down the list!" (CIR2/44_086). Having got the idea for this strategy from a TV cartoon series, David is aware that he has pushed the boundaries of what is acceptable in this forum just about as far as possible: "I was tempted to put something like "******* porn" or something 'cos then some of the lads would have clicked it but I thought I might get the chop for that one!" (CIR2/44_087-8).

Conclusions from critical incident recall 3

In presenting his knowledge claim to the community, David seeks to draw attention to it in a way that is unconventional. David is aware that there are explicit rules that govern behaviour in the community, and uses this knowledge to behave in a way that is on the borderline of acceptability. In doing so, David applies a tacit rule relating to the *social* dimension (triad RCO), using cues drawn from outside the realm of science to direct attention to his claims for knowledge.

Critical incident recall – critical incident 4 (appendix 35)

Critical incident 4 concerns two comments made by one student as part of two series of postings in the forum on the evening of 22 October.

In two postings, five minutes apart (folg68_001 at 20:00 and folg33_005 at 20:05), Mary reports the experience of having "a ping moment", saying that "I kinda get wat I'm supposed 2 b doing ..." (folg68_001). This post was the only post up to this point in which a student had reported any experience related to their own developing understanding. Statements in which students reflect upon their own developing understanding have the potential to provide insight into the tacit tools (triad TCO) in use within the community. Although neither of Mary's postings appear to reveal information of this sort, in view of the unique nature of these postings it was decided to identify them as critical incidents and to invite reflection on them in critical incident recall in order to see if any such information emerged.

The interview in which Mary was asked to recall this critical incident took place on 24 October. At the start of the recall students are asked to define a "ping moment"; in doing so, they confirm that this is a term used by their teacher:

Leila	[A "ping moment" is] when you've just worked something out and a light bulb comes on in your head or something.
Mary	If you don't understand it then you're, like, PING!
Connor	Like a light bulb over your head!
researcher	And what's it like?
Mary	Well, you don't really get a light bulb in your head! ... You kind of like suddenly work out what it is and ...
Andy	Yeah, it suddenly comes to you.
Leila	Oh yeah, I get you, yeah!
Mary	Or come up with, like, the language to understand it or come up with an idea.

(CIR2/44_097-106)

The four students here (who include Mary, the author of the original post) are all agreed on the sudden nature of the kinds of insight that they describe, involving little in the way of conscious effort to understand (Mary, CIR2/44_108-9; Leila, CIR2/44_116-8). This description is strikingly similar to that given in Poincaré's personal account of solving a particularly difficult mathematical problem (Penrose, 1999:419-20).

At the end of the recall, in response to a question to David concerning whether he has experienced a "ping moment", Leila breaks in, saying "No, he knows everything! He's never not known something!" (CIR2/44_122). The implication of this interjection appears to be that Leila views David as someone whose knowledge claims are imbued with an air of infallibility, based on her perception of David's *personal qualities* (triad RCO).

Conclusions from critical incident 4

Mary's statement relating to the rôle of language in developing understanding appears to reflect insight into the way in which new uses for words are central in developing understanding (Sutton, 1992). Such insight implies a degree of non-naïvety in respect of *naïve realism* (triad TCO), since language is regarded as a way of seeing rather than as a reflection of the world based on *undisciplined* modes of thinking (Sheeran & Barnes, 1991:54).

Leila's interjection concerning her perception of the status of David's knowledge-building claims suggests that *personal qualities* (triad RCO) may play a rôle within the community in deciding whether to accept or reject statements concerning new knowledge.

Critical incident recall – critical incident 5 (appendix 36)

On the evening of 22 October one student (Leila) from Pynebrook School posted a description of some practical work that she had carried out, using solutions of washing powder at different temperatures – other students responded to this, encouraging her to develop her ideas:

clive_shp	Very nice leila
darren_bsp	Wat else happen anything?
nadine_lnp	Hi Leila wot happened 2 ur egg ie. the mass
sara_grp	wat else happend? wat about the mass????

(folg57_003 to 006)

Although Leila states clearly in her original posting that the mass of the egg decreased, she reports only one numerical result and nothing in the way of qualitative observations. The postings by Darren, Nadine and Sara encourage her to expand on her initial report, although she does not do this.

Leila's original posting is of interest because in it she asserts that "the higher the temp the more the mass of the egg decreases or the ... bio digests the egg quicker" (folg57_001). This suggests that Leila is

interpreting her results in the light of *preferred scientific meaning* (Millar, 1989a), and may indicate some degree of non-naïvety in respect of the dimension of *blissful empiricism* (triad TCO) – Leila brings to bear some kind of scientific theory when she reports her observations, making a distinction between the language of observation and the language of the phenomenon under observation.

Leila recalled this critical incident during a group interview two days later (CIR2/44_260-322). Due to limits on the availability of students none of the other students involved in the critical incident took part in the recall – however, since the principal purpose of the recall was to explore ideas concerning the use of preferred scientific meanings in interpreting practical outcomes based on Leila's contribution to the forum, this was not judged to be critical.

Leila's recall begins as she reads out her posting, adding the comment at the end: "... somewhere I put however, if the temperature is too high then it will denature the enzyme" (CIR2/44_272) – in doing so she creates a link between her practical work and scientific theories that underpin the behaviour of enzymes. She also refers to the "effectiveness" of the experiment (CIR2/44_267), indicating that she may not view data gathering to support hypothesis testing as leading to conclusive results. In order to explore these ideas further, Leila is asked to describe what she means by "denature the enzyme" (CIR2/44_274). This question stimulates two other students (Andy and Mary) to join Leila in the discussion; the question is addressed obliquely, through a description of their ideas about enzyme action, focusing on the shapes of molecules, a topic that the students had covered in the previous year's science lessons (CIR2/44_291-2):

Andy	It means they won't fit in, it's like a key, they won't fit properly into there so they can break up the, um ...
Leila	Protein.
Mary	Like an odd-shaped thing that'll go like that and then they can't all fit in a little triangle.

...

Andy If they weren't little triangles, they were little circles it wouldn't work, so ...

(lines 275 to 281)

This then leads into a discussion of how scientific models and reality are related (CIR2/44_294-321), through Connor's description of a computer animation about enzymes that he produced (CIR2/44_284-290). The descriptions that emerge in these discussions can be classified into three categories, according to the function that the students see models fulfilling (table 6.8) – *representation*, *visualisation* and *learning*. (These three categories are not dissimilar to those described by Justi and Gilbert (Justi & Gilbert, 2003), who interviewed science teachers to discover their views of the nature of scientific models.) Whilst *representation* refers to the relationship between theory and reality, both *visualisation* and *learning* refer to the process of developing understanding. The existence of these two types of functions reflect Gilbert's view that "models are one of the main products of science ... [and] models are a major learning and teaching tool in science education" (Gilbert, 1993:5).

Representation	Visualisation	Learning
It represents.	... a visual image that you can see with your eyes ...	To help you learn what it looks like.
Just represents it.	... electrons and protons ... don't actually look like a nucleus in the middle and loads of rings around it	Help you learn how they work.
... like a caricature, it doesn't actually look like the person, but it represents them.	It's just to show the path of the electron.	It helps you understand, like a visual image.
	a solid isn't, like, ... made up of circles or spheres.	It kind of helps you learn.

Table 6.8 – three categories of students' statements about models

Conclusions from critical incident 5

The recall of this critical incident does not allow further judgement to be made about Leila's use of theory in making and reporting her observations, since students directed the discussion towards the models used, prompted by the word "denature" (CIR2/44_274).

The students' views of models link clearly with their use as means of learning – their descriptions indicate that their teachers have stressed to them that a model is not a *reproduction of something* but rather that it is a *representation of something* (Justi and Gilbert, 2003:1380-1). In themselves, these views imply a degree of understanding of the use of models in science that may be regarded as non-naïve, since they recognise the representative nature of models (*naïve realism*, triad TCO). The emphasis on the rôle of models in learning is consistent with students having developed their ideas about models in the context of learning (Gilbert, 1993).

Critical incident recall – critical incident 6 (appendix 37)

Very early in the investigation (16 October) one Pynebrook student posted a message to the forum asking for practical results:

julie_fep smile be happy, hoz every1 does any1 know wot happened at the end of the experiment yesterday.

(folg49_001)

In response to Julie's message, Laura (another Pynebrook student) posted the reply:

laura_mrp dont think [our] experiment went wrong i just think the temp of water wasnt right. we should get better as we get more used to all this

(folg49_002)

These two messages comprise the entirety of critical incident 6. This incident was identified on the basis of Laura's final sentence ("we should get better as we get more used to all this") which suggests that students may regard the outcomes of practical work as linked to practice. This has two implications for tacit tools and rules:

1. if an experimenter can produce "better" results through increased familiarity with an experiment, this suggests that observation alone is insufficient to produce scientific knowledge (relates to *blissful empiricism*, triad TCO);
2. if "better" results are produced by individuals with greater experience, this suggests that *personal qualities* (triad RCO) influence the extent to which a knowledge claim may be believed.

Both of these are consistent with a non-naïve epistemology, since they stress the contingent nature of knowledge.

The critical incident was followed up in a group interview the following week, in which Laura was involved. Julie was not able to be present in this interview, but this was not judged as critical since the recall was based primarily on Laura's posting. In addition, although no Castleford students had been involved in the incident itself, the implications of the incident were subsequently explored with a group of Castleford students on 4 November.

Prompted to expand on her statement, Laura says "Well, someone writ [sic] ... that they thought their experiment went horrible 'cos all the egg got heavier or something, and it did with ours as well ... it's where it's all new ... and no-one really knows ... we're still learning how to use it so we'll get used to it and soon we'll know what we're doing ..." (CIR2/44_154 to 158).

Laura's concern about results showing that "the egg got heavier" is indicative of the way in which the students are quite clear about the nature of the outcomes they expect from the practical work. The basis of this expectation is unclear from this critical incident or its recall, but the previous incident and its recall support the idea that students believe the loss of mass to be due to the digestion of protein in the egg white by enzymes in the washing powder; this is certainly consistent with an "accepted" scientific viewpoint of what is likely to be happening in the investigation. Laura is clearly keen to ensure that her results reflect this underlying theory, and views the ability to achieve this as something that increases with experience.

Recalling and reflecting on this in the interview, Leila sees this developing ability as concerned with language ("You get used to, like, the terms you use" – CIR2/44_163), whilst Andy thinks simply in terms

of expected outcomes ("And what should happen and stuff" – CIR2/44_164). When asked to consider whether chemistry undergraduates – as much more experienced students of science – might obtain different results from the practical work Laura is quick to highlight the importance of experience: "They've had more experience though, 'cos they're older than us" (CIR2/44_168). At first (CIR2/44_167) Leila suggests that the outcomes obtained by the undergraduates might be "more accurate", but shortly after this she appears to have changed her mind, suggesting that the undergraduates' outcomes might be "less reliable" (CIR2/44_177), because "we've had everyone to help us ... no-one's on the wrong track ... sir keeps telling us ... the right answers, sort of ..." (CIR2/44_179-182).

Leila's position may also have been influenced by David's contribution to this discussion (CIR2/44_170-5), which contains the idea that "they [the undergraduates] might get quite different results" since they think "[they're] brilliant and [they] know what [they're] doing" so "they might just jump in and then stumble at the first hurdle ...". This is contrary to Laura's argument that practical ability improves with practice – instead, David's position is that increasing familiarity with science practical work may lead to a tendency to be over-confident and to over-estimate one's abilities.

The idea that technique is an important aspect in determining experimental outcomes is also evident in the responses of a group of Castleford students during recall of critical incident 1, when thinking about what someone might mean when they say "my results aren't very good" (CIR3/45_012-3): "You didn't do it right" (CIR3/45_016); "You've got things messed up ... got the weights wrong ... I did that – it went up" (CIR3/45_021); "Yeah, we didn't wash them" (CIR3/45_027). Like the Pynebrook students, these students have mixed ideas about the effect of experience on the outcomes of practical work – initially,

Hayley, Elena and Alana argue that undergraduate chemistry students conducting the investigation may obtain results that are "a lot more detailed" since "they would look into it deeper" and they have "better equipment than us [school students] to do it", and also that they would "probably know what to look for, 'cos they do these sort of things more often than us" (CIR3/45_120-6). However, further discussion about this, prompted by a question about comparing school students' results with those obtained by university students (CIR3/45_133-4) leads Elena to conclude that "... because it's the same experiment, it shouldn't matter what equipment they've got or if they're older ... if they do it exactly the same conditions", with which Hayley, Alison and Alana all agree (CIR3/45_149-154).

Conclusions from critical incident 6

The recall of this critical incident confirms that students may view the outcomes of practical work as fixed, with the intention of producing a particular outcome. In this respect, experience of practical work is seen as desirable since it leads to a "better" technique which may lead in turn to the desired result. This confirms the link noted earlier between this critical incident and a non-naïve perspective of experimental work in respect of *blissful empiricism* (triad TCO). However, it may be that the closed conception of outcome of practical work is an indication of a naïve perception of this dimension, in which practical work leading to answers already established and validated as part of scientists' science. The responses to practical work noted by Millar et al (1994) are relevant here – this link is discussed in the next chapter.

Students appear to hold mixed ideas about the effect of increasing experience of practical work on the ability of an experimenter to obtain results. There is no question that all are agreed that *personal qualities* (triad RCO) – of which experience is one – have a bearing on this. However, David's insistence that practical experience may lead to results in which one may have little faith (and Leila's apparent support

of this) is surprising. It is possible that this position may be explained in terms of a *Baconian narrative* (Curtis, 1994), already noted on page 34. This is explored in the next chapter.

Critical incident recall – critical incident 7 (appendix 38)

This critical incident occurred in the chatroom on 16 October, and involved two students, Hayley from Castleford and Annie from Pynebrook. (This was at a very early stage of the investigation for both students, especially Hayley.) These students entered into a short private conversation, of which other participants in the chatroom were unaware; this was recorded in the chatroom logfiles. The interaction was identified as a critical incident for the same reason as critical incident 1 – it concerned the discussion and classification of preliminary outcomes of practical work, and as such might provide insight into the tacit tools (triad TCO) used in handling knowledge, especially the dimension of *blissful empiricism*.

In their private conversation Hayley and Annie share information about their initial practical work. Annie begins by noting that her practical "went wrong" because "we either didnt leave it for long enough or didnt do somthing else right" (choct16_183 & choct16_206). Hayley confirms that she has similar results: "yeh ... it s[h]rank ... lol our first one did [go wrong] cos it grew" (choct16_179, choct16_184 & choct16_189).

Recalling this critical incident, Hayley and the other Castleford students confirm that results showing that the egg white had increased in mass were quite common among students (CIR3/45_033-9), and are quick to suggest that this was because they had yet to develop appropriate practical techniques: "... we didn't dry it properly, did we and it had water on it still" (Alison, CIR3/45_0040); "... obviously the water makes mass more ... we didn't wash it properly, we just stuck it back on the scales" (Hayley, CIR3/45_042-3). Describing the various sources that lead them to believe that the enzymes in washing powder react with the

protein in the egg white, causing it to decrease in mass (CIR3/45_044-053), the students then argue that results in which the egg increases in mass do not indicate that this idea is wrong, but rather that the measurement should be repeated, rejecting other results since "we actually made sure that we dried it properly and things like that" (CIR3/45_074). Only one student opposes this view, saying that both categories of results (involving both increases and decreases in mass) should be taken into consideration (CIR3/45_067) so that "you can compare them" (CIR3/45_072).

Conclusions from critical incident 7

With its focus on the conduct of practical work, taken at face value the recall of this critical incident appears to indicate that students believe that increasing experience of practical work leads to more reliable outcomes, a position that would be consistent with a non-naïve position with respect to *blissful empiricism* (triad TCO). However, it is also possible that students' focus on a particular outcome (in this case the decrease in mass of the egg white) is what drives the development of practical skills through experience – this would be naïve with respect to *blissful empiricism*, since it is the absolute knowledge of the outcome that leads to confidence in the "correctness" (or otherwise) of method.

Critical incident recall – critical incident 8 (appendix 39)

In this critical incident, a student (Jamie) from Castleford School posts some results on the forum. In this post he describes how his results indicate that both biological and non-biological washing powders cause the same percentage decrease in mass when used to digest egg white. He is puzzled by these results: "Why does this happen coz I don't think it's meant to ..." (folg87_001). Subsequently, another student (Alison) from Castleford posts a response to his posting, saying "Cool gd results!" (folg87_002). This incident was identified as potentially providing insight into the tacit tools (triad TCO) used to handle knowledge, although the exact nature of these tools is unclear from

Jamie's posting. Alison's response also provides an additional aspect for exploration through recall.

When prompted about her posting, Alison is reluctant to is reluctant to clarify it, but other students indicate that this post may have been purely for social reasons:

researcher	There's another one of Alison's posts here, look, Jamie's posted some results ...
Elena	I know why she wrote that one!
...	
Hayley	[Aside to Alison] I know why you posted that one!
Alison	[Aside to Hayley] Why?!
Hayley	[Aside to Alison] 'Cos you felt sorry for him!
...	
researcher	OK – so why is it a good result, Alison?
Hayley	[Aside, to Alison] It wasn't, you just wrote it! [laughs]
Alison	I don't know, no.

(CIR3/45_083-097)

Alison has thus acted to support Jamie through her posting. This is not significant in the context of the use of tacit tools used in knowledge-building, but does represent the way in which these students have taken discussion seriously, responding to one another in *helpful, supportive ways* (Bereiter & Scardamalia, 1993:210-11).

When Jamie discusses his posting he seems unclear about the way in which he might deal with conflicting results, proposing to use both of them in his report (CIR3/45_098-101). Further discussion among students based on the possible criteria for deciding whether to make use of another student's results produces two criteria – *repeat observations* and *results consistent with expectations*; in this case, a decrease in the mass of the egg white (CIR3/45_110-14). There is also the suggestion (CIR3/45_115-6) that the use of repeat results from a secondary source may lead to increased certainty regarding the outcome of the practical work: "... if they took two people's results ...

they could work out that it was the same. Work out if it was right." This is consistent with the link between the quality of practical work and the number of tests conducted described by Carl when recalling critical incident 1 (pages 186-7).

Conclusions from critical incident 8

The emphasis on repeat measurements and duplicating tests brought out by the students when discussing the criteria for deciding on the quality of results produced by practical work is consistent with a naïve position in respect of *credulous experimentalism* (triad TCO), since it suggest that experiments can be used to decide absolutely and conclusively between competing hypotheses.

Critical incident recall – critical incident 9 (appendix 40)

This critical incident consists of a single posting to the forum, made by a Castleford student at an early stage of the practical work. In the test described by the student, an egg in its shell was placed in ice. The ice was then melted and the temperature of the water raised to 30°, when non-biological washing powder was added. After short time the egg was removed from the solution, dried and measured. The final sentence in the posting reads: "Unfourtunately the egg did not shrink but it was good to do this experiment for it out ruled some possible explanations" (fol70_001). The posting was identified as a critical incident since the test was very different to other work being conducted by students, and it was thought likely that recall of the incident could provide data relating to *blissful empiricism* (triad TCO) – there was no theory reported by the student that would help to explain why this particular test was conducted.

Recall of this incident showed that the test had been conducted by three students working together – Elena (the author of the forum posting), Alison and Hayley (CIR3/45_157). In response to a request to explain

their reasons for carrying out this test, the students appear to be unable to provide a clear rationale for what they had done:

Hayley We were just, like, mucking ar..., like, with the ice, the egg in the ice, and then we stuck it in the water bath to make it melt.

...

Alison 'Cos we were trying to make the ice melt 'cos we weren't supposed to have it in there so we just put it in the water bath but we didn't measure it before but we thought it had got smaller comparing it to the other eggs.

...

Alison And it hadn't!

Hayley And we just kind of, we didn't measure the washing powder or anything...

Alison No ...

Hayley ... we just kind of guessed.

Alison ... we put 10.5 or something in.

(CIR3/45_181-192)

However, the students' intentions become clearer when they describe why "it was good to do this experiment":

Hayley ... because it proved that it couldn't be done. 'Cos we had a fair idea that it wouldn't shrink because the egg shell hasn't got protein in, but we, it was better to do it and to prove that it wouldn't shrink.

Elena Yeah, it proved that it is actually the egg white that makes it disappear and not anything else.

(CIR3/45_197-201)

Conclusions from critical incident 9

The statements from Hayley and Elena show that the students appear to have lost sight of the original intention of the investigation, that is, to investigate the possibility of using the effect of washing powder on egg white as simple test of the efficacy of a washing powder. Instead, this test has a different kind of reasoning behind it, in which the egg white is seen as an agent that causes change ("... it is actually the egg white that makes it disappear ..."). For this reason, the tacit tools employed by the students are not characterised by *blissful empiricism* since the practical work *is* related to a guiding theory. However, the clear relationship drawn between the outcomes of this work and simple

"proof" is characteristic of a naïve position with respect to *credulous experimentalism*, where experimentation leads unproblematically to certainty.

Critical incident recall – critical incident 10 (appendix 41)

This critical incident consists of a series of interactions between students from both schools, conducted in the chatroom over a period of slightly less than 25 minutes on the evening of 6 November. At this point the students in both schools had largely completed their practical work and were engaged with writing the reports about it.

As part of the discussions about their results taking place in the forum, students had posted a number of contributions discussing the "right results" (eg folg39_008; folg56_004) or asking "am I right?" (eg folg52_001). To follow this up, part of the chatroom session focused on what students might mean when they say they have the "right results" or when they say they are "right" – the interchange therefore began with the researcher posing the question "... how do you know if a set of results is right or not?" (chnov06_769).

The discussion that follows this question is carried on principally by four students – Chrissie and David from Pynebrook, with Hayley and Richard from Castleford. Chrissie is of the opinion that "u cant get right or wrong result in science coz every xperiment is different!" (chnov06_777) and "ders nufing thats goin right or wrong in science coz everything different. its just ur doin the experiment differently" (chnov06_806); in doing this she appears to be making a reference to students' science, although it is possible that she refers to scientists' science as well. David disagrees with this position, basing his argument on scientists' science: "u cant say iron is more reactive than magnesium because it no it hasent ever been and never will b!" (chnov06_810). However, at the end of the interchange (some 20 minutes later) David appears to have changed his position: "like chrissie sed earlier there is

no rite or rong answer in this particular experiment" (chnov06_1033). The discussion between Hayley and Richard (the Castleford students) is focused on their different results (chnov06_888-93) and whether or not both students can be "right" or whether "one of them [is] right and the other wrong" (chnov06_958; chnov06_1022). Although Hayley and Richard both argue in support of their own results, they do not see their disagreement as problematic, Richard saying that this does "not necessarily" imply that one of them is right and the other is wrong (chnov06_961; chnov06_1027) and Hayley saying "were both right aren't we Richard" (chnov06_1032).

The extract from the chatroom session was identified as a critical incident since it was felt likely to provide some insight into the tacit tools (triad TCO) used by the students as they discussed their results and who was "right". In the context of the interactions concerning "rightness" this particularly concerned the dimension of *naïve realism*, relating to the context in which observation statements are made and interpreted. The critical incident also appeared to offer some insight into the tacit rules (triad RCO) applied by student when considering knowledge claims – in particular, the *social* dimension of these rules. The incident was recalled in two group interviews with the five students who were most active in the chatroom during the critical incident:

- Castleford School, 11 Nov 2003 – appendix 46
  Richard, Hayley and Alan
- Pynebrook School, 12 Nov 2003 – appendix 47
  David and Chrissie

Both recall sessions begin with students reflecting on what it might mean to be "right" when discussing the outcomes of science practical work. The Castleford students start out regarding the notion of "right" as meaning the extent to which the outcomes of practical work conform to expectations or prior predictions (CIR4/46_065-75), but further discussion quickly leads to the conclusion that it is possible for a student to obtain the "right" outcomes from practical work even where

their results do not confirm initial predictions ("... as long as [the student says] that they'd got their prediction wrong" (CIR4/46_086). If this speculation about the meaning of "right" is extended to include students' perceptions of possible teacher definitions, these include results which conform to teacher expectations (CIR4/46_277) and the quality of the conclusions drawn (CIR4/46_286-7; CIR4/46_295-9) – Richard sees conclusions emerging in a straightforward way from the results of practical work: "... you look at all the data and you just put 'your data means' ... so that would be your conclusion ... And then they could mark the conclusion right" (CIR4/46_289-93).

At the start of their recall session the Pynebrook students regard "right" results as being those which reflect any predictions made before conducting practical work (CIR5/47_019-21), and which are also consistent with scientists' science (CIR5/47_024): "If you've done your research right then your hypothesis should be along the lines of what other scientists have done before" (CIR5/47_029-30). Where competing knowledge claims are involved, "rightness" can best be judged by considering the extent to which a student's results fit their prediction, because this reflects the extent to which they have "thought ahead" and "planned it [the investigation]" (CIR5/47_132-7). This aspect of the investigation is highlighted by students when they discuss the way in which an investigation might be marked by a teacher, where "rightness" is indicated by a measure of student effort: "... done the experiment as accurately as you can" (Chrissie, CIR5/47_195); "... done it all as best you can ... so you've got the results as best you can" (CIR5/47_203-5). The implication of this appears to be the application of a tacit rule (triad RCO) within the *social* dimension, judgements about knowledge claims involving qualities with no direct bearing on science practical work.

Having begun by considering ideas about "right results", students are prompted to think about Chrissie's idea that there are no "right or wrong results in science", raised in the critical incident under discussion.

Expanding on her posting, Chrissie assigns this ambiguity to the fact that controlling the variables in a piece of science practical work is highly problematic: "... everything changes in each experiment you do, you can't always get the exact same amount of everything and the exact same amount of time and the variables might change slightly ..." (CIR5/47_036-9). This confirms that her reference in the chatroom is to students' science. The other students agree with this position to an extent:

Richard ... if you have, like an experiment, an investigation, then you can't really have a right or wrong because, if you've done the experiment ... well, you're trying to find out what's happening, you can't really say it's right or wrong 'cos you've done it, so it can't be wrong ...

(CIR4/46_317-20)

Hayley Yeah

(CIR4/46_321)

However, the students contrast students' science with scientists' science:

Alan ... there's a type where you can't have rights and wrongs which is with facts, like Richard said about magnets ...

(CIR4/46_314-5)

David ... in a way there is a right and wrong answer in science, but it depends what experiment you're doing. So ... if you're doing something like this [investigation], there isn't necessarily a wrong answer or a right answer, but if you're doing something like that [reference to practical work related to relative reactivity of iron and magnesium], that is the right answer because iron is at the bottom of the reactivity series and magnesium is at the top

(CIR5/47_054-9)

It appears from this that students hold the two worlds (of students' science and scientists' science) apart – while results can be contended in students' science, the outcomes of scientists' science remain fixed.

Conclusions from critical incident 10

The discussion about "right answers" reveals that students regard the status of knowledge in "students' science" and "scientists' science" in different ways. Students view inconsistent and competing knowledge

claims in students' science as permissible because of the difficulty that exists in obtaining results that can be replicated (by the original investigator or by another student). However, students view the outcomes of scientists' science as providing "facts" which are fixed and not open to debate. This suggests that students have a naïve conception of both students' science and scientists' science in which scientists' science provides, through experiment, direct access to knowledge about the material world. However, the same process in students' science may lead only to uncertainty, from which there is no way out. This view is consistent with the dimension of *naïve realism* within triad TCO; the divergence of students' ideas about students' science and scientists' science is noted by Driver et al (1996:46), and is discussed further in the next chapter.

This discussion also highlights a view among students that the "right" outcome from an investigation may depend upon or may reflect the "effort" put into it. This is evidence that, in making judgements about knowledge claims, students are making use of tacit rules (triad RCO) that have a *social* dimension.

Critical incident recall – critical incident 11 (appendix 42)

The final critical incident is drawn from the interactions taking place in the forum among two groups of students selected to discuss the reports of the investigation written by six of them. Initial examination of these interactions suggested that they were a rich source of insight into the tacit rules (triad RCO) used by the students as they undertook their critiques of each others work, advancing reasons to support or criticise knowledge claims. In view of this, it was decided to use nearly all of the student postings contributed during these discussions (only those which did not directly concern discussion of reports were excluded) as the basis of critical incident recall – these totalled the 20 messages shown in appendix 42. (Because of the nature of this critical incident, the presentation of data in this appendix differs slightly from that used in

other critical incidents. Reference to specific parts of this incident are made in the form CI11_nnn, where nnn = line number.)

Five of the six participating authors posted opening statements to the forum. Although the sixth author had previously agreed to participate in this way he did not post any opening statement to the forum, and did not contribute to the discussion of the reports; it is unclear why this student chose not to participate, since follow-up interviews did not afford the opportunity to explore this. Inspection of these opening statements shows that there are three types of tacit rules (triad RCO) which students appear to be applying as they advance a case for their own report – these relate to the dimensions *personal qualities (q)*, *presentation (p)* and *technical (t)*. In addition to these three tacit rules students also appear to argue for their report on the basis of a rule concerned with *explaining* and/or *understanding* in the context of personal cognition relating either to the author or of the reader. All five students make reference to *presentation* and to *explanation/understanding* in their opening statements. Rules relating to the *personal qualities* or *technical* dimensions are applied by two students. Table 6.9 summarises this, and provides examples.

Rule	Number of students	Example
p	all	i have ... recorded my results clearly (CI11_004-5) i displayed my results ... using both a table and a graph (CI11_013-4) my report explains ... what i could have done better (CI11_089-90) it is set out well and easy to read (CI11_094)
q	2	I tested thoroughly ... being very fair (CI11_021-2) i did the experiment as accurately as can be done (CI11_086-7)
t	2	the amount of scientific detail and explanation i have encluded (CI11_011) other scientists ... have shown the same as my results (CI11_087-9)
explanation/ understanding	all	otherwise [the reader] might not understand (CI11_024) the results are all correct with a good explanation (CI11_094)

Table 6.9 – tacit rules applied by students in their opening statements

In discussing other students' reports and making decisions about the quality of these, students apply the same rules as when arguing the merits of their own work, with the addition of one other rule relating to the *social* dimension, implied by personal comments relating to readers'

responses to particular reports. In this case all students apply rules relating to presentation, with varying proportions of students applying other rules, as table 6.10 shows.

Rule	Number of students	Example
p	all	elenas is written best (CI11_032) good contructive points about the way se would do the report again (CI11_055-6) her results were well presented (CI11_103-4) he used diagrams (CI11_117)
q	1	he was ... sure his way was a good way of going about it (CI11_063-4)
s	2	I enjoyed reading it ... (CI11_048-9) it was boring to read and too long winded (CI11_072-3)
t	1	she compares her results to other scientists (CI11_122)
explanation/ understanding	5	it explains the investigation thoroughly (CI11_035) she shows strong understanding of what to do (CI11_036) gave ... good insight into ideas (CI11_054-5)

Table 6.10 – tacit rules applied by students when discussing reports

Recall of this critical incident was conducted in two group interviews carried out immediately after the online discussions (appendices 48 and 49), the first at Castleford School on 17 December, the second at Pynebrook School on 18 December. Each group interview involved all students from that school who had participated in the online discussion sessions relating to the reports during the previous two weeks. Limited data are available from the first of these interviews due to technical problems with the recording equipment.

Various postings in the discussion forum include mention of "research", including one of the postings during the discussion of the reports (CI11_081-090). Asked about including "research" in their reports, students in both recall sessions argue that it is important to make links in a report which draw comparisons between students' science and scientists' science since scientists "would be more controlled over the experiment", "would have better equipment" and "they'd know more stuff about what is going to happen" (CIR6/48_024-8). Where such links can be drawn students see this as enhancing the status of the report of students' science "because then you can show that it's not that however old the people are that are doing it, the results may still be the same" (CIR6/48_018). However, for such enhancement to occur it is

critical that the author of a report which incorporates scientists' science can demonstrate that they understand it:

Alan It's alright if you read it and understand it but if you don't understand it at all and you're just putting it on there, you shouldn't really do it.

...

Sarah You should put it in your own words, and explain it your own way instead of copying someone else's way to do it.

Alison You have to make sure you understand what it actually says and not just write it because it's good or you think it's good.

(CIR6/48_034-41)

Billie You have to put it in your own words, so people can understand it as well as you.

(CIR7/48_078)

This link between students' science and scientists' science is consistent with the application by students of a tacit rule within the *technical* dimension of triad RCO, where knowledge claims are supported by reference to authoritative scientific knowledge. The comments by Alison and Billie during the recall of this incident confirm the analysis of the online discussions, which show that there is also a cognitive aspect to the technical dimension.

In addition to the personal understanding required when an author makes reference to scientists' science, students also regard the quality of *explanation* (which may enable the reader to gain increased *understanding*) as an important element of a report. Thus: " ... if it's going to be for someone else to read, you really want them to be able to understand it" (CIR7/49_092-3) and "...and how they've explained, like, after every set of results if they've, like, explained it whatever ..." (CIR7/49_241-2).

The online discussions of reports featured many postings relating to *presentation* of reports (eg CI11_004-5, CI11_013-4, CI11_089-90, CI11_117), some examples of which were included in tables 6.9 and 6.10. Recall confirms that presentation has a number of aspects, which include appearance (eg CI11_094 and CIR7/49_244-5), the use of

graphs and diagrams (eg CI11_113, CI11_130 and CIR7/49_105-111, CIR7/49_140-1) and the inclusion of a section which evaluates the work (eg CI11_047 and CIR7/49_019-020). All these aspects appear to be important to students as they make judgements about a report; in Roth's terms these are *inscriptions*, mental abstractions that "sum up that which it took to construct, the embodied experiment, the situated negotiations of meanings" (Roth, 1995:95). The power of these inscriptions lies in the way in which students marshal them in order to differentiate a scientific report from any other piece of school writing, raising its status as they do so:

Mary ... you have to make the point then you have to explain it. And you have to make sure your conclusion's at the end, and you're opening paragraph's got to be at the front ... it doesn't really matter about [the order] ... well it does in some subjects I suppose – in science it does otherwise you muck it all up and it won't look right, but in English you can just put the middle bit in any order, really.

(CIR7/49_267-72)

The presence of an evaluation as an inscription in a report also influences the status of the author, implying the *personal qualities* of detachment and impartiality; two students demonstrate this when they describe evaluation as including "constructive criticism" (CIR7/49_027) "rather than being biased" (CIR7/49_028). This reflects that way in which some report authors make reference to evaluation in their opening statements online in a clear attempt to enhance its status: "... at the end i have concluded the experiment and wrote what could be improved" (CI11_005-6); "... the rest of my report explains clearly how we did the experiment and what i could have done better" (CI11_089-90). Reference to such claims are also made by the report discussants: "[she] has evaluated her work well, saying what she thought was wrong with it ... and what she would do better" (CI11_047-8); "connor has said what he could do to improve [his investigation]" (CI11_148-9).

Conclusions from critical incident 11

Tacit rules within the *technical* dimension concern links made between students' science and scientists' science. Students often refer to such links as "research", reflecting the rôle played by background knowledge in understanding the context of an investigation. An important element used by students in judging the quality of research is the extent to which the user (ie the author of the report in which the research in included) is judged to have understood it.

Tacit rules within the *presentation* dimension apply to various elements (or *inscriptions*) within the report. Together these act to influence the status of the report, and may also confer enhanced *personal qualities* on the author in the case of evaluations.

The critical incident recall does not provide any further insight into tacit rules within the *social* dimension (occurring online in comments about the personal response of the reader in the case of two reports), and there is no evidence of tacit rules based on *private information*.

Students also see the quality of a report in terms of the *explanations* contained within it, related to the *understanding* that this may bring about in the reader.

Summary of outcomes from critical incident recall

Tables 6.11, 6.12 and 6.13 summarise the outcomes from the sessions of critical incident recall as reported in the previous section. These clearly show the range of tacit tools within triad TCO, with evidence for both naïve and non-naïve conceptualisations in the dimensions of *naïve realism* and *blissful empiricism*; all evidence relating to *credulous experimentalism* suggests a naïve position with respect to this dimension. Nine tacit tools (T1 to T9) drawn from the conclusions to critical incident recall are presented in table 6.12.

Tacit rules used by students in advancing and scrutinising knowledge claims relate to all dimensions except *private information*. Evidence for the use of tacit rules related to the *personal qualities* and *social* dimensions is derived from interactions during practical work prior to report writing as well as those occurring during the discussion of the reports of practical work. Tacit rules relating to the *presentation* and *technical* dimensions were manifested solely during the discussion of reports. Six tacit rules (R1 to R6) identified from the conclusions to critical incident recall are presented in table 6.13.

One unforeseen aspect of students' discussions of each other's reports relates to the *cognitive* features of reports; students appear particularly impressed where a report provides evidence of the *author's understanding* of scientists' science which is clearly linked to students' science, and also see a report's ability to increase the *reader's understanding* as evidence of high-quality work.

Of the eleven critical incidents selected for critical incident recall, four were based on interactions occurring in the chatroom. The presence of a significant number of synchronous interactions which give rise to critical incidents providing rich ground for recall is discussed in the next chapter, which places this and other findings in the theoretical context set out in the early chapters of this thesis.

CI number	triad TCO			triad RCO					source of CI
	nr	be	ce	q	i	p	s	t	
1	naïve	naive	naïve						chat
2	naïve	naive							chat
3							✓		forum
4	non-naïve			✓					forum
5	non-naïve								forum
6		naïve / non-naïve		✓					forum
7		naïve / non-naïve							chat
8			naïve						forum
9			naïve						forum
10	naive						✓		chat
11				✓		✓		✓	forum

Table 6.11 – summary of outcomes from critical incident recall

	tacit tool	dimension	CI number
T1	Use of exhaustive tests lead to increasing certainty and establish the truth (or otherwise) of a hypothesis	ce (naïve)	1, 8, 9
T2	Classification of outcomes of practical tests as 'good/bad'	be (naïve)	1, 2
T3	Construction of conditions in practical tests as a copy of reality	nr (naïve)	1, 2
T4	Use of prior knowledge (non-systematically) in planning investigations	be (naïve)	2
T5	Use of language in developing understanding	nr (non-naïve)	4
T6	Use of models to represent reality	nr (non-naïve)	5
T7	Fixing of outcomes of practical work in students' science	be (non-naïve) / be (naïve)	6
T8	Experience of practical work provides a guide to the reliability of results	be (non-naïve) / be (naïve)	7
T9	Judgements about knowledge claims in students' science differ from those in *scientists' science due to difficulty in controlling variables*	nr (naïve)	10

Table 6.12 – tacit tools identified from critical incident recall

	tacit rule	dimension	CI number
R1	Social cues may be utilised in order to direct attention to knowledge claims	s	3
R2	Personal qualities influence perceptions of the status of knowledge claims	q	4, 11
R3	Personal qualities influence the ability of an experimenter to obtain results	q	6
R4	The status of a knowledge claim is dependent upon the amount of "effort" put into it	s	10
R5	Links between students' science and scientists' science enhance the status of a knowledge claim	t	11
R6	The presentation of a report influences the status of the knowledge claims associated with that report	p	11

Table 6.13 – tacit rules identified from critical incident recall

Chapter 7

Discussion and conclusions

This chapter is concerned with the discussion of the research described in the previous chapters and relates this to the research literature, much of which was reviewed in chapter 2. As part of this discussion, the research questions are revisited, and the outcomes of the research are considered. Implications of the research are also dealt with in relation to the future use of networked CSCL in schools as a vehicle for classroom-based discussion in science, and in other subjects too. The chapter concludes by outlining some future directions for research which build on the findings described here.

The research and its outcomes

The methodological approach adopted in this study was explored at the start of chapter 3, where it was concluded that a non-positivistic, naturalistic approach to the research was most likely to lead to a deep and rich description of the research setting involving human interactions. A key part of the approach used in this study is the active involvement of participants in constructing the meaning associated with the products of the research (in this case, the logfiles of online discussions). Lincoln and Guba describe such an approach, in which the enquirer also plays a rôle as participant and facilitator, as set within a *constructivist* paradigm (Guba & Lincoln, 1994:113). One of the implications of this is that the intended outcomes of the research are "subject to continuous revision, with changes most likely to occur when relatively different constructions are brought into juxtaposition in a dialectical context" (Guba & Lincoln, 1994:113).

The research in this study had its beginnings in the desire to examine the possibility of supporting discussions surrounding school science practical work using a CSCL environment (page 18). As the issues around this were explored through reviews of both academic and policy

literatures, this process led to the study being framed using Activity Theory. As well as uniting a variety of theories impinging upon the social, technical and pedagogical aspects of the work (summarised in figure 3.6), this framing directed the line of enquiry towards the tacit rules and tools used by students in a knowledge-building community (page 69). Two taxonomic frameworks were developed and tested in order to define the dimensions of these tacit rules and tools, so that it would be possible to identify and classify them.

The previous three chapters of this thesis contain an account of the empirical work undertaken in pursuit of this enquiry, through the use of critical incident recall applied to the logs of online interactions. Undertaken over a period of some months, this empirical work involved a number of complex decisions about the direction of the enquiry, this being represented by a set of personal *constructions* held by students, teachers and researcher which were brought into *juxtaposition in a dialectical context* through the online discussions. These discussions about the research highlighted the radically different pedagogical approach embodied in the research, in the course of which online discussions were the subject of reflection and discussion with the learners through the use of critical incidents. This method of exploring the ideas of students had been intended only as a research technique, but all those participating in the study noted its powerful effect of directing the attention of learners and teachers towards the processes of knowledge-building. As a result, the focus of the research – which had always centred on the rôle of networked CSCL in promoting discussion among learners – shifted towards a description of the pedagogical implications of the practice developed in this research, a shift that resulted directly from the constructivist approach taken in the study.

Consistent with this shift in focus, the first part of this section of the chapter therefore considers the description that critical incident recall

provides of the tacit tools and rules apparent in this particular knowledge-building community undertaking discussions of practical work. The second part of the section addresses the implications of using networked CSCL combined with critical incident recall as a pedagogical approach to developing learners' understanding of some of the processes used in knowledge-building, especially the tacit tools and rules employed by the community.

Tacit tools and rules

The taxonomic frameworks used to address the research questions are based on two triads within the activity theory triangle (figures 3.4 and 3.5). Concerned with the tacit tools (triad TCO) and tacit rules (triad RCO) used by the student community when building knowledge and advancing/examining knowledge claims, the frameworks resulted in the production of a series of critical incidents derived from logfiles of interactions in the online forum and chatroom. The transcripts of critical incident recall were then scrutinised and classified using the taxonomies, resulting in the identification of the tacit tools and tacit rules summarised in tables 6.12 and 6.13 on page 218. The following section discusses these tools and rules – all references to them make use of the identification (eg T2, R4) assigned in these tables.

Tacit tools

The use of tacit tools by the student knowledge-building community was discussed in chapter 3, with reference to Popper's three worlds and the movement of knowledge about real objects (in W1) between W2 and W3. Critical incident recall shows that the tacit tools used by the knowledge-building community in this research exhibit a range of characteristics within the three dimensions of *naïve realism*, *blissful empiricism* and *credulous experimentalism*. This diversity reflects the findings of other studies which have probed the understanding of the nature of science amongst students of a range of ages between early adolescence (Carey et al, 1989; Solomon, Duveen & Scott, 1994; Driver

et al, 1996) and senior secondary school (Aikenhead, 1987; Lederman & O'Malley, 1990; Driver *et al*, 1996). Reflecting on the range of views about the nature of science held by the students they studied, Solomon, Deveen and Scott refer to this diversity as a "kaleidoscope of epistemological images" (Solomon, Duveen and Scott, 1994:367).

Tools T3 ("Construction of conditions in practical tests as a copy of reality") and T9 ("Judgements about knowledge claims in students' science differ from those in scientists' science due to difficulty in controlling variables") both imply a *naïve realist* epistemology of science in which theories emerge "from collected data ... providing a faithful account of nature" (Driver *et al*, 1996:54). This is a position consistent with that described by Carey et al, who found that – prior to studying a unit specifically designed to introduce them to ideas about science – most of the students in grade 7 classes thought that "knowledge directly reflects reality" (Carey et al, 1989:526). Similarly, Desautels and Larochelle describe the concept of the "*thingified* nature of scientific knowledge" held by many students of science (Desautels & Larochelle, 1998). Counter to this conclusion, tools T5 ("Use of language in developing understanding") and T6 ("Use of models to represent reality") are consistent with a non-naïve epistemology, implying the use of tools in which practical work and ideas are seen as distinct entities within an "operationalized exploration of a phenomenon" (Carey et al, 1989:523). However, the evidence for this position in respect of T6 is weak – careful analysis of the critical incident recall from which this tool is derived suggests that it is likely that students' statements about the nature of models strongly reflect what they have been told (by their teacher) about models:

Connor Sir did one up on the board like that and then I just thought maybe I should make it animated.

David Did you use those shapes because last year we were doing it, weren't we, and it showed those shapes for proteins, I think it was?

Connor Yeah.

(CIR3/45_289-93)

There is also no evidence to suggest that the non-naïve nature of tool T5 (derived from a single comment by one student about the rôle of language in the construction of (personal) meaning) is based on perceptions held more widely among the knowledge-building community, ie within the *intermental development zone* or *IDZ* (Mercer, 2000:141).

Tools T4 ("Use of prior knowledge (non-systematically) in planning investigations") and T2 ("Classification of outcomes of practical tests as 'good/bad' ") are consistent with *blissful empiricism*, a naïve epistemological position characterised by induction, in which facts are established unproblematically through direct observation with no intrusion of organising theory; Chalmers (1982a:11) describes this philosophy as "dangerously misleading". As with *naïve realism*, these findings are consistent with other studies, which have found evidence of *blissful empiricism* among students at all stages of secondary education. For example, Carey *et al* describe students in early adolescence as thinking "that scientists seek to discover facts about nature by making observations and trying things out", an understanding of science that they describe as "a 'copy' theory of knowledge" (Carey *et al*, 1989). Even some much older students may hold *absolute* positions regarding the nature of scientific knowledge (Lederman and O'Malley, 1990); Driver *et al* (Driver *et al*, 1996:141-2) describe a shift in student epistemologies in this age range through a three-stage model involving reasoning based on *phenomena* (evident in pre-secondary students), *relations* (evident in most secondary-aged students up to 16) and *models* (evident in only a minority of students at 16). While there appears to be good reason to think that blissful empiricism generally characterises the tacit tools used by the student community in knowledge-building, two tools appear to be more consistent with a non-naïve position, in which observations do not lead unproblematically to experimental data.

In critical incident 6 and its recall, students are concerned with the way in which "practice makes perfect" – that is, the way in which it becomes in some way "easier" to obtain results from practical work as the experimenter gains in experience. This is reflected in Leila's statement in the critical incident "... we should get better as we get more used to all this" (folg49_002). Taken by themselves, the data relating to this incident appear to indicate an understanding that effective observation involves background theories and techniques which take time to be acquired (whether by individuals or by the community as a whole). This is supported by the data from critical incident 7, where two students describe the development of the technique needed to obtain results with the egg white. The implication here is that students are utilising a knowledge-building tool that is non-naïve with respect to *blissful empiricism*.

An alternative interpretation of the situations in critical incidents 6 and 7 is possible, based on the work of Millar *et al* (1994). Observing students conducting practical investigations, Millar *et al* describe four frames within which students engaged with the work:

frame	description
engagement	students undertake investigation but with little in the way of planning or purpose
modelling	students try to produce an effect or outcome
engineering	students try to optimise effect or outcome
scientific	students actions are based on an exploration of cause and effect

Table 7.1 – frames of engagement with practical work (after Millar *et al* (1994))

Observations in this study showed that only a minority of students based their actions on the scientific frame at the age of 14. Assuming that these results may apply to the students in this research (and there is no reason why this should not be so, given the comparability of the groups on which the two studies were conducted) it seems quite likely that students' statements about improving their results as they gain experience is not a reflection on the complexity underlying observation. Instead, students may be understood to be simply discussing the way in

which they may *engineer* their practical techniques in order to produce results which reflect the expected outcome (in this case, a loss in mass when egg white is exposed to solutions of biological washing powder), expressed as "good" or "bad" in the context of T2 ("Classification of outcomes of practical tests as 'good/bad' "). The (age-related) tendency of students to look for confirmation of theories in this way (*confirmatory bias*) is described by Kuhn *et al* (1988) and by Leach (1996).

Unique among the three dimensions of tacit tools (triad TCO), there was no evidence of any non-naïve character in respect of tools within the dimension of *credulous experimentalism*, a position in which scientific experiment "is able to establish beyond all doubt what should be believed or disbelieved" (Nadeau & Desautels, 1984:29). Critical incidents 1, 8 and 9 all provide evidence that students see the number of tests that they carry out as an essential part of the process of judgements about the quality of work, leading to certainty. As an example of this, one student is most proud of the number of tests he must do in order to reach a sound conclusion: "We've got 72 different variables in our experiments, that's 72 experiments we've got to do ..." (CIR1/43_016-7). Even if all of these can be done, it may still not be possible to be certain about the outcome because "the best ... situation with the washing powders might be the one we haven't done, so we don't really know" (CIR1/43_118-9). Similar comments about repeating results and the number of observations needed are present in critical incidents 8 and 9 and their recalls. One possible source of this conception of science may come from students' perceptions of the "scientist as all-knowing" (Solomon, Duveen and Scott, 1994:366), where students see science as already having all the results, and thus being the source of ultimate certainty. Authority figures of this sort are also referred to by students when questioned about warrants for belief of scientific theories (Driver *et al*, 1996:99-100).

Tacit rules

Tacit rules were discussed in chapter 3 in the context of the way in which students approach making or judging a knowledge claim. The tacit social rules developed through analysis of critical incidents and critical incident recall are described in table 6.13. In summary, these tacit rules indicate that:

1. the ability of an individual to achieve reliable results, and the quality of a knowledge claim are influenced by *personal qualities* (R2 & R3);
2. attention may be directed towards knowledge claims, and the quality of a knowledge claim are influenced by *social factors* (R1 & R4);
3. the status of a knowledge claim is influenced by the *technical* links made between students' science and scientists' science (R5);
4. the status of a knowledge claim is influenced by its *presentation* (R6).

Not much work exists which relates to students' understandings of the social aspects of science (Driver *et al*, 1996:54), especially in the context of the classroom (Bartholomew, Osborne and Ratcliffe, 2004:656). Studies of Canadian high-school students indicate that students believe that scientists are logical and methodical (Ryan, 1987), and that social contact between scientists plays a rôle in the development of scientific theories (Aikenhead, 1987). The same group of students displays a wide variety of positions regarding the relationship between science, technology and society and the part that scientists and technologists should play in making controversial decisions about issues with a scientific or technical dimension (Fleming, 1987), while nearly half of a group studied subsequently see no rôle for consensus-making in science, believing that disagreements about theories in science are resolved when scientists make the theories more accurate (Ryan & Aikenhead, 1992). Studying a group of young adolescent students in the UK, Solomon *et al* (1994) derived a range of images of scientists, including vivisectionists, technologists and entrepreneurs, many of which appeared to be held simultaneously.

They also noted that students viewed both themselves and their teachers as scientists.

Little of this work relates directly to the outcomes of critical incident recall in this research. Indeed, Larochelle and Desautels argue that there is scant reason to think that any understanding that students have of scientists' science is similar to the understanding that they have of students' science, which Larochelle and Desautels characterise as *technico-empiricist*: "scientists do not create the facts; they notice them and are guided by their indisputable recurrence and empirical evidence" (Larochelle & Desautels, 1991:385). Like many of the other studies described here, the work of Larochelle and Desautels is based on interviews with students in which questions were asked about scientific knowledge and experimentation; there is little evidence in the literature of any insights into students' ideas about science which are derived from the *conversations* (Sutton, 1998) among students related to practical work, and which capture the immediacy of students' thinking about practical work and its links with theory. It is perhaps therefore not surprising that such work does not create strong links between the practice of scientists and what students do in the school science laboratory.

Whilst students' experience of scientists' science is obviously limited, the strong links made between *social factors*, *personal qualities* and *presentation* when the status of a claim for new knowledge is made by students in the knowledge-building community in this research are strikingly similar to those listed by Collins and Pinch when describing the factors used by practising scientists when scrutinising a knowledge claim (Collins & Pinch, 1994:101, summarised in table 3.3 on page 99). The rôle played by all of these factors in the practice of scientists' science has also been documented by scientists and historiographers – for example, Watson's account of the discovery of the double helix (Watson, 1968), the disputes of priority between Pasteur and his fellow

scientists (Geison, 1995) and the presentation of debates about the nature of evolution (Ree, 2003). In many ways this should not be surprising. After all, both student scientist and "real" scientist are human beings, so why should they not use similar criteria when making judgements about knowledge claims? Millar has shown the fallibility of arguments suggesting that "scientific skills" are divorced from any kind of everyday skill set (Millar, 1991); the decision about whether to believe another person's claims is also an everyday skill.

The *technical* aspects of knowledge claims are mentioned by students almost uniquely in the context of the extent to which they illustrate or promote *cognition*. Rather than implying any particular insight into the rôle played by technical discussions in scientists' judgements of knowledge claims, it seems likely that this emphasis arises as an outcome of the way in which the study is framed and its school context. This is discussed below, in relation to knowledge-building.

One striking feature of some students' perceptions about the rôle of *personal qualities* in respect of knowledge claims is the idea that "practical experience may lead to results in which one may have little faith" (discussion of critical incident 6, pages 198-202) and that "the 'right' outcome from an investigation may depend upon or may reflect the 'effort' put into it" (discussion of critical incident 10, pages 207-11). It seems likely that such perceptions are the outcome of what Curtis refers to as *Baconian values* which are present in the majority of stories about science found in the mass media, stories which describe how, "when their virtue is proven by their hard work, nature decides to reveal herself to the scientists" (Curtis, 1994:439). There are inevitable parallels with students' science here, since an exhortation to "work hard" is part of most teachers' vocabulary – this may be the source of Larochelle and Desautels' *techno-empiricism* (Larochelle and Desautels, 1991:385), and indicates the importance of encouraging students to think about the rôle of creativity in science (Osborne, 1998:169).

There is no evidence in any of the critical incidents themselves, or in their recall, that students make use of *private information* in making judgements about knowledge claims. (Such information might relate to the results from a test conveyed between students by word of mouth or by other communication channel.) This lack of evidence was also noted in the second study, where it was concluded that any such interactions might be happening *outside* the CSCL environment, eg using *Instant Messaging* (IM) programs. That interactions outside the environment occur alongside those inside it is evidenced by "asides" between students:

hayley_wnc alison just came online cos she noes carl is coming ;0 only jokin

(chnov06_1028)

However, there is no evidence from any such asides that disclosure of *private information* happens in such interactions, and it must be concluded that there is no evidence of a tacit rule related to *private information* being used by students making judgements about knowledge claims.

Summary

The use of networked CSCL combined with critical incident recall as a way of helping students to reflect on their online discussions appears to be successful as a strategy which can externalise ideas regarding knowledge and knowing held by the student community. Evidence for this comes from the rich description of tacit tools and rules provided by this method when used with the community in this study. These tools and rules are located within triads TCO and RCO of the activity triangle – to complete the discussion, the following section considers the third triad, SCO, which frames the pedagogical environment experienced by students.

Knowledge-building and networked CSCL – triad SCO

The framework surrounding the practical work carried out by students in this research is based on the notion of a knowledge-building community, proposed by Bereiter and Scardamalia (1993) and described in chapter 3. This knowledge-building community was supported by networked computers, providing

- access to records of what other students are doing, and an opportunity to comment upon it;
- access to other sources of information (in addition to the teacher and school books);
- access to experts outside the classroom and school.

(chapter 2, page 44)

The discussion that follows concerns firstly, the conditions needed to promote knowledge-building and secondly, the networked CSCL environment itself; it is structured around the theories framed by triad SCO of the activity triangle supporting knowledge-building and its extension into an online environment (the relationship between these

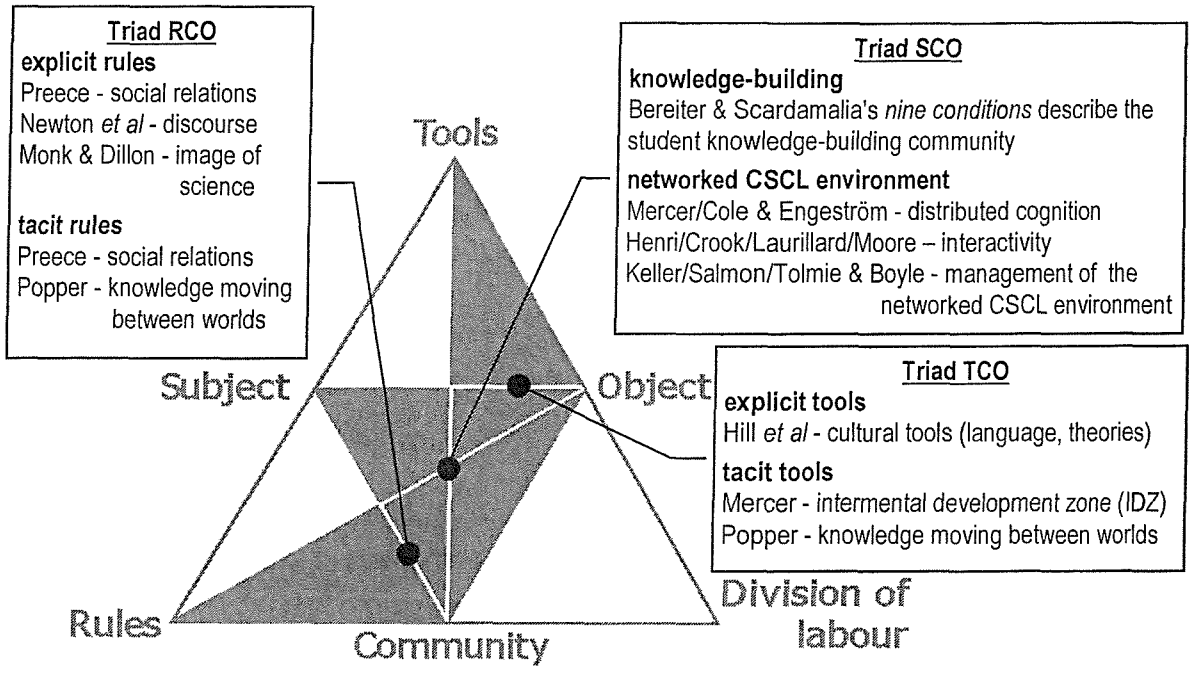


Figure 7.1 – activity theory as the unifying theoretical framework

theories and the activity triangle were described in figure 3.6 on page 93), repeated here as figure 7.1.

Knowledge-building

In establishing the knowledge-building community, nine conditions were described for the way in which the community should be constructed and maintained (chapter 2, page 43). In chapter 3 it was shown how these conditions relate to triad SCO within the activity theory framework (table 3.2, page 84, repeated below as table 7.2). These conditions are examined below in the light of the outcomes of the study, to review the effectiveness of this approach to managing the discussion surrounding a practical science investigation.

Activity theory	Conditions needed for knowledge-building
nature of tasks to be undertaken	1. sustained study of topics in depth rather than superficial coverage 2. focus is on problems rather than on categories of knowledge 3. enquiry driven by students' questions 4. explaining is the major challenge 5. day-to-day focus is progress toward collective goals of understanding and judgement
organisation of community	6. students typically work in small groups, each with a different task
nature of the relationships between individuals and the community	7. discourse is taken seriously
rôle of the teacher and the student/teacher relationship	8. teachers can contribute what they know to the discourse, but there are other sources of information; 9. teacher's role shifts to leading it by virtue of being a more expert learner

Table 7.2 – activity theory as related to knowledge-building communities

Nature of tasks to be undertaken

This aspect of the triad relates to five of the conditions for knowledge-building (table 7.2).

The timing of the investigation in the main study was described in table 6.4 (page 177). In addition to the four weeks allocated to practical work, a further week was added for report writing, with another two weeks (largely outside school) for report discussion. This timing represents a considerably sustained study of the topic, as evidenced by the volume of communication between students, maintained over the entire period (table 6.5, page 178) of the study. The richness of

students' interactions discussed in the previous chapter provides evidence for the depth of the coverage of this topic.

Web-based briefings provided to students (an example is given in appendix 29) were constructed in such a way as to "problematise" the investigation in an authentic way (Helms, 1998). Evidence that this, together with appropriate management of the learning environment, guided students to focus on finding solutions to the problem set are evident in the transcripts of the critical incidents. For example, critical incident 10 (appendix 41) shows how students are concerned with developing an understanding, in discussion with each other and moderated by the researcher, of the way in which conflicting results may be interpreted. This structure was also designed to promote enquiry by students through a series of initial tasks focusing on the way in which washing powders work, with the emphasis on providing explanations for the behaviour of the egg white in washing powder solution. The logfiles of the forum discussions about reports clearly indicate the importance of "understanding" and "explanations" among students, as noted in the previous chapter.

The emphasis in knowledge-building is on the collective nature of the activity, an emphasis that is also reflected in the research questions which address the understandings developed by the community as a whole (and represented by the *IDZ* (Mercer, 2000:141)). The *collective* nature of students' understandings and judgements here is evidenced by the ability of students to interact with one another in building knowledge. Thus, simple sequences of interactions like those in critical incident 5 (appendix 36) – which are representative of many such interactions in the forum and chatroom – show how students support one another in developing ideas in a manner that is *socially situated* (Driver, Newton & Osborne, 2000).

One factor relating to the scrutiny of knowledge claims that was identified at the end of the previous chapter was unexpected – the importance of evidence for reports to have some kind of *cognitive* quality, either demonstrating *understanding by the author* or appearing particularly good at developing *understanding in the reader*. It seems very likely that there are two possible sources for this emphasis, both arising within the SCO triad. The first of these is the language of the National Curriculum, which places emphasis on the understandings developed by students (DFEE, 1999:75), and which is reflected by the language of teachers and the materials used in formal instruction. In chapter 2 of this thesis the effect of language on the nature of the curriculum was discussed in the context of the nature of practical work, where it was shown how subtleties in language may affect the way in which the curriculum is conceptualised. In the same way, the use of language which encourages and emphasises students' understanding is reflected in the language used by teachers when talking to students about science investigations, who require students to "show understanding" when they write about their science work. The second source of this cognitive emphasis is the rules for the knowledge-building community, which also emphasise *explanation* and *understanding* (conditions 4 and 5). Given these two influences, the importance of these cognitive factors in students' discussions of knowledge claims is understandable and unsurprising.

Organisation of community

This relates to the sixth condition for knowledge-building (table 7.2), *students typically work in small groups, each with a different task*. This condition was supported by the structure of the task and the classroom organisation facilitated by the teachers taking part in the study, as described in earlier chapters. Although each group of students carried out its own investigation, the diversity of ideas among the groups had the effect of providing a range of different approaches to solving the problem of finding an explanation for the behaviour of the egg white.

Critical incidents 1 and 2 show how this division of the labour effectively arises out of the individual investigations, with students comparing data from a range of investigations that differ slightly in their approach.

Nature of the relationships between individuals and the community

This condition is important in respect of the seventh condition for knowledge-building, in which *discourse is taken seriously*. There is no positive evidence to show that this condition was met throughout the study. However, there is also no evidence in the logfiles to suggest that knowledge-building was not taken seriously by the community, and there were no instances where the researcher or teachers moderating online discussions found it necessary to intervene because students were abusing the online forum or chatroom. Both of these suggest that the community took the business of discussion very seriously.

Rôle of the teacher and the student/teacher relationship

The fourth and final aspect of triad SCO concerns the part played by the teacher in acting as a *more expert learner* (table 7.2). Although no exhaustive analysis of teacher contributions to online interactions has been carried out (since this is not directly related to the research focus), the teacher contributions in critical incident 2 show a typical pattern of interactions with students, consisting of three (prompting) questions and a simple statement – "1.44g is a big decrease" (choct21_441). There is also evidence from critical incident 4 that students are making use of sources of information other than teacher and textbook (in this case other students); this is supported by other evidence from logfiles not identified as critical incidents (table 7.3).

student	they include enzmes, natural protiens you can find in your own body i may be a boffin here with the first post but i dont see why i cant be 1!
student	it is is economical to use, includes 15 - 30 %: zeolite, chlorine free bleach. 5 - 15 %: plant based non-ionic tensio-active, surfactants. < 5 %: plant based soap, enzymes (guaranteed non gmo). Other ingredients: soda, salts, silicate, citrate, polypeptides, bleach activator, natural lavender fragrance, biodegradable complexing agent, cellulose derivatives. better do sum research on them.
teacher	Well done [name] this is what I want to see. :wink:
student	Dictionary definition Any one of a family of hydrous aluminum silicate minerals, whose molecules enclose cations of sodium, potassium, calcium, strontium, or barium, or a corresponding synthetic compound, used chiefly as molecular filters and ion-exchange agents. Does that mean its highly reactive?

Table 7.3 – sources of information from outside the classroom (chatroom, 9 October)

Evidence from critical incidents and logfiles shows that the conditions for knowledge-building identified in chapter 3 and lying within triad SCO of the activity triangle were satisfied during the conduct of the final study. The significance of this lies in the *validity* of the research, defined by Tesch as whether the research *leads to a result that others can accept as representing the data* (Tesch, 1990:304). In the context of qualitative research, judgements about validity are contingent upon what Walker calls the *natural history* of the research (Walker, 1985:184); in this case, triad SCO provides essential background to the research setting. Confirmation that the conditions under which knowledge-building occurred conform to the planned research setting provides support for the validity of the research findings.

The networked CSCL environment

The three key features of the networked computer environment used to support students' discussions ins this study relate to the distribution of cognition among the knowledge-building community, interactivity between members of the community, and management of the networked CSCL environment itself.

Distributed cognition

The distribution of cognition throughout the knowledge-building community was discussed in chapter 2; it was also noted in chapter 3 that *memory* is not solely located in human minds. The importance of the distribution of cognition in the context of networked CSCL lies in the

ability provided by the computer "memory" (in a metaphorical rather than literal, technological sense) to act as an inspectable history of the community's cognitive development. There is evidence from this study to suggest that distribution of cognition plays an important part in the day-to-day conduct of knowledge-building (logfiles of both forum and chatroom showing clearly how students make reference to and build upon other students' contributions through online interaction with them) as well as the process of critical incident recall within triads TCO and RCO (in which tracing the development of ideas provides the community with opportunities to reflect on the way in which emerging knowledge claims have been managed and priorities set concerning potential claims for new knowledge).

Interactivity

The need to support interactivity between students engaging in discussion is self-evident, since without it discussion would be impossible. However, a deeper consideration of interactivity suggests that it is particularly important in terms of the need to support the community's cognitive development through the engagement of *masters* in the community (see chapter 2, pages 52-55). These *masters* may be teachers, or they may be students who take the lead in encouraging students to develop their ideas (see for example critical incidents 5 and 8 in study 3, documented in appendices 36 and 39). Structured around these ideas, interactions may also be seen as *conversations* between master and learner in which a dialogue about actions (eg describing a set of results) leads to developing understanding at a second order, cognitive level (Laurillard, 1993:94). There are many examples of these kinds of interactions in the logfiles of online discussions (for example, critical incident 2 in study 3 (appendix 33); critical incident 10 in study 3 (appendix 41)). On one occasion in the chat room, no response from a teacher was evident for an extended period of time; one student's response to this indicates the importance of interactions in which cognitive challenge is present: "i am gonna go

soon it boring with no teachers" (choct16_1725). The richness of many of the chat room interactions is also strongly supportive of the idea that the reduced *transactional distance* (Moore, 1993) of synchronous communication is particularly effective in engaging the attention of these students. This is explored below, in the contex of managing the networked CSCL environment.

Management of the networked CSCL environment

The success of the knowledge-building community in this study is founded on the CSCL environment being used to support students as they exchanged ideas during the practical work and discussion of each other's reports. This support also extended to the way in which students were motivated to engage in online interaction, through engagement of attention and appropriate reward (Keller, 1983) and through carefully structuring students' initial introduction to the CSCL environment (Salmon, 2004).

Whilst the initial work with students consisted purely of an environment in which asynchronous interactions were possible, both the second and third studies were conducted with the opportunity for students to engage in synchronous "chat" at pre-specified times during the week, outside school. Synchronous CMC was introduced in order to provide an additional mode of communication to asynchronous CMC, with the idea that it could offer different possibilities, and might encourage students to challenge each other's ideas (Chou, 2002), as discussed in chapter 2.

The identification of critical incidents in the two studies incorporating synchronous CMC shows that critical incidents occur in the numbers shown in table 7.4.

	second study	main study
forum (asynchronous)	23	7
chat (synchronous)	11	4

Table 7.4 – sources of critical incidents

Out of a total of 45 critical incidents, 15 originate in synchronous interactions. This represents a significant proportion of incidents resulting from synchronous communication, and is an indication of the quality of interactions occurring in synchronous mode. In the context of the literature described in chapter 2 the richness of these synchronous interactions is encouraging and a little surprising, since most researchers (with the exception of Chou, 2002)) are positive about synchronous CMC because of its inclusivity and immediacy rather than because of any perceived advantages in the quality of interactions: "[in asynchronous interactions] students have more time to think, to search for information, to elaborate ideas, explain ideas and to reflect on each other's contributions ... take time to reach shared understanding, to create their own ideas and to formulate points of view as clear as possible" (Veerman & Veldhuis-Diermanse, 2001:7). The negative attitude towards synchronous CMC may in part be due to Hiltz and Turoff's early and vehement rejection of CMC: "of all the communication forms and conditions permitted by computerized conferencing, the synchronous discussion seems to cause the most difficulty and feelings of confusion" (Hiltz & Turoff, 1978:90). Coming at an early stage of the development of online conferencing, it seems almost as if this dismissal of synchronous communication has acted as a deterrent to others seeking to use synchronous interaction. This, coupled with the ability of asynchronous communication to produce *flextime* (Toffler, 1981), effectively determined that asynchronous communication would become the dominant mode for CMC in future educational settings. As Higgins observes: "asynchronous CMC (computer conferencing) was propelled to the leading edge of a new communications revolution primarily because of the way it alters human communication patterns" (Higgins, 1992).

The ability of synchronous communication to produce a high number and quality of interactions among adolescent students in this research should not be altogether surprising, however. Surveying over 1,500 9-

19 year-old children across the UK between January and March 2004, Livingstone and Bober report that, of the 84% of this age group who go online at least once a week, 55% use instant messaging (IM) software to send and receive messages (Livingstone & Bober, 2004:21). These figures are consistent with the class survey of Internet use conducted in December 2002 (figure 4.2 on page 121), which indicated that nearly half of the class claimed to have use IM software in the two weeks prior to completing the questionnaire. The use of IM software by the students in the second and main studies in this research was also signalled in chatroom references to it, and by occasional requests for help via IM software from students having problems with the chatroom software. The apparent expertise in using IM software among this cohort suggests that a growing ability to use synchronous communication, among this and subsequent generations of young Internet users, is likely, and that this mode of communication may act as an important channel for interactions within knowledge-building communities for this age group.

Conclusions and implications

The previous sections of this chapter have shown how critical incident recall may be combined with the networked computers as a vehicle for students' discussions. This approach to discussion has five important features:

1. The use of networked computers provides an *inspectable history* of discussions that provide the community (including the teacher) with access to a record of the community's developing ideas.
2. The use of critical incident recall based on this inspectable history enables students' ideas to be brought out of the discussion.
3. Students find the use of online discussion powerfully motivating, and are encouraged to participate in discussion.
4. This encouragement extends to leading discussions out of the classroom (in school time) and into the home (out of school time).

5. The approach provides a way for teachers to manage discussion in which no contribution from a student needs to be "lost" from the recorded discourse but can be recalled at any time.

All of these features apply to discussions conducted through CMC, whether asynchronous or synchronous; the latter communication mode is comparable with asynchronous communication in its ability to promote discussions in which interactions between students contain a rich diversity of ideas.

The implications of these findings for the structure and management of discussion in school science classrooms and in other school subjects where lively debate about ideas is sought as part of student interactions are considered below.

Combining networked CSCL with critical incident recall

The difficulty that many teachers have in managing classroom discussions was described in chapter 3 in the context of the explicit rules necessary for the management of social interactions between students. This concern has also been raised recently by Bartholomew, Osborne and Ratcliffe, who note that many teachers have difficulty in managing students' discourse and argumentation and the consequent need to organise and establish an environment that "supports dialogic discussion" (Bartholomew, Osborne and Ratcliffe, 2004:678). The establishment of such an environment in an online setting was a key principle in the research described here.

The use of networked computers in such a setting has a crucial part to play in the management of discussions. If we consider the task facing a teacher in a conventional classroom who wishes to harness the discussion of practical work as a way of helping students to reflect on the tacit rules and tools they use in knowledge-building, we can see that this represents a considerable challenge. In order to do this, the

teacher needs to draw upon students' ideas from their discussions and must then make these ideas explicit in order that students have the opportunity to reflect on them. In managing such a discussion, students' ideas are required to represent the starting point for "getting students *thinking* or reasoning about the scientific processes involved" (Bartholomew, Osborne and Ratcliffe, 2004:670) – yet drawing upon a range of ideas produced by students in an oral discussion in order to do this is extremely problematic. One important reason for this is that the records of such discussions are, by their very nature, largely ephemeral, since it is almost impossible to conceive of students and/or teacher being able to keep any kind of comprehensive record of these through the use of an overhead projector or whiteboard, through students' notebooks or through any other kind of conventional record keeping technology. Discussions using networked computers are a different matter however; the importance of the ability to recall any or all elements of computer-mediated discussions was noted on page 44 and earlier in this chapter. As Feenberg writes:

> *A group which exists through an exchange of written texts has the peculiar ability to recall and inspect its entire past. Nothing quite like this is available to a community based on the spoken word.*
>
> (Feenberg, 1989)

Feenberg refers to this modified use of language as *social memory*; such memory is not available to students and teachers interacting in the "traditional" classroom, whether in science or in other subjects.

Drawing on work with 11 UK teachers, Bartholomew, Osborne and Ratcliffe describe five *dimensions of practice* which they regard as important as indicators for explaining or predicting the success that teachers have when teaching about science. Table 7.5 shows these dimensions.

1. Teachers' knowledge and understanding of the nature of science		
Teacher is anxious about their understanding	←→	Confident that they have a sufficient understanding of Nature of Science
2. Teachers' conceptions of their own role		
Dispenser of knowledge	←→	Facilitator of learning
3. Teachers' use of discourse		
Closed and authoritative	←→	Open and dialogic
4. Teachers' conception of learning goals		
Limited to knowledge gains	←→	Includes the development of reasoning skills
5. The nature of classroom activities		
Student activities are contrived and inauthentic	←→	Activities are owned by students and are authentic

Table 7.5 – the five dimensions of practice
(Bartholomew, Osborne and Ratcliffe, 2004:664)

There are clear parallels between the knowledge-building community in this study – with its underpinning rules (table 7.2) and *authentic activities* – and dimensions 2 to 5, which relate to the setting in which discussion occurs. Both emphasise the rôle of the teacher in facilitating learning, leading students by virtue of being a more experienced learner (Bereiter & Scardamalia, 1993). Networked computer environments also offer a key *affordance* (Gibson, 1977) in this regard, since the records of discourse that they provide may provide the teacher with an opportunity to identify and make explicit key aspects of students' thinking in a way that would not be possible through oral discourse alone.

A framework for pedagogy

The success of activity theory as a *research* framework to structure an enquiry into knowledge-building may be translated into a *pedagogical* framework to support the use of discussion in classrooms. To do this requires a process similar to the *concretisation* of Wells (2002), in which important variables are described and made relevant.

Figure 7.2 shows this pedagogical framework, which relates directly to the research framework in figure 7.1. Within this framework, triad SCO describes the conditions that must be addressed if discussion is to be established successfully and if it is to be extended into an online setting

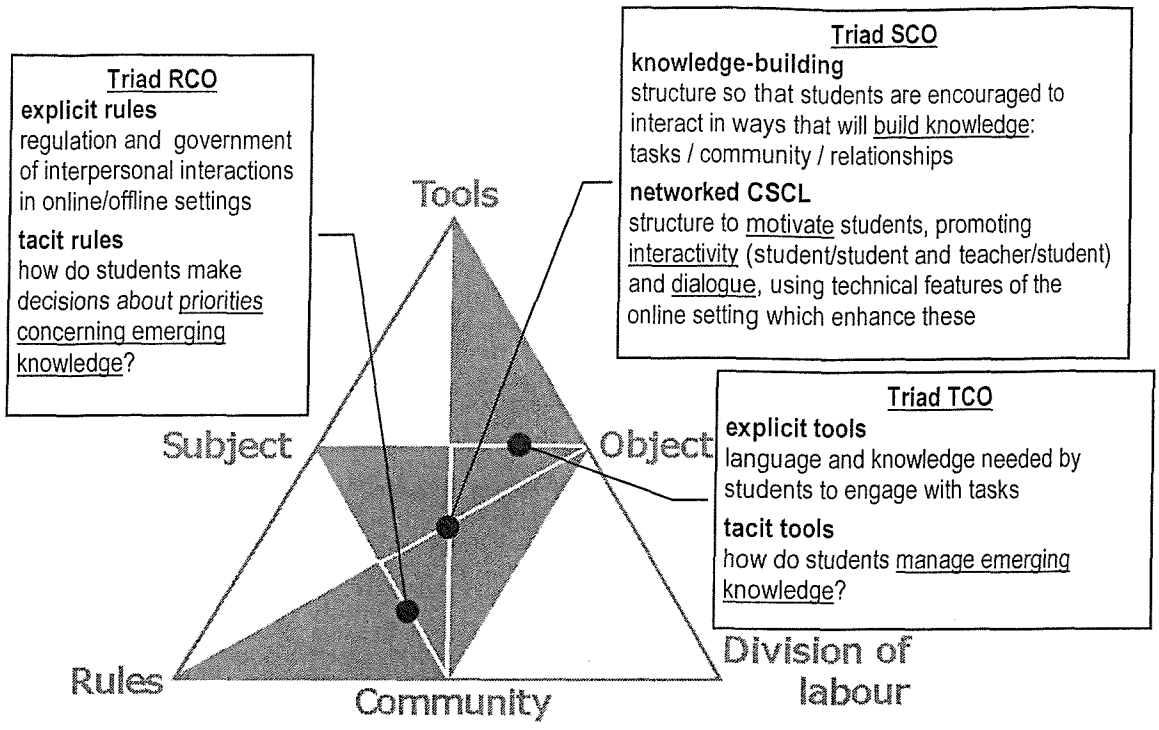


Figure 7.2 – activity theory as a framework for pedagogy

(whether synchronous, asynchronous or both). These conditions are those which have an external impact on the community, concerning the building of knowledge (through factors such as the use of authentic tasks, community organisation and community relationships). Consideration must also be given to conditions which promote productive interactivity through the extension of discussion into an online environment, and in particular those factors which motivate students to contribute online and which promote dialogue. In addition, triads TCO and RCO draw attention to further conditions, in the form of explicit tools (the language and knowledge needed to engage with the learning tasks) and rules (concerning the way in which interpersonal relationships are governed and managed); the research shows that it is important to be able to specify these clearly in order for the community to engage in the learning tasks assigned to it in a climate where mutual respect prevails among its members.

Having attended to all of these conditions, attention may be then directed towards the tacit tools and rules which emerge through online discussions. Considering the contexts in which these tools and rules are found as critical incidents, *recall* of these incidents can be conducted as

a follow-up to online discussions, in which students explore the way in which the community has managed the development of knowledge and emerging competing knowledge claims. Although this study has specifically considered this process in science classrooms, and related only to practical work, there seems to be no reason why the process should not be applicable more widely, in any classroom in which the teacher seeks to foster discussion in which understanding the *processes* through which new knowledge is constructed is at least as important as understanding the knowledge itself. The application and generalization of the framework is considered below.

Applying and generalizing the framework

Although the framework as represented in figure 7.2 provides some links to pedagogy, further concretisation is necessary if it is to function as a clear form of guidance for teachers and policymakers – the intended users of such guidance. Crucial to the re-presentation of the framework for such users is to make it "vivid, credible and meaningful to the client (or reader)" (Walker, 1985:193). Table 7.6 does this by providing a checklist (in the right-hand column of the table) to guide practitioners. This checklist relates directly to the conditions to support knowledge-building identified in figure 7.2; these conditions, and associated factors, are described on the left-hand side of the table. A further description of the checklist is provided below.

Authenticity of tasks – ownership

The discussion of knowledge-building in chapter 2 highlights the importance of authentic tasks (pages 28-30) which students see as important to them and which therefore lead to *ownership* – "they think the questions really matter, and they are right" (Bereiter & Scardamalia, 1993:215). There is no single kind of authenticity, even within one area of the curriculum, since an activity regarded as authentic by one group of students may seem highly artificial to another group – what matters is that the task should as far as possible engage

all students to participate actively in the knowledge-building process, most likely through activities that "tap into 'real world' resources and techniques" (McGuiness, Roth, & Gilmer, 2002:52, quoted previously on page 29).

triad	condition	key factors	Checklist
SCO	Tasks to be undertaken	Authenticity of tasks	Ownership of tasks by students is essential - they need to feel that the activities they undertake are important and matter to them.
	Structure of the knowledge-building community	Organisation of students into working groups responsible for tackling tasks	Working groups should be constituted so as to encourage a diversity of ideas.
	Relationships within the knowledge-building community	Teacher and (in some cases) students act as "masters" who can scaffold learning	Expertise within the community must be considered in respect of ability to act as a "master" rather than as a source of knowledge.
	Students' motivation	Management of the online community	Online discussions must be supported through appropriate moderation to achieve motivation.
	Interactivity / dialogue	Structure of the online environment to support development of relationships within SCO triad	Interactivity must be promoted through appropriate relationships (teacher/student and student/student) which target dialogic structures and provide cognitive challenge.
TCO	Knowledge and language (explicit)	Ability to engage with tasks and activities at a technical level	The knowledge and language needed for students to engage in tasks must be clearly identified.
RCO	Rules (explicit)	Online rules must be commensurate with offline rules and must support/be consistent with other key factors	Rules must be established which set clear boundaries for interactions and which are consistent in both online and offline worlds.

Table 7.6 – a checklist for online discussions (fourth column) derived from the pedagogical framework (columns 1 to 3)

Organisation of students – working groups

The notion that understanding within the knowledge-building community is not individually-situated (pages 235-6) means that different individuals will make different contributions to knowledge-building. The constitution of groups (who may work together online, offline or both) is therefore critical in order to ensure that a diversity of ideas and approaches are present across the community, and that these ideas and approaches are themselves the subject of discussion. The teacher's knowledge of students is important in this respect, and it may also be necessary to consider students' own desires where these are not in strong conflict with the teacher's preferred way of organising groups.

Teacher (and students) as "masters" – expertise

Productive discussion as part of knowledge-building depends upon the involvement of members of the community who are able to encourage others to work within their ZPD, or in the case of the community as a whole, the IDZ (see pages 39-43). In most cases this rôle is likely to be fulfilled by the teacher, but as this research shows, this does not have to be the case. Rather than considering expertise in the sense of knowledge, the ability to scaffold the work of others "by virtue of being a more experienced learner" (Bereiter & Scardamalia, 1993) governs relationships between individuals in the knowledge-building community, and also informs decisions made about the constitution of group work discussed above. It is thus important to recognise the rôle of the teacher more in terms of being a leader of learning than a source of knowledge, and that this rôle may also be undertaken by student members of the community at appropriate times.

Management of the online community – motivation

Management of online interactions is critical if students are to be motivated to engage in discussions with one another. As an example of this, a networked CSCL environment which encourages students to participate in online discussions which have a *social* dimension as well as those which focus on the *object* of the collective activity is likely to be more motivating to students than a similar environment which bans all off-topic interactions (Salmon, 2004). The ability to engage with others online, both socially and cognitively, acts to encourage learners to become confident that such interactions are likely to be rewarded, making it more likely that they will contribute in future and so enrich the discussion (Keller, 1983). Whilst the school-age learners in this study were clearly intrinsically motivated to interact online from the outset, other groups of learners may require more support in order to become confident and motivated – models for e-moderation of groups like this (for example, Salmon's five step model in figure 2.3 on

page 51) provide clear and structured guidance in increasing confidence and motivation.

Structure of the online community – interaction and dialogue

Using CMC as a medium for students to "establish a shared purpose" (Tolmie and Boyle, 2000:135) in building knowledge involves the development of an environment in which dialogue and interactivity promote cognitive development through *conversations* (Laurillard, 1993). This aspect of structure relates very closely to the rôle of "masters" within the community discussed above, since cognitive development proceeds through appropriate challenge, leading to the community extending its ways of thinking into the IDZ. In order that these learning conversations take place it is necessary for students to see the discussion environment as a place where half-formed ideas (page 86) may safely be put forward and where they do not feel threatened by such discussions, even when their own ideas are challenged.

Explicit tools – knowledge and language

If students are to be able to participate fully as members of a knowledge-building community, it is essential that they possess the tools needed to enable them to engage with the tasks undertaken by the community and with the discussions held about these tasks and their outcomes. Therefore the community must have at its disposal not only an adequate grasp of the key elements of knowledge concerned with tasks but also appropriate language for their discussion. The distributed nature of understanding within the community means that this expertise does not have to be held in its entirety by each individual; however, for any knowledge-building community there will be a certain minimum level of expertise without which any one individual is likely to be impeded in contributing to knowledge-building through participation in tasks and/or discussion. It is important to be clear about minimum

levels of language and knowledge that are likely to be necessary for full participation in the community by individuals.

Explicit rules – boundaries for interactions

Whether online or offline, communities are governed and regulated by rules (Preece, in press). Establishing explicit rules for conduct provides students with important messages about their participation as members of a knowledge-building community. The exact nature of these rules will vary according to the setting of the community (school or college, cultural community etc) and the students themselves (for example, rules for adult students are likely to be very different to those for students in the early years of secondary school). Of greatest importance is the consistency of rules between the online and offline worlds, which should also be consistent with the other factors considered here. For example, an online rule set in order to establish a climate which promotes discussion might be: "treat other people and their ideas with respect". This rule is not only likely to reflect the rules found in many schools and classrooms but is also consistent with the desire to promote interactivity and dialogue.

Emerging knowledge – tacit tools and rules

Based on the checklist in table 7.6, the previous sections considered the application of activity theory to the practical organisation of a setting for learning in which online discussion and offline tasks are combined as a way of building knowledge that is new to the students. This final section considers how, having successfully organised and managed such this undertaking, a teacher may draw on the logs of online discussion as a source of critical incidents, and may then use the recall of these as a means of drawing out and making explicit ideas held by the knowledge-building community about the processes involved in making new knowledge, described within the activity theory framework in terms of tacit tools and rules.

The rôle of tacit tools and rules in knowledge-building has already been discussed in chapter 3, where it was shown how tacit rules are concerned with the way in which the knowledge-building community views and handles knowledge (ie its *epistemology*) and tacit rules are involved when judgements are made by the community about claims for emerging knowledge. In the context of discussions relating to practical work in school science, tacit tools were particularly concerned with the relationship between experimental observations and scientific theories, while tacit rules applied in situations where students examined statements about new knowledge made by fellow students. However, it is clear that the tacit tools and rules of interest in a particular knowledge-building community will be highly dependent upon the subject and nature of the discussions. Thus, the resolution of a controversial issue involving science might focus on tools relating to the use of knowledge gathered by students seeking information about the possible courses of action that might be taken, while rules might concern the way in which decisions about possible courses of action were taken. Whatever the context, successful identification of critical incidents will depend upon the prior establishment of the nature of the tacit tools and rules of interest before analysis of the logfiles to produce critical incidents. For the purposes of teaching, the definition of these tools and rules need not be as rigorous as it would have to be in the case of research, but it should still involve some careful thinking about the ways in which the community may regard knowledge.

Once a set of suitable critical incidents have been identified these may then be the subject of recall in order that the "joint, co-ordinated intellectual activity" (Mercer, 2000:16) can be used "to make new, joint, knowledge and understanding" (Mercer, 2000:46). This process is similar to the use of group interviews used in this research as a means of exploring students' ideas, except that the purpose here is a pedagogical one with objectives such as increasing students' understanding of the way in which knowledge is produced and used.

Generalization

Since the use of online discussions related to knowledge-building tasks is not limited to science, the use of critical incidents and their recall may be extended to other subjects in the school curriculum where discussions as part of knowledge-building is seen as a legitimate activity. Clearly the exact nature of the tools and rules concerned in each case will be highly dependent upon context – not only curriculum subject, as discussed above, but also such issues as the age of students and the nature of the educational setting are likely to be influential. Given these differences, the application of this pedagogy in areas other than science is likely to require further research and development, which is discussed below.

Further work

The research described here offers a number of opportunities for further work, relating particularly to the practical application of what has been learned and its evaluation.

Primarily, further work is needed in order to develop and refine the pedagogical approach described in the latter part of this chapter. This work should establish practical ways in which this approach may apply to a range of contexts, including not only science classrooms but also other areas of the curriculum and a variety of settings (ie varying schools, ages of students and so on). Such work would have as its specific objective the development of techniques for using online discussion and subsequent critical incident recall as a means of developing students' ideas about knowledge and knowing in a way that may be relatively easily adopted by teachers. Aspects of this development work would include:

- constructing detailed guidance on structuring the use of knowledge-building in different subjects;

- developing methods for supporting this knowledge-building using online discussions, the precise details of which may differ quite widely between curriculum subjects and settings;
- producing guidelines for online discussions including both technical (choice of software, synchronous/asynchronous CMC etc) and pedagogical aspects (for example e-moderation);
- developing ways for teachers to identify critical incidents in online discussions;
- devising and trialling ways in which critical incident recall can be conducted as part of a whole-class lesson.

Another important aspect of developing this pedagogy is its subsequent evaluation in terms of effectiveness (ie whether it really can increase students' understanding of the production and/or application of knowledge) and the factors which may contribute to its being more or less successful. Other areas for examination would also include teachers' perspectives on the practical utility of the pedagogy, and the students' own opinions about it.

Related to pedagogical development is the technological development work that might provide some practical means of allowing teachers more easily to identify and isolate critical incidents occurring in logfiles that may be very extensive, especially where asynchronous communication is concerned. At its simplest this may involve the use of software with which the teacher may "tag" and then organise critical incidents as part of the preparation for recalling them in class discussion. Clearly this is a similar task to that faced by the qualitative researcher who needs to code and organise large quantities of data, for which software tools like NUD*IST already exist. Use and/or adaptation of such tools for pedagogical purposes may be possible, although it is more likely to prove fruitful to provide the required functions within a widely available program like Word through the use of proprietary methods like Microsoft's VBA. However, more a more sophisticated

approach to critical incident identification and recording may also be envisaged, in which the software itself may play a part in critical incident recognition through text recognition. This is likely to prove complex due to the wide range of renderings of even simple textual communications that occur in online discussions.

Finally, returning to science classrooms in which practical work is being conducted, further research is also needed into the way in which CMC-mediated discussions among students conducting practical work might develop the procedural understandings of practical work in the context of the work of projects such as PACKS (Procedural and Conceptual Knowledge in Science (Millar & Lubben, 1996)). The importance of this lies in the idea that discussions relating to science may enable students to move towards a *scientific* framework for practical work rather than simple *modelling* or *engineering* (Millar et al, 1994). Such development would imply an increased understanding of the relationship between experiment and theory of the type advocated by many commentators, and which has proved hard to achieve.

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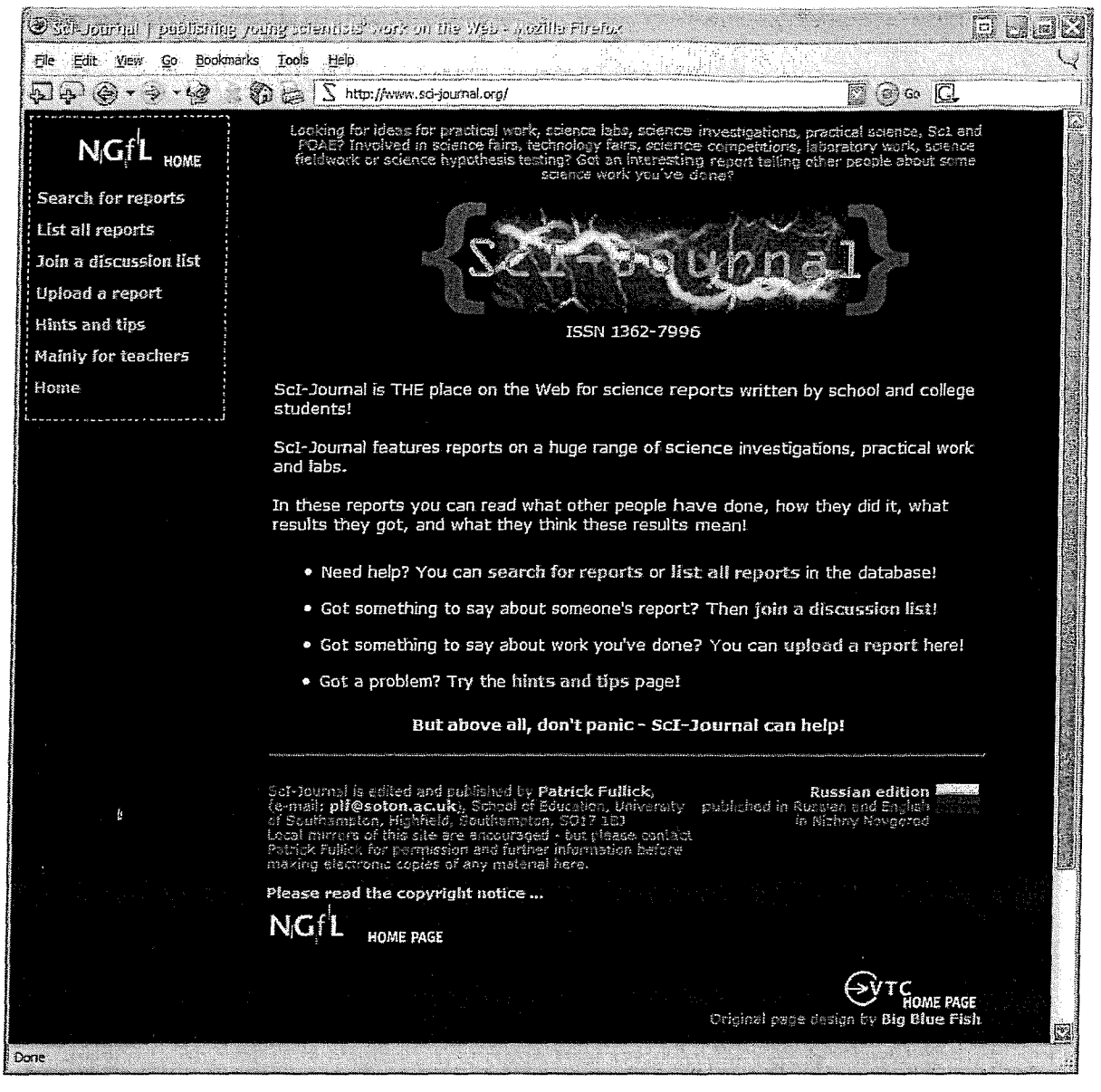
Appendices

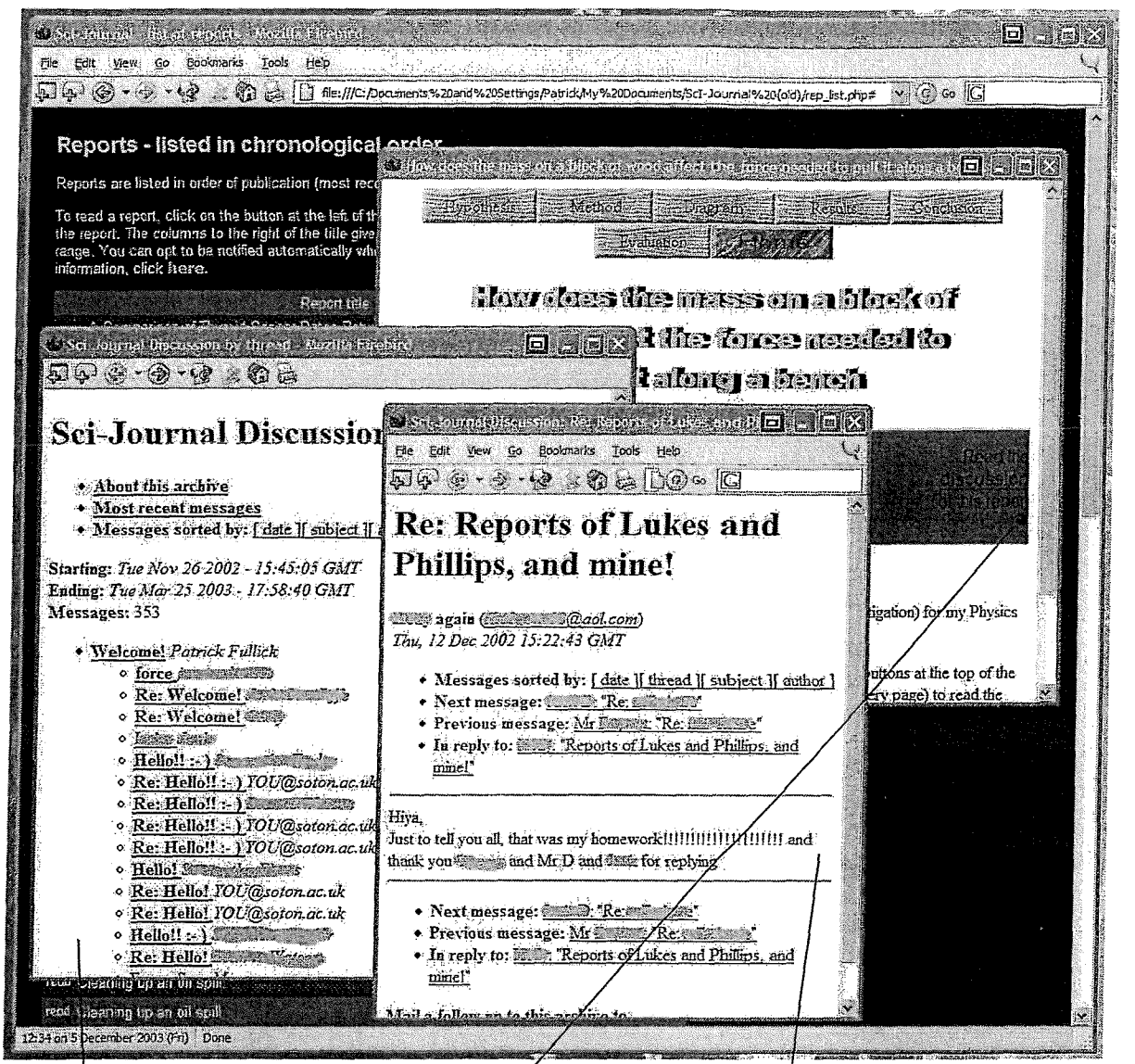
ScI-Journal homepage



The homepage of *ScI-Journal*: the journal contains a database of more than 50 reports of science investigations written by students. In addition, the "hints and tips" link on the left hand side of the page provides access to support for students who are carrying out science investigations.

Hypermail discussion forum

Note red dot on report, providing students with access to the forum. (Students' names and references to schools have been airbrushed to preserve anonymity; exceptions are names of student authors of reports already published in the journal.)



Pynebrook School – extract from student organiser

Student Code of Conduct

As a student I will:

- ☺ Listen when asked to do so
- ☺ Arrive at school fully equipped for my day
- ☺ Complete all tasks to the best of my ability
- ☺ Meet all deadlines
- ☺ Treat staff, visitors and each other with respect
- ☺ Wear the correct uniform with pride
- ☺ Be punctual and strive for 100% attendance
- ☺ Follow instructions from members of staff and prefects without comment
- ☺ Move around the school in a safe and responsible manner
- ☺ Treat the school environment with respect

Internet Access Questionnaire

Please answer the following questions as correctly as you can.

				Please don't write anything in this last column ↓
Q1	How many computers do you have at home? (Please circle ONE of these answers)	0	go to Q8	0
		1	go to Q2	1
		2		2
		3		3
		more than 3		4
Q2	What operating system(s) do these computers use? (Please circle ALL answers that apply)	Windows		1
		Mac OSX		2
		Linux		3
		other		4
		not sure		5
Q3	Where in the house are these computers? (Please circle ALL answers that apply)	living area		1
		bedroom		2
		study		3
		kitchen		4
		other		5
Q4	Are any of these computers connected together in a network? (Please circle ONE of these answers)	all of them		1
		some of them		2
		none of them		3
		not sure		4
Q5	Are any of these computers connected to the Internet? (Please circle ONE of these answers)	all of them		1
		some of them		2
		one of them		3
		none of them		4
Q6	Do you have a broadband ("always on") Internet connection? (Please circle ONE of these answers)	yes		1
		no		2
		not sure		3
Q7	Is your access to the Internet at home controlled in any way? (Please circle ONE of these answers)	by software (eg Net Nanny)		1
		by adults		2
		no		3
	Now go to Q9			
Q8	If you use the Internet, where do you access it? (Please circle ALL answers that apply)	school		1
		friend's house		2
		other		3
	Now go to Q9			

	Please don't write anything in this last column ↓		
Q9	In an AVERAGE WEEK during the school term, how much time do you spend using the Internet? (Please circle ONE of these answers)	less than ½ hour	1
		½ hour to 1 hour	2
		1 hour to 2 hours	3
		2 hours to 5 hours	4
		more than 5 hours	5
Q10	Which of these activities have you carried out during the last TWO WEEKS? (Please circle ALL answers that apply)	using the Web for homework	1
		using the Web for your own interests	2
		using e-mail	3
		using MSN messenger	4
		using Internet chat rooms	5
		downloading files	6

Internet Access Questionnaire - results

Question 1

How many computers do you have at home?	0	1	2	3	>3
Number of students responding	2	5	11	2	1

Question 2

What operating system(s) do these computers use?
All students report use of Microsoft Windows

Question 3

Where in the house are these computers?	living area	bedroom	study	kitchen	other
Number of students responding	6	11	5	1	4

Question 4

Are any of these computers connected together in a network?	all	some	none	not sure
Number of students responding	1	3	15	

Comment: Analysed in conjunction with question 1, the responses indicate that 4 students' homes have networked computers:

- 2 homes have a network of two computers
- 2 homes have three computers, two of which are networked

Question 5

Are any of these computers connected to the Internet?	all	some	one	none of them
Number of students responding	9	2	7	1

Comment: Analysed in conjunction with question 1, the responses indicate the following pattern of Internet connections from home:

Number of computers	1	1	2	2	3	>3*
Number connected to Internet	0	1	1	2	2	all
Frequency	1	4	6	5	2	1

* household with >3 computers all connected together in network

Question 6

Do you have a broadband ("always on") Internet connection?	yes	no	not sure
Number of students responding	8	10	0

Question 7

Is your access to the Internet at home controlled in any way?	s/w	adult	no
Number of students responding	1	4	13

Question 8
(students with no Internet at home ONLY)

If you use the Internet, where do you access it?	school	friend's house	other
Number of students responding	3	0	0

Question 9

In an AVERAGE WEEK during the school term, how much time do you spend using the Internet?	<0.5hr	0.5 to 1 hr	1 to 2 hr	2 to 5 hr	>5hr
Number of students responding	0	1	5	6	9

Question 10

Which of these activities have you carried out during the last TWO WEEKS?	web for h/w	web for self	e-mail	MSN mesgr	chat rooms	file dwnld
Number of students responding	19	17	17	10	0	0

Questions to students about the Hypermail forum

Message posted to the Hypermail discussion forum
on Tuesday, 17 Dec 2002 at 21:17:00

Hi folks!!

There are lots of interesting ideas here, and you've all worked very hard at using the discussion board. Now I'd like you to think a little bit more about it. In particular I'd like you to think about answers to the questions below. Please either e-mail your answers to me (plf@soton.ac.uk) or write your answers on a piece of paper and give it to me when I see you in your lesson on Thursday. Please DON'T post the answers to the discussion board - I'd like you to think about your answer without reading what everyone else thinks!!!

1. Have you ever done any school work using an on-line discussion board before? (Answer yes or no.)
2. Did you have any difficulties in using the discussion board? (Answer yes or no.) If the answer to this question is ""yes"", please describe the difficulties you had as clearly as possible.
3. Was there anything about using the discussion board that you particularly liked? If so, please say what it was.
4. Was there anything about using the discussion board that you particularly disliked? If so, please say what it was.
5. If you could change any aspect of the discussion board, what would it be?
6. How do you think working like this has helped your science work?

See you Thursday, Patrick Fullick

Students' responses about the Hypermail forum

	Laurel	James	Sarah	Eleanor	Andrea	Lisa
Have you ever done any school work using an on-line discussion board before?	No	No	No	No	no I have never done anything like this before.	no
Did you have any difficulties in using the discussion board?	No	No	No	I didnt have difficulties, (well no major problems!!)	I also think it is a very straight forward process to follow.	no
Was there anything about using the discussion board that you particularly liked?	We could help each other out and ask you and Mr D questions if we got stuck, I really like the idea!	you don't have to wait for your message to appear.	I think that the dicussion board has given the less confident members of our class an opportunity to discuss work comfortably.	I liked the way we could just come on & help each other out from home. it was good because people find it hard to talk face to face so its better them doin it over the net.	I think some good things about this is that it involves only our class so you know who your talking to. I also think it is a very straight forward process to follow.	I liked it because it gave me a chance to chat to friends about the experiment.
Was there anything about using the discussion board that you particularly disliked?	Some of the boys messed about and that didtn help	You don't know if anyone else is on the disscusion board	-	i didnt really dislike anything.	One the things I think could be altered is the fact that every single message is still on there from the beginning so it can get a bit confusing may be every few days they could be deleted.	no
If you could change any aspect of the discussion board, what would it be?	That you or Mr D checked and erased inapropiate messages before they got posted	Let others see if you are on the site	-	i wouldnt really change anything.		no
How do you think working like this has helped your science work?	We have been able to explain and help each other, it sometimes easier this way instead of face to face!!!	Other people can tell you what they think	I think discussing the work online has given me a chance to express my views more confidently, and also to use the ideas of others to help me to develop my ideas further.	I think this discussion board has helped me alot. i find it much easier speakin over the net & i understand alot more things!! I think WE should carry on doin this after christmas!! PLEASE. Thanx for everything, ive really been helped.	My opinion on the website is that I don't think it helped me. The reason for this is that all the stuff people have written is their opinions not necessarily facts. Personally I prefer not to read other peoples opinions in depth in case it confuses me. However I don't think it was a waste of time because a lot of my friends find it easier to discuss things with people of they ability so they can understand each other. On th other hand I think the actual website with all the hints and tips on was very helpful because it helps me to know what to include in my report. Once again, thank you for choosing our class to work with, I hope you have enjoyed it as much as I have. I hope you decide to try this out with another school as i think they will find it very helpful.	i think it has helped us by giving us a chance to talk to friends and to expand on the work by talking about what other people are doing.

Interview with group of students – 1 April 2003

researcher	… I'd like to start off by asking you … you use the Internet at home – what kinds of things do you use it for?
Andrea	Talking to people on MSN or Hotmail or whatever … just basically talking to my friends
Eleanor	Homework [inaudible]
researcher	How do you use it for homework; what kinds of things do you do?
Eleanor	You can go on research programs and stuff [inaudible]
researcher	Alan?
Alan	There's some homework sites you can find and stuff … GCSE Bitesize is good
researcher	Bitesize GCSE, is that the BBC website?
Alan	Yes
researcher	Any other kind of things?
James	Play games.
researcher	[repeats] Play games … what kind of games do you play?
James	Um, you know … chequers maybe … play against someone else on the Internet
researcher	You play against someone else on the Internet?
James	Yes.
Andrea	The Liverpool website … Liverpool football club … you can send three texts [SMS text messages] [inaudible]
researcher	OK – so … let's get a sense from each of you, how long you use the Internet each … day. Alan?
Alan	From about 3:30 to about 10 every weeknight [general laughter] … all day on weekends, mostly.
Andrea	I do about 3 hours a night.
Eleanor	I do about 4 or 3 hours.
researcher	So you get home from school, you're on the Internet … do you have your tea while you're on the Internet?
Andrea	Yes, I do, I eat it …
Eleanor	I don't, I don't have tea [laughs]!
researcher	Does anyone else use it that much?
Laurel	I used to, but Mum put a timer on it so now I can only go on it for an hour.
researcher	… you used to use it a lot?
Laurel	Yes, and then my Mum thought I was using it too much so she made it a timer so I can only go on for an hour.
researcher	Does anyone else have that?
Eleanor	No!
Andrea	My Mum just says, um, go on it when you want – and all that happens is that me and my brother argue about when to go on it.
Eleanor	I've got my own computer, so … no one else can go on it.
researcher	Is that in your room?
Eleanor	No, not at the moment, but it will be.

41	researcher	OK – Simon?
42	Simon	I don't go on it as much as that on weekdays 'cos it's like cheaper at weekends, so ...
43		I'm on it mostly at weekends.
44	researcher	Right, OK – Alan?
45	Alan	I have broadband, so I can go on as much as I like!
46	Andrea	So do I!
47	Eleanor	We're getting it!
48		[general agreement about positive aspects of broadband]
49	researcher	So a lot of you have got unlimited access – is that the case with you, Simon, as well?
50	Sarah	[nods agreement]
51	researcher	So ... what do you like about using the Internet, what's good about using the Internet?
52	Lisa	You can talk to people.
53	Carly	Yeah!
54	Lisa	I talk to Carly and Laurel on the Internet, and then you go on different chat ... and
55		Eleanor and stuff like that ... I talk to them, and you can have, like, instant message,
56		and you can contact, people, like, in the US and stuff like that, and you can talk to
57		people.
58	researcher	And you do that, do you?
59	Lisa	Yeah
60	researcher	Do you go home and talk on the Internet to people that you've been talking to at
61		school?
62	James	}
63	Andrea	} [together] Yeah!
64	Carly	}
65	Lisa	}
66	Sarah	[nods agreement]
67	Eleanor	Yeah, I do that but if you haven't noticed, right ... when I speak to people all day I
68		don't really speak to them much on the Internet now, it's just ... you can meet new
69		people on there and then I spend all night chatting to them ... but Andrea I can't
70		actually ... I don't speak to her.
71	researcher	How do you meet new people?
72	Andrea	Chat rooms.
73	researcher	[repeats] Chat rooms?
74	Eleanor	[laughs]
75	Andrea	But ... I've done that before then they've just turned out to be weirdoes, so I've deleted
76		them!
77		[general laughter]
78	researcher	Does anyone at home monitor – watch out for – the kinds of things you're doing on the
79		Internet?
80	Eleanor	No!
81	Andrea	Yeah, my mum does.
82	researcher	Eleanor, no one with you?

83	Eleanor	My mum don't know how to turn it on yet ... she doesn't, literally ... !
84	Andrea	She lets me go on MSN 'cos it's just your friends, but not on the chat rooms ...
85	Lisa	My mum and dad do check it, but not that often 'cos they don't know my password, so
86		... [laughs] ... but they tell me what not to do and what not to say and stuff like that.
87	James	My parents don't have a clue really about how to use a computer, so ...
88	Laurel	My mum used to but then I kind of find a way around it ...
89	Carly	She had to prove it to her ...
90	Laurel	Yeah, I had to prove who I was talking to!
91	researcher	So you haven't got any kind of software on the machine at home that stops you
92		accessing chat services ...
93	Andrea	My mum did that but then something went wrong 'cos you can go on anything to chat
94		to ... plus, 'cos she doesn't know how to do it ...
95	researcher	Is there anything you don't like about using the Internet?
96	Eleanor	[quite quietly] Porn! [quickly puts hand over mouth and shrinks into chair]
97	Andrea	All the free stuff that comes up!
98	Simon	The free adverts!
99	Carly	Yeah!
100	Laurel	[nods agreement]
101	researcher	How do you mean, the free adverts?
102	Andrea	} They just come up ...
103	Simon	} They just ... yeah
104	Andrea	... and, I went on this site yesterday called ww [sic] dot [inaudible] dot com - don't go
105		on it anyone – and what happens is that it comes up on the screen and it says "you
106		are an idiot" and then they keep, like, reproducing and at the bottom of the bar they
107		keep coming up and I had to shut down the computer and everything ...
108	Lisa	... and sometimes when it freezes and goes really slow ...
109	Laurel	My Internet disconnects me sometimes ...
110	Eleanor	Yeah, so does mine ... I'm getting broadband soon though.
111	researcher	Do you know why it disconnects you?
112	Laurel	No, I don't. I think it's that some sites have got a ban against AOL or something ...
113	researcher	Would you say that you use the Internet as much or more than you watch television?
114	Andrea	Less – no, the Internet more.
115	Alan	I watch TV and go on the Internet [general laughter]
116	Carly	That's what I do!
117	Lisa	So do I!
118	researcher	What, at the Simone time? Wow! Does that mean that you've got television on your
119		computer, or that you have a television and a computer?
120	Alan	No, I've got TV over there [gestures] and I watch that while the computer's on .. I
121		s'pose I could find the TV on my computer if I looked.
122	researcher	I'm going to move on ... and ... ask you some questions about what we were doing
123		before Christmas. If you remember, we had a web site with science investigations on

124		it, and you then did a science investigation your selves and you were talking online to
125		each other about your science investigation. What did you like best about doing that?
126	Eleanor	It was safe, because you chatted to people you know, and ... you could ... mostly,
127		'cos there was, like, a large amount of us on that web site – it was, like, a whole class
128		– even if you had a problem or something you could always log on there and there'd
129		guarantee one person would be on there so they could help you.
130	researcher	What do the rest of you think about that – Alan?
131	Alan	It was, kind of, like a chat room, but a chat room just for a certain amount of people
132		and not everyone you don't know
133	Eleanor	So it's safer.
134	researcher	Alan, is that good for you or is it bad?
135	Alan	[pauses] In the middle!
136	Eleanor	[laughs]
137	researcher	OK ... how many of you use chat rooms regularly on the Internet?
138	Laurel	}
139	James	}
140	Sarah	} [raise hands]
141	Alan	}
142	Lisa	}
143	Carly	}
144	Simon	I never use them.
145	Andrea	MSN, not chat room. MSN isn't chat rooms, where you just talk to your friends.
146	Eleanor	I used to go on chat rooms.
147	researcher	OK, let's be very specific about this, then – how many of you use MSN regularly?
148		[students raise hands, researcher counts aloud] One, two, three, four, five – Laurel, do
149		you? [Laurel shakes head] No. How many of you use chat rooms? [students raise
150		hands] Three, OK fine.
151	Alan	[to James] Yes you do James!
152	James	[half raises hand, waves it] Kind of.
153	researcher	[repeats] Kind of, OK. Can any of you explain to me, then, the difference between
154		MSN and a chat room? [all students raise hands] I don't mind – James, go on.
155	James	MSN is where you can get, like, a certain person's e-mail then you can talk to them
156		personally without lots of other people joining in the conversation.
157	Laurel	Oh, right, I know what you mean.
158	Eleanor	You have one to one conversations with people, not like ...
159	Andrea	You can on chat rooms as well ...
160	researcher	So ... is MSN better than chat rooms or ...
161	Andrea	No, with chat rooms it's just anyone in the whole world can go on it ... and that anyone
162		can just talk to you ... and on MSN it's just your friends.
163	Carly	You put down their names.
164	Eleanor	You can add friends – you get a list ...
165	Andrea	You get a buddy list.

166	Eleanor	... yeah, and then you can add the people you want to on there nobody ... nobody can
167		just add themselves they have to ask you and you can either decline them if you don't
168		want them to ...
169	James	And it tells [inaudible] the whole time.
170	Eleanor	Yeah.
171	researcher	OK, right.
172	Laurel	[inaudible] because they've got a buddy list ... also you can instant message them and
173		you can invite them to private rooms like you're on about [gestures towards Andrea
174		and Eleanor].
175	researcher	So, thinking about MSN and chat rooms, and what we did before Christmas, what's
176		the difference between those ... two things and the thing we did before Christmas?
177	Andrea	The thing we did is basically just like MSN really.
178	Eleanor	Yeah – something like that – but that was based on a topic, that was science, but
179		MSN is chat.
180	Andrea	On MSN it tells you who, when people are on.
181	Lisa	It was like a message board on ... our web site ... like a message board.
182	researcher	So is a message board something different to MSN and a chat room?
183		[general agreement]
184	Lisa	'Cos you aren't talking ... to them directly, you've got to wait for them to come online.
185	Andrea	You have to be online, yeah, and you click on this thing, you sign in, you put your e-
186		mail address in, and there comes up with all the people you've got on your list they,
187		say like your address book at home but e-mails, and if, like, Eleanor's on it'll say "a
188		sweet little chick is online" and you double click on her ... and you can say hello –
189		well, if she's talking to me!
190	Eleanor	[laughs]
191	researcher	That's MSN is it?
192		[general agreement]
193	researcher	But a message board isn't like that?
194	Eleanor	A chat room is ... they have like thousands and thousands of rooms and you can just
195		go into the room and you get loads and loads of people just asking you like your age,
196		sex and location and that, just wanting to chat to you, so I mean it's not specific
197		people, it's just anybody from anywhere.
198	researcher	What's the difference between those two things and a message board?
199	Andrea	What, the thing that we ... the message board.
200	Carly	The Scl-Journal thing?
201	researcher	Well, the Scl-Journal thing or ... Lisa, have you used message boards before?
202	Lisa	Yes.
203	researcher	So what's the difference between how a message board works and how the other
204		things work?
205	Lisa	In chat rooms and messengers and MSN you're actually talking to them at that time
206		and they're actually replying at the Simone time but with a message board you have to
207		wait for a reply.

208	Andrea	'Cos it's like an e-mail not like a conversation.
209	Alan	On MSN you can send whole files, like you could send a picture or music or
210		something.
211	Eleanor	... and documents.
212	researcher	So, thinking about what we did before Christmas, what would make that better and
213		more useful for you, do you think?
214	James	When you entered it, to see who else is on it as well ... so you'd know if someone else
215		would be there to answer you.
216	Laurel	Chat room, so it's more like a flowing conversation instead of, like, one topic at a time.
217	Eleanor	Yeah.
218	Laurel	'Cos that's what it's like in message boards, because you have to wait for them to
219		reply. But if when it's in a chat room it's just flowing constantly.
220	Andrea	Just like us talking, but I could like send Mr D a message then ... you could have a
221		reply from him half an hour later or something. But on that you can just have a normal
222		conversation.
223	researcher	So ... what would we have to do to make it work?
224	Andrea	I don't know.
225	Carly	You'd have to turn it into a chat room, sort of.
226	Alan	Actually have usernames and stuff, yourself.
227	Eleanor	Have your own, like ... secret names and have, then you can see – I think they should
228		have a list of everybody who's on and it should, like, colour co-ordinated a bit – red if
229		they're not online and green if they are on so you can just click on them and have your
230		online conversation with them about your topic.
231	researcher	Right ... so some of you would have to be online at the Simone time.
232	Andrea	Yeah ...
233	researcher	Well, it sounds as though anyone would be online at the Simone time as Alan doesn't
234		it, because Alan's on there a lot!
235	Andrea	I reckon he's like, Saturday morning on there, midday on there!
236	Alan	I was in there all day!
237	researcher	Right, OK, so if we were to do that, would that be something that you would be
238		interested in trying?
239	[general assent]	
240	researcher	OK ... was there anything about doing science online that you didn't like?
241	Eleanor	No, not really.
242	Laurel	It was a bit hard, like, to stay to the topic of science because you wanted to talk about
243		something else!
244	Eleanor	Yeah, me and Laurel we were always ...
245	Alan	} [laughs] It being science was bad enough!
246	Andrea	} Or, maybe it's because it's ...
247	Andrea	it's just, um, us, on there, it's not like a teacher that we can actually ask them what
248		necessarily they will know , do you know what I mean? Someone that will know about
249		science.

250	Alan	Mr Dupont was online sometimes.
251	Andrea	So it's just us, it's just the students and ... we're not ... if we want help with someone
252		else they might not know it, 'cos they're the Simone as us but if there's someone like a
253		teacher or someone ...
254	researcher	So if we were to repeat it, what would you think about having more people involved?
255	[general assent]	
256	Andrea	} Yeah
257	Carly	} Yeah
258	Alan	More people to ask for help.
259	Simon	Other schools as well.
260	Eleanor	Yeah ...
261	researcher	Now somebody said ... something rather interesting in one of the responses [to the
262		survey] – let me just read it out to you: "I find it much easier speaking over the Internet
263		and I understand a lot more things" someone wrote. Do you find it easier to talk to
264		people online than you do face to face?
265	Alan	} Yeah.
266	Laurel	} [Nods]
267	Lisa	} [Nods]
268	Sarah	} {Nods] Yeah.
269	Andrea	No.
270	Carly	Yeah, sometimes you can because they can't see who you are.
271	Eleanor	Best thing is they don't know what you look like.
272	Andrea	I find it easy to talk to people one on one or on the Internet.
273	researcher	When you're on the Internet are you <u>you</u>, or are you somebody else?
274	Andrea	No, I'm me.
275	Alan	Depends.
276	Andrea	Oh, what do you mean, do I change how I ... ?
277	researcher	Do you change your name?
278	Eleanor	} I'm even stupider on the Internet, aren't I [to Alan – he nods to Eleanor in agreement]
279	Andrea	} No, my name's "I like boys" 'cos my brother put it up as that..
280	Alan	Yeah! [smiles]
281	Eleanor	I'm even stupider on the Internet, because I mean ...
282	Alan	} She's worse than normal.
283	Andrea	} No, but I act normally.
284	Eleanor	Yeah, though I am character normally then, aren't I?! [giggles]
285	Andrea	You act like you act in your life, most of the time.
286	researcher	Do you think it might be easier to talk to people about – I'm thinking about science, I'm
287		not thinking about personal things – talk to people about science if you didn't know
288		them?
289	Andrea	Yeah, probably.
290	Eleanor	[has raised her hand, urgently seeking to speak] I want to say something – [comically]
291		I want to speak!

292	researcher	Yes?
293	Eleanor	I reckon [laughs] because – if it were on a science topic sometimes people get
294		embarrassed if they think that face-to-face someone will laugh if they don't know
295		something ...
296	Laurel	} [nods vigorously] Mmm!
297	Andrea	} [Quietly] Yeah.
298	Eleanor	... so that's why I found it easier speaking on that, because I mean they could ... like,
299		explain things better than you could face to face and then it was just I had more
300		confidence on there.
301	Andrea	But ... that thing you said about more people getting involved is, if we don't know them
302		we don't know, like, how ? ahead they are...
303	Eleanor	Yeah.
304	Andrea	... so if you say something they might laugh at you, say "Oh, you don't know that!"
305	Eleanor	Yeah, that's the only thing, 'cos we all know each other, we're all friends kind of –
306		apart from Andrea! – [bell goes]
307	researcher	... so it might be easier for some of you if you felt that ... are you worried about saying
308		something or writing something in the discussion group that someone else is going to
309		criticise?
310	James	} [Shakes head]
311	Simon	} [Shakes head]
312	Sarah	} [Shakes head]
313	Andrea	} No.
314	Eleanor	... if we bring people in though, say like we joined up with another class let's say from
315		another school, we don't know them, and I mean people could be really, really brainy
316		and someone ... we could ask them something and they could be, like "well, didn't you
317		know that?!" so you don't really know, but we all know each other so we all help each
318		other.
319	Andrea	We all know to ask James! [general laughter]
320	Alan	[laughs] No, we all know to ask you!
321	James	But it would be easier – you wouldn't, like, walk up to someone who you hadn't got a
322		clue about and ask them "Oh, what's, like, this ..." and, but on the Internet everyone,
323		you could, like, make yourself anonymous or something, so they would answer
324		anyway.
325	researcher	How would you feel about something where you could ask a question anonymously, or
326		you could contribute ...
327	Andrea	} It doesn't bother me anyway.
328	Eleanor	} It doesn't bother me.
329	Lisa	[Nods in agreement]
330	researcher	) ... without people knowing it was you?
331	Andrea	It doesn't bother me if they know that I'm thick or whatever ...
332	Carly	Yeah, but ...
333	Eleanor	You're not thick!

Carly … some people would prefer it though. Sometimes I would prefer it.

Eleanor Yeah, I would sometimes.

[Pause for brief discussion with teacher concerning bell which has just sounded]

researcher What I was wondering was whether you might like to involve pupils from another school?

Simon [nods]

Carly Yeah.

Laurel I was going to say that, if we were going to do that they'd have to be in a top set, 'cos then we'd know the abilities that they'd have.

Eleanor Yes, there's good and bad points to that …

[fire alarm sounds, end of interview]

Interview with class teacher – 1 April 2003

researcher I'd like to start off by asking you to tell me a bit about yourself and where you've taught … that kind of background …

teacher Yeah, this is my seventh year of teaching, I came into teaching later on, having been a technician for about 12 years in total, both at [name of sixth form college] and at [name] University, and in between, milkman, vacuum cleaner salesman – so a bit of everything!

researcher … how long have you been here?

teacher This is my fourth year. I came in as second in department; deputy curriculum leader and the head of department left after my first year. I didn't get the job, the second head of department came in and left after another 18 months or so. I then took over as acting curriculum leader at the Christmas, and was confirmed from after Easter. So I've been there for almost a year.

researcher I've known you since you were at [secondary school], and I've … always associated you as a science teacher who is interested in ICT …

teacher Yes

researcher … that's an accurate description of you?

teacher Yes, yes it is, yes

researcher … and what cultivated your interest in ICT?

teacher I don't know really, I kind of, just sort of got into it. I taught myself, when I was a technician, the basics of DOS and then Windows, and really it's all been self-taught. I did a C course – C++ language course – but, I mean, generally things have been self-taught. They just interest me – the wealth of information that's out there … and how powerful the tool is, it's fantastic, I think it's still under-used.

researcher Right. And is ICT a part of your portfolio of things that you are responsible for in the job here, or is it just an interest, as it were?

teacher Within the department, when I came in, I took over as ICT person as we were very poorly equipped for ICT. And that was then written in to various schemes of work over the next few years. And I've taught a little bit of IT at GCSE level and Key Stage 3.

researcher So you've encouraged some of the youngsters that you've taught to contribute things to Scl-Journal, I know …

teacher Yes …

researcher … and so, when I contacted you and said "are you interested in a study involving some of your youngsters?" you responded … positively … and I wonder what you thought about in terms of getting involved and why you made a choice to get involved in a research study?

teacher That's a hard question really. It interests me. I did part of my dissertation for my BEd on the use of ICT in schools, and it's just really developed from that. I just find it interesting. I think … I don't think we use them enough, and for the right way, I don't think kids are using them properly, I think they need a lot more guidance. So I was just really interested to see what you were doing. I've always used the [Scl-Journal] site,

41		and I found it particularly useful, and I think the kids that I've used it with found it
42		useful as well.
43	researcher	So did you have any ideas about what you or the school or what the pupils might get
44		out of whatever it was that we were going to try and do?
45	teacher	I was hoping that the kids were going to get inspiration. Inspiration to carry out Sc1
46		properly really, which I think some of them have, because it's not really something that
47		is carried out properly in school at Key Stage 3 or 4 – Key Stage 4 is hoop jumping,
48		and Key Stage 3 is really preparing them to jump those hoops. It doesn't sit right, but
49		at the end of the day that's what we have to do.
50	researcher	When you say "carry out science investigations properly", what kind of vision do you
51		have for a properly carried out science investigation?
52	teacher	Well ideally it's: Here's the title, find this out – where are you going to go from here?
53		What evidence are you going to look for, how are you going to do that? Has anyone
54		else already done it? Go away and see what you can find out. Do you agree with what
55		they've done?
56	researcher	So you'd like something fairly open-ended in other words, then?
57	teacher	Yes, yes
58	researcher	And very much – would the word "creative" describe ...
59	teacher	Absolutely, yes.
60	researcher	Right. What do your colleagues in the department think about this kind of work?
61	teacher	It's mixed. Generally they're interested in what's going on and will be interested in the
62		feedback afterwards. One in particular is dead keen to get in there and do the same.
63		She's got a top set Year 9 group as well, so it follows in really.
64	researcher	And this is the one we think we might use after Easter?
65	teacher	Absolutely, yes.
66	researcher	Have you discussed this at science department meetings?
67	teacher	We have, yes, and I want to give a bit of feedback today, we've got a meeting tonight,
68		and I want to give a really good feedback of what's happened now that we're wrapping
69		up, and after the interviews.
70	researcher	Oh that'll be very good
71		...
72	researcher	OK, I'd like to spend a bit of time thinking about the class, we've set the context here –
73		we've talked a bit about you, the department we're working in – an environment that's
74		positive, favourable and supportive. So the class that we've been working with is a
75		Year 9 group ... can you describe where they fit in the school, and in the year in
76		general ...?
77	teacher	They were chosen as an accelerated group ... we have two accelerated or top groups,
78		and the other two are mixed-ability. So theoretically in the year half, which is
79		determined by tutor group, they are the best in that year half – at science.
80		...
81	researcher	So the group that we've been working with are in one half of the year, and they are the
82		top group?

83	teacher	Yes.
84	researcher	And ... what would you mean by "top"?
85	teacher	They've consistently produced levels that are above the others. So we've looked at
86		the test results from the year before, we looked at their indicated grades, and it was
87		also attitude ... which generally is pretty good across the board.
88	researcher	So ... they're doing their SATs in a few weeks time ... what kind of SAT scores are
89		you looking for from that group?
90	teacher	They should be sixes, sevens. There may be one or two fives that pop in at the
91		bottom, but there certainly shouldn't be anything below that.
92	researcher	From that description, that seems to imply that they were brought together as a group
93		for the first time this year, is that true?
94	teacher	That is true, yes. There is a certain amount of overlap in different subjects, certainly
95		the core subjects, but there are some in there who are top set for science but are way
96		down in English or maths, which is quite interesting, so they are very mixed across the
97		rest of the curriculum.
98	researcher	So in September of 2002 that would probably be – or would be – the first time that
99		they'd met together as a group?
100	teacher	Yes.
101	researcher	Would it be fair to assume that they all knew each other – approximately as it were –
102		before they met?
103	teacher	Yes, they would have been year-halved fairly early on from at least Year 8 and maybe
104		in Year 7 as well, so those three tutor groups would have been working together right
105		through. So they would have known each other, if not been in the same classes all the
106		time.
107	researcher	So obviously you've known them as a group since September ...
108	teacher	Yes.
109	researcher	... does your knowledge of them as individuals go back before that?
110	teacher	Some of them – probably four of them, maybe five of them – I've taught before.
111		Possibly in Year 7 – I didn't teach any of those in Year 8.
112	researcher	So they are fairly new to you as well.
113	teacher	Yes.
114	researcher	How would you judge them as a group? How do they seem to you?
115	teacher	They're pulling together now pretty well. They were very slow to stick together at the
116		beginning, but they're actually pulling well as a group together now, and ... they've
117		sort of divided themselves up into little cohorts and within those cohorts there's a
118		definite academic achiever I would say, who is actually helping the others.
119	researcher	And you haven't engineered that?
120	teacher	Not at all, no. I very much prefer them to work how they want to work, as long as
121		behaviour and things is OK I don't have a problem with that, and it's worked really well
122		in a couple of the instances, there's been some high achievers who've really pulled
123		the others up. It hasn't been a downward ... they [the lower achieving] haven't pulled
124		them [the higher achieving] down to their level, they've pulled them up.

researcher Is that something the school encourages ... or has that come from the youngsters themselves?

teacher It's come from them. We have a bit of an issue across the school about where kids sit and how they sit and who they interact with in class. I don't particularly in my lessons, I make it absolutely clear to them that I will sit them around if I need to, and I haven't needed to – certainly not with that group. I've also made it very clear to them from the beginning that they were the best, so they were in the accelerated group, and I think that's had a really positive effect on them this time, and developed what they've given me in terms of answers and things, very much on at levels. They've pulled themselves up, they've wanted to be up.

researcher Right. Would there ever have been any question of them moving out of that group if they weren't pulling their weight?

teacher Yes. We lost one at the first changeover (we have periods when people are doing the same topics and we can change down), we had one who changed down ... and we've got one who's been struggling and I've actually moved out before the SATs.

researcher How do they get along as a group? You seem to paint a picture of a group that support each other, is that true?

teacher They do, yes, and across the cohorts as well. Took a little while to do it, but they've really pulled together, and I think because I've very much told them that I've told them that they are a group apart from everybody else in that year half I think that's made a difference to them.

researcher I know that when teachers get together they often describe the characters that are in a class. Is there anyone that you would particularly highlight in there as interesting?

teacher Well we've got one who's excluded at the moment – in fact two of them are now excluded, two boys, neither of which I've had any trouble with at all – who are really interesting characters and who have actually stayed on task pretty much. You met Andrew – he didn't get his [permission] form back, and so he didn't take part in the whole thing. And one of the brighter ones, Liam, who is excluded for setting fire to the maths room. We've got Carly who I think is in on the interviews ...

researcher She is.

teacher ... she's one who has interesting friends ... and there's Andrea who's probably the brightest kid I've ever taught. Eleanor's a character – I taught [her] in Year 7 and – very lively girl, very chatty. She went into the accelerated group in Year 8 and felt she was struggling because her friends weren't on the same level as her, and I don't think she's ever really been pushed. So having her in this group has worked really well because she's been working really closely with Andrea and there's been a change around from ... October.

researcher They sit together don't they?

teacher They do, and I don't think they were particularly friendly before, so that friendship's developed (they're probably in other groups as well) over the year, and it's really seen Eleanor go up. I thought on a good day she'd get a 6, but there's a possibility she could get a 7.

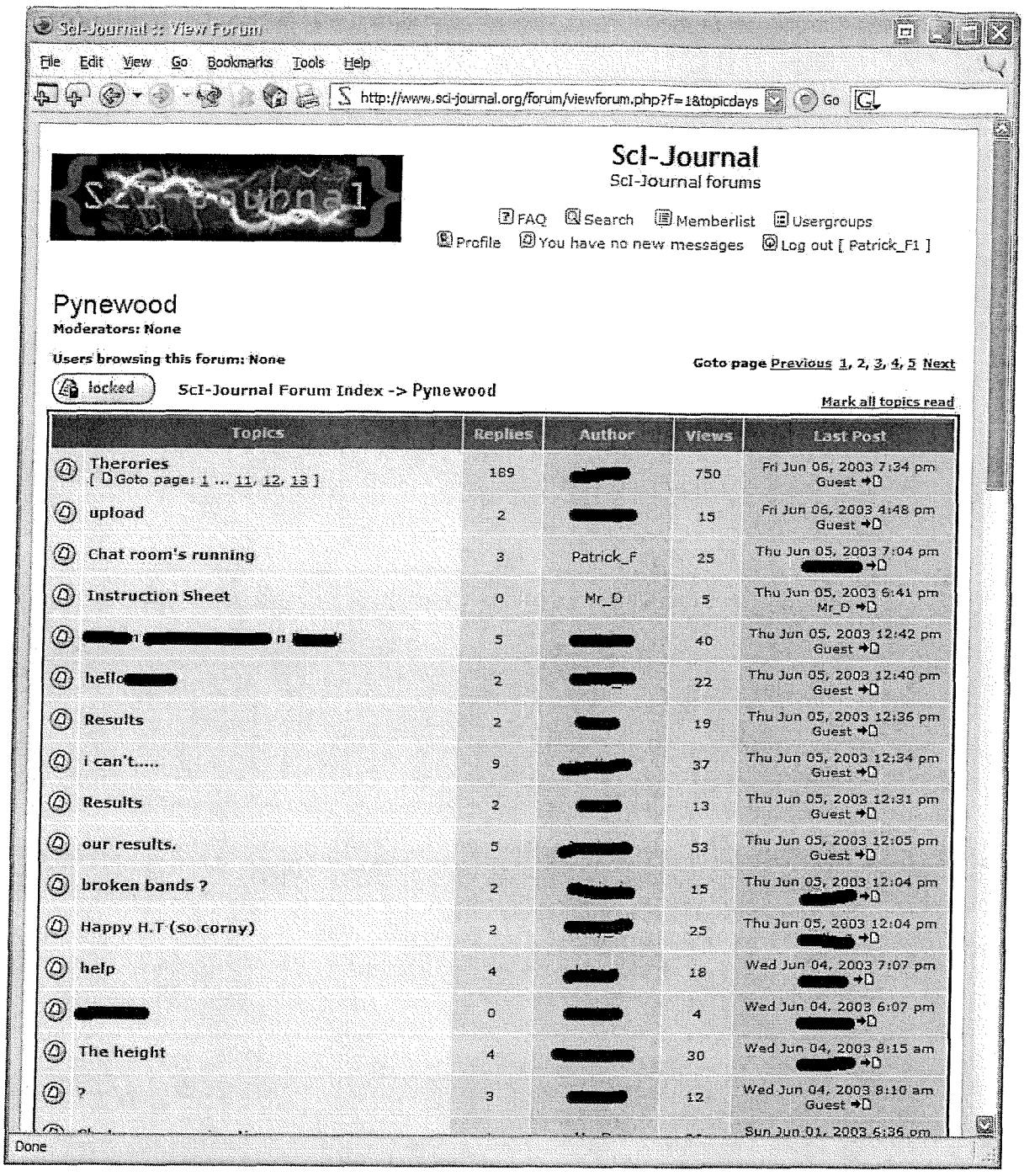
167	researcher	I'm hoping that we've got [for a group interview] six of them who responded by e-mail
168		to me when I asked them to think about what they'd done ... [lists names]
169	teacher	Laurel and Andrea, now they're quite interesting. Laurel has come on so much after
170		doing this. She was a bit of a quiet one, she certainly wasn't at the top of the group,
171		but this really sparked her, and I had e-mail after e-mail over Christmas about the
172		whole thing.
173	researcher	I've had lots of e-mail from Laurel too!
174	teacher	And her parents were really positive about the whole thing at parents evening, which
175		was wonderful, really, really good. Alan is the typical bright but bone-idle lad.
176	researcher	This is one of the additional three [over and above the six who reflected on the online
177		experience by e-mail].
178	teacher	Simon I've actually moved out of the group. He 's the one who was struggling a bit, so
179		he's not in the group any more but I thought it was worth putting him in because ...
180		there was some correspondence from him.
181	researcher	So let me just go through these systematically ... you've mentioned Eleanor already
182		as somebody who's really come on during the course of this year ...
183	teacher	Absolutely.
184	researcher	... are you surprised about any of these and their reactions to the group and so on?
185		Eleanor was somebody who responded very positively.
186	teacher	She's got an awful lot of energy, and she's starting to channel that in the right way.
187		And she very much got into the whole project ... and I think that's pulled her and
188		Andrea together, that's really formed their friendship.
189	researcher	And James is actually the only boy out of that group of six who responded – now is
190		that typical of James?
191	teacher	He's very quiet, he's one of these lads that just gets on with everything ... he worked
192		with the girls. They were the ones who, when they were doing their practical work, had
193		built the sail and put over the flag on it and things. They work very well. He's the
194		guiding character I think academically in that group [cohort] – he always works with
195		the girls.
196	researcher	James and Laurel certainly, and maybe one or two of the others, have produced their
197		work as web pages rather than as Word documents. Is that something that activity has
198		encouraged them to do, do you think?
199	teacher	Yes. James I think is probably the sort of lad who's been doing that before, because
200		his web pages are very ... pleasing to the eye. In fact, if I were to look at it [James's
201		work] I'd say it's either the computer-nerdy type person or a girl. And James is not a
202		computer-nerdy type lad. So he's put the extra in there to get it like that.
203	researcher	How is he in class – is he outgoing and extrovert, does he contribute a lot to class
204		discussions?
205	teacher	He'll contribute, but he's not very outward ... he's one of these people that, if the right
206		answer isn't coming out, he'll then come out with it, as if to say "for goodness sake!",
207		you know.
208	researcher	Does he like to close discussion down a bit? Is that the case?

209	teacher	Yes, if he thinks it's going off on the wrong tack.
210	researcher	That's interesting, because I think many of his contributions to the discussions were
211		quite concise and focussed and to the point, where some of the others were engaged
212		much more in a chatty kind of approach.
213	teacher	James is straight to the point.
214	researcher	And you would say that was typical of James?
215	teacher	Absolutely.
216	researcher	OK. Sarah.
217	teacher	Yes, we had two Sarahs, so that made it a bit awkward. The one that actually
218		contributed the most is probably the slightly lower academic [sic] of the two. She
219		works with Andrea and Eleanor – so they work as a group and there's five of them.
220		Carly has kind of gravitated into that group as well. Carly was very much on her own
221		at the very beginning and was very, very quiet – [I] had trouble getting anything out of
222		[her] – however, now she's come out of it, and I think she's got confidence through
223		working with these other people. As I said, her friends, the ones she hangs round with
224		at school, are not anywhere near as bright, so it's really done her the world of good to
225		get away from them.
226	researcher	And again, there were a number of quite lengthy contributions from them, are they
227		active contributors in class those three [four] [Eleanor, Sarah, Andrea, Carly]?
228	teacher	Andrea will. Andrea's very much up the front there, contributing the whole time.
229		Eleanor will as well. Sarah needs a bit of poking to get an answer from, I think
230		because they will have discussed it in their group … because I think that sometimes
231		Andrea does the talking for them. But they've usually discussed it first. Eleanor will get
232		in there because she's trying to get up to where Andrea is in the group. And Carly will
233		… Carly's actually just starting to … offer things forward. Happy if I ask her; she's not
234		one of these shrinking violets, if I say come on, she'll come straight out with it. So
235		she's coming on.
236	researcher	And Lisa is not associated with those?
237	teacher	No, Lisa works with Laurel.
238	researcher	And we know that Laurel was one who [from analysis of the online transcripts] came
239		out very, very strongly.
240	teacher	Absolutely.
241	researcher	Now would that be the case if you were to hold a classroom discussion?
242	teacher	No, not at all. I heard almost nothing from her until that point. It was like a trigger for
243		her and she really bit into it, and it was wonderful to see. And, to be perfectly honest,
244		what she produced wasn't fantastically high level, but she took it and she ran with it.
245		She'd never produced a web page before, so in terms of just switching her on, that
246		was fantastic.
247	researcher	I certainly got the sense in which she was engaged with it all, and certainly seemed to
248		be the most enthusiastic member of that class as far as this was concerned …
249	teacher	Definitely.

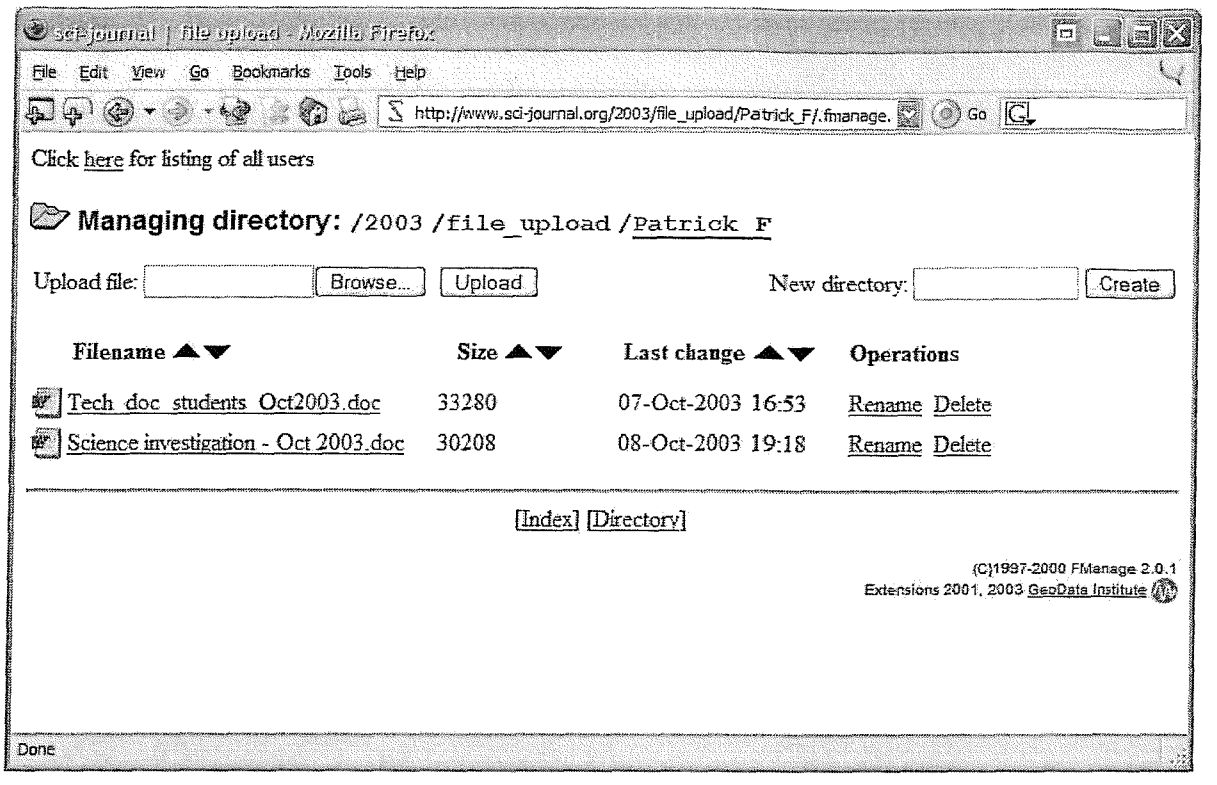
researcher ... although lots of them were writing and saying wow this is great, can we do more of this? How about Lisa? Does she go along in Laurel's wake?

teacher Normally in class it's kind of equal, but definitely Laurel's led this. They're both quite quiet girls, they sit on their own, it's just the two of them sitting there; they are quite quiet girls. And there's been a lot more class participation since they've done the project, there's no doubting that.

Scl-Journal phpBB forum (study 2)

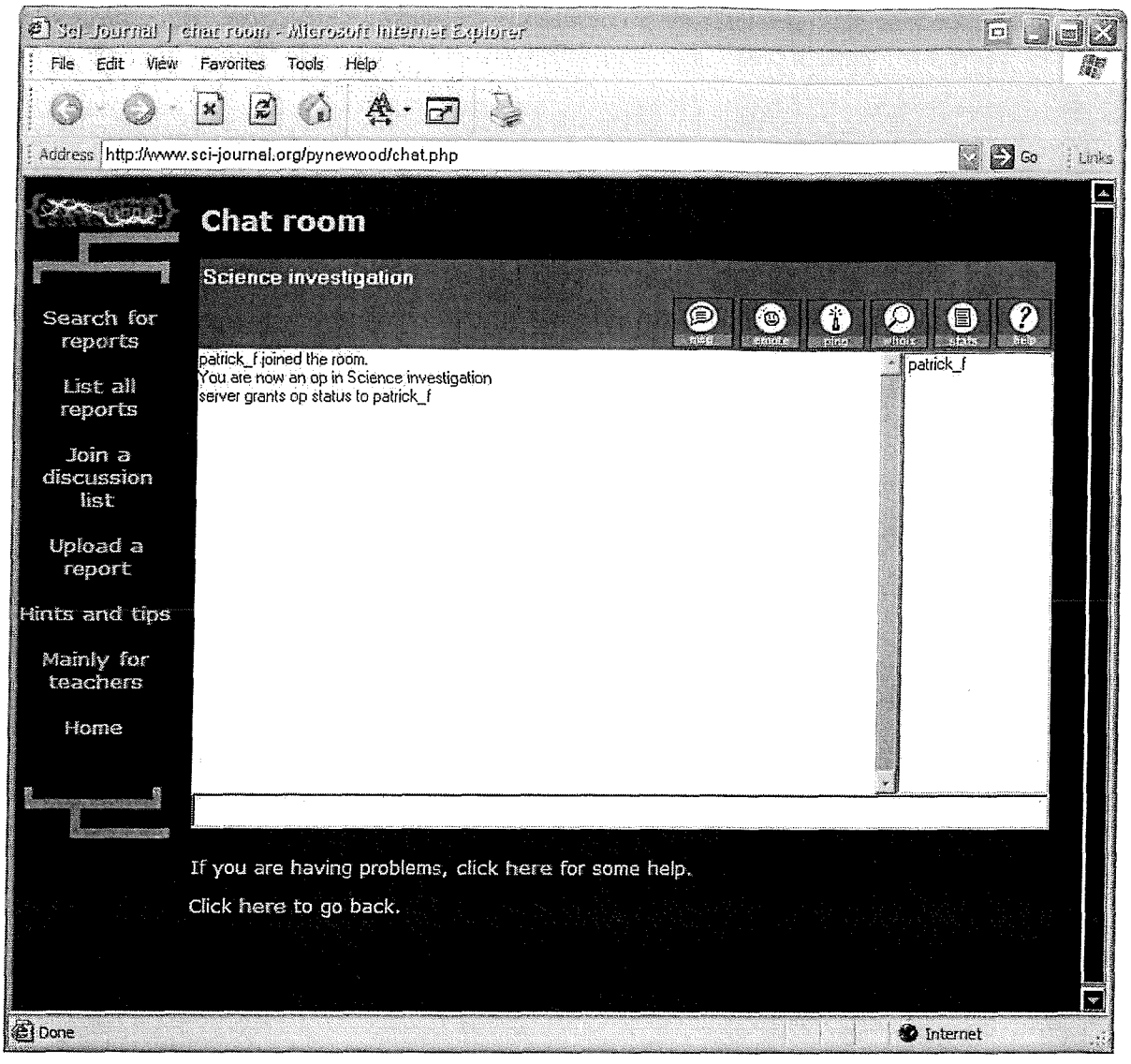


File-sharing interface (studies 2 & 3)



Note – this screen capture shows the file-sharing environment employed for the final study (study 3). This was almost identical to that used in study 2, with the addition of some small refinements such as the ability to create new directories and a header line ("click here for a listing of all users") as an aid to navigation.

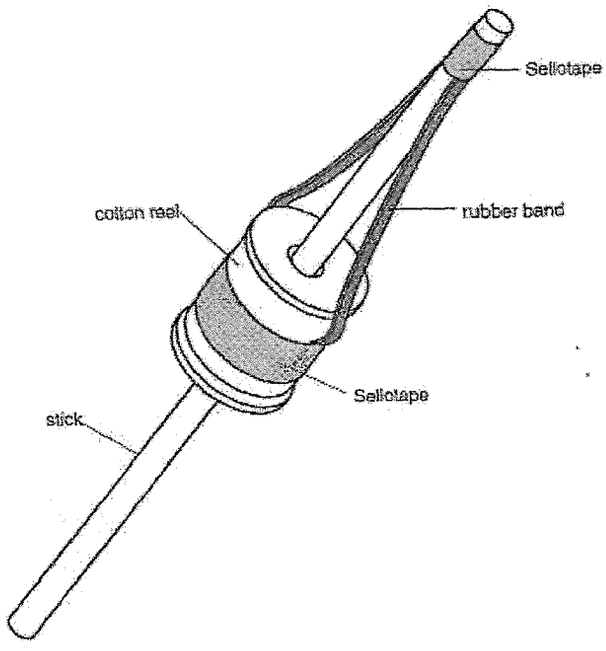
Chat room (study 2)



Study 2 – investigation briefing

A company producing toys for children aged 4 to 7 has had an idea for a new toy which they plan to market as *Jumpin' Jiminy*. This toy will have a clown's head and body mounted on a rubber band connected to a stick. When the stick is placed on a flat surface and the head and body are pulled downward and released, the toy will jump into the air.

The company have engaged you as a consultant to advise them about the design of *Jumpin' Jiminy*. They particularly want to know about the height to which the toy will rise when the head and body are pulled downwards and released. To help you to do this, you will need to build a simple model of the toy from everyday materials, like this :



Build this model, and then design and carry out an investigation using it to see how the height to which the toy rises depends on how far the head and body (the cotton reel!) are pulled down. Before you start, use your science knowledge to predict the relationship that you think you will find.

Hints

- Remember that you will need to take enough systematic and reliable results.
- Some sort of preliminary trials may prove useful too.
- You will also need to consider how you will present your data.
- To help you, refer to the "Hints and Tips" section of the Scl-Journal website at `www.ScI-Journal.org/hints.php`

Good luck!

Please remember that this will count towards your GCSE marks!

Study 2 critical incidents – triad RCO dimension q

CI no	CI recall	source ref	data
1	✓	chmy14_1287	its a bit hard to follow [name]
		chmy14_1288	i no
		chmy14_1290	she cant spell properly
		chmy14_1293	she rushes to say evry thing
2	×	folg06_089	[name] ur a bit of a boff outside of school aren't you
3	×	folg16_014	[name] is correct as allways
4	×	folg11_011	maybe we dont know yet but once we have done the test we will know
		folg11_012	[name] does i bet
		folg11_013	lol yeah i guess she prob would no
5	✓	folg58_028	WE SHOULDN'T HAVE TO PROVE IT 2 U [NAME] BECOZ ME AND [NAME] R DA THE BEST AND UR NOT
		folg58_033	yes u do have to prove it
		folg58_037	i do not agree with u [NAME]!!!
		folg58_038	[NAME] U CAN BE GREAT 2 BECOZ U USED A CAMERA BUT [NAME] CAN'T
		folg58_049	If u read mine properly u will see that I do in fact actualy say why I picked this method over other ones similar to the ones you used
6	×	chjn05_273	that the futher we push down, the higher the jumpin jiminy goes
		chjn05_274	[teacher] but is it even each time?
		chjn05_275	dunno
		chjn05_276	ask [name] lol

Notes (refer to CI numbers)

1. Chatroom, private conversation (2 students) – personal qualities of another student and the nature of her personality in class and online.
2. Forum (3 students) – closing comment in discussion about factors affecting behaviour of Jumping Jiminy.
3. Forum (2 students) – comment following initiating contribution concerning measuring height.
4. Forum (2 students) – personal qualities of another student at end of discussion (involving 5 students in total) about behaviour of Jumping Jiminy.
5. Forum (3 students) – discussion (involving 7 students in total) of methods of measurement described in report.
6. Chat room (teacher + 2 students) – reference to (implied) personal qualities of another student.

Study 2 critical incidents – triad RCO dimension p

CI no	CI recall	source	data
1	×	folg06_086	exactly and the rubber band because if it is longer it will jump higher because it won't be stopped as early(i can't think of any scientific words so just play along with it)
2	×	folg43_003	Loooking at [name]s results, I could see that where she had circled and labelled points "odd" that these were her errors made and think that she could have put error instead of odd, and should have mentioned that
3	✓	folg44_004	I agree with [name], [name], you explained about the heat proof mat in your method, which makes us think that that is yhour chosen idea. but then, you go onto the ideas on accurate measuring, explaining how you are going to you use a heat proof mat, as if we hadnt read the last bit, its hould have come first, i hope this makes sense and does any 1 else think the same?
		folg44_005	yeah i agree. I think he could have also put more detail in ova parts of the work and shoul dhave showed his understanding more??
4	✓	folg50_005	yes [name] i also agree stevens report was detailed but he needed to explain his results more carefully

Notes (refer to CI numbers)

1. Forum (1 student) – variables and measuring them.
2. Forum (1 student) – presentation of anomalous results in another student's report.
3. Forum (2 students) – importance of presenting arguments and detail.
4. Forum (1 student) – importance of presenting arguments and detail.

Study 2 critical incidents – triad RCO dimension s

CI no	CI recall	source	data
1	×	folg20_004	Hi [name] Same here we have had loads of ideas but none seem 2 work , wot have you tried so far? We also are now using plasticine to hold the Jumpin jiminy steady because we found that sometimes it didnt just go striaght up, so it lost some of its height which made are measurements less accurate. Luv [name]
		folg20_005	Hiya [name]! I saw u doin that, and i may try it, weve had ideas such as measuring it horiztonaly instead of vertical, having a launching pad, puttin it in a tube and loads mre! Its quite hard! But weve been really lucky cos we got loads of ideas!
2	×	folg06_063	[name] and [name], i don;t think people in [the other set] have a clue what we're talkin about lol
		folg06_065	I think you are rite [name] they dont have a clue do they
		folg06_066	no we don't have a clue!!!! we will do soon though coz we r 1 lesson behind u!!!
3	×	folg06_115	for some reason [name] u always agree wit me
		folg06_116	lol i ave noticed that aswell
4	×	folg32_009	Hooks law: if you double the force, the extension is doubled aswell.
		folg32_010	u think u know eveything [name].

Notes (refer to CI numbers)

1. Forum (2 students) – variables and measuring them.
2. Forum (2 students) – variables and measuring them.
3. Forum (3 students) – variables and measuring them.
4. Forum (2 students) – relationship between the stretch of the rubber band and the height to which the Jumping Jiminy ascends.

Study 2 critical incidents – triad RCO dimension t

CI no	CI recall	source	data
1	✓	folg37_003	Does anyone thinK that there is a positive correlation between the extension of the jimini and the height it reaches? a lot of people think that if the elastic bands on the jimini are longer , the jj will jump higher but i dont think this is true. If any one wants to know , hooks law is ' double the force=double the extension
		folg37_004	yes i think there is a relationship. i didnt no hooks law thanks
		folg37_005	that theory has been used loads already u should of known it by now have u not been reading anybodies theories already?

Notes (refer to CI number)

1. Forum (3 students) – variables and measuring them.

Study 2 critical incidents – triad TCO dimension NR

CI no	CI recall	source	data
1	✓	chjn05_538-9	i drew all my graphs on excel
		chjn05_541	[teacher] AND WHAT SHAPE ARE THEY
		chjn05_542	and they are quite different
		chjn05_544	diagonal
		chjn05_545	[teacher] in what way
		chjn05_546	going up
		chjn05_547	there is positive correlation in all of them
		chjn05_548	but mine is kinda jaged
		chjn05_549	[teacher] so positive correlation
		chjn05_550	yeah
		chjn05_551	because the test isnt perfect
		chjn05_552	ye
		chjn05_553	u can predict that tho
		chjn05_554	[teacher] how do you know not perfect
		chjn05_555	its buit obvious dont u thinik?
		chjn05_556	yerah
		chjn05_557	yeah*
		chjn05_558	why
		chjn05_559	i we spose 2 state the obvious?
		chjn05_560	yes
		chjn05_561	lol
		chjn05_562	u get more marks i think
		chjn05_563	thats what i did
2	✓	folg25_012	... Ave u got any idea how 2 ave an accurate line of best fit.
		folg25_013	can sum 1 answer my question. Plez
		folg25_014	no i dont know how to draw it accurately when it is curved ? :x
		folg25_015	How can we draw it then. :?
		folg25_016	Can sum 1 Plez answer me!
		folg25_017	free hand
		folg25_018	Obviosly no1 nos
		folg25_019	How do you draw a line of best fit!!!!!!!!!!!!!!!!!!
		folg25_020	to get accurate line of best fit make sure there is the same amount of results on each side of the line
		folg25_021	Thanx! I never new that David.
		folg25_022	thats ok by the way make sure the line of best fit begins at the oragin
3	×	folg26_014	u could think back 2 wot u did and then write in word or sumthing ya know. or u could (ahem) bend the truth slightly if u cant remember.
		folg26_015	good point but thaere wouldnt be much evidence to mtch it if i bend the trut

Notes (refer to CI numbers)

1. Chatroom (3 students + teacher) – presentation of results.
2. Forum (6 students) – presentation of results.
3. Forum (2 students) – presentation of results.

Study 2 critical incidents – triad TCO dimension BE

CI no	CI recall	source	data
1	×	chjn05_929	but the reason y we mite not have found a relationship between the two is because we might not have been able to calculate the height the jiminy jumps correctly yet
2	×	chjn05_1699	i think that measuring this was really hard, we should have been given height measurers to attach to them that automaticall tell us
3	×	chmy14_209	i got sum but not very accurate
		chmy14_368	but we have to put 1 cm lines on t omake it accurate
		chmy14_434	i know that it wil b very difficult 2 b accurate
		chmy14_437	any ideas how to make it accurate?
		chmy14_439	not yet but we are using digi cams to capture how high the jiminies go so we can do a more presise thingy
		chmy14_456	so its not v accurate bcoz of that aswell
		chmy14_780	we tried but r results r very very unaccurate
		chmy14_806	[name] rnt u findin this really difficult 2 get accurate?
		chmy14_819	[name] use [name]s camara dat is accurate
		chmy14_829	yeah mr D said 2 find and compare the results but that just goes bck 2 the same problem bout how 2 measure [it] lol
		chmy14_1389	is it v accurate?
		chmy14_1393	yeah it is quite accurate because when you film it you can stop the film when the jimini starts to fall
		chmy14_1650	there is no way of doing it accurately enuf
		chmy14_1653	even wen u u se the camers u cant c exactly how high it went
4	×	chmy21_191	its dodgy to get accurate results on this expirment
		chmy21_213	no. all the answers are as accurate as each other
		chmy21_1226	we should have thouse electronic height measurers to attack to them
5	×	folg06_043	we could atatch a height measurement readin thing 2 it, but that probaly wont work
		folg06_057	i've found out a way of measuring how high the jiminie will jump..... on a digital camera you can take about 5 pictures a second so it will be like a movie and then we just do the jiminie thing in front of a piece of paper or card with height measurements on it, then watch the movie clip and see how high it has jumped. it will be accurate
6	×	folg08_003	I had an idea that to measure it you could stand it against a measured wall, and then launch the humping jiminy. Then i thought it may not be accurate so i thought about having a plank of wood attached to a kinda wall, like how they measure u @ doctors or hospital, i will upload a drawing from paint 2 help understand if u want peeps.
7	×	folg47_003	I feel this is where my report excels if nowhere else i put a lot of thought and care into a neat and clear method of measuring the behaviour of the jiminy
8	×	folg50_006	i noticed that if you used string to measure thje string will effect your overall results because it is not an accurate way of measuring height

9	✓	folg58_003	I think my investigation probably had much more accurate results because of the cammera method and being able to use it as proof etc ...
		folg58_014	in [name]s experiment he used a camera, he doesn't say whether he had any trouble reading the data accuratly from the digital screen!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!! Please explain this!
		folg58_015	It was a little tricky but it was very accurate in the end!!!
		folg58_016	I tink [name]z method iz more accurate becus of da camera. But [name] iz rite 2!!! 8)
		folg58_017	it was easy 2 read off the screen because we zoomed on in on where the JJ jumped :twisted:
		folg58_020	I also agree with [name]! then how were you ([name]) sure that you read the number correctly? Even when you zoom in onto the number the photo gets blurier!
		folg58_021	Because we had 4 people all checking each one more than 3 times so we didnt missread the numbers, AND we zoomed in!!!
		folg58_022	NO IT DO NOT [name] BECAUSE IT IS DIGITAL
		folg58_023	And when you zoom in it doesnt become blurry!!
		folg58_025	[name]...[name]s method is obviously supiriour 2 [name]s method for he has a accurate and reliable way of checking his infomation and data.

Notes (refer to CI numbers)

1. Chatroom (1 student) – measurement.
2. Chatroom (1 student) – measurement.
3. Chatroom (4 students + teacher) – measurement and accuracy.
4. Chatroom (2 students) – measurement and accuracy.
5. Forum (2 students) – concerning measurement.
6. Forum (1 student) – concerning measurement.
7. Forum (1 student) – measurement methods and presentation of results.
8. Chatroom (1 student) – measurement.
9. Forum (4 students) – concerning measurement.

Study 2 critical incidents – triad TCO dimension CE

CI no	CI recall	source	data
1	×	chjn05_1256	ive decided that im going to do 12 graphs
2	✓	chmy14_948	[teacher] but how can you make results clearer? Anyone? lets have some discussion about it?
		chmy14_954	do it more times ...
		chmy14_961	and then find the averadges
		chmy14_966	... take other peoples results and compare them with yours
		chmy14_967	yea use averages
		chmy14_969	no don do that , that wud b unfair
		chmy14_971	[teacher] ... why unfair?
		chmy14_980	bcoz its a hole differnet jimini, dif elastic band etc
3	✓	chmy21_149	weve done each measurment up 2 10cm twice
		chmy21_151	i did em 3 times
		chmy21_152	wsame here
		chmy21_172	[researcher] Hi guys - one thing that interests me is why you repeat your results 3 times ...
		chmy21_173	thats to get an average result for each one
		chmy21_174	so we can get a mean
		chmy21_175	[researcher] Ok - but why three ...?
		chmy21_176	yeah
		chmy21_177	seems like the right amount
		chmy21_178	2 is too less
		chmy21_179	and 4 will take too long
		chmy21_180	cause it will give us a reasonable answer
		chmy21_181	[researcher] But say you get three results like this - 2.0cm, 2.1cm, 2.8cm - what do u do?!
		chmy21_182	fint the mean
		chmy21_183	u add them together and divide the answer by 3
		chmy21_184	[researcher] But think about it - is that reasonable?!
		chmy21_185	it gives u the mean
4	×	chmy21_457	do we have 2 do graphs 4 each of the results incl. averages?
		chmy21_853	me and andy have some results and we have done the test 3 times
		chmy21_858	my groups only done 2 tests
5	×	folg06_059	i am gonna try as many tests as i can
		folg06_117	oh ok then! im goin be making bout 50 then coz every1 is givin out loads of ideas
6	✓	folg43_003	In Analysis 2, [name] mentioned that her graphs gave her evidence to know that her hypothesis was correct, because her graphs went up, proving the relationship [name] described.
7	×	folg58_011	but [name] it doesn't matter if u can't double check it because u have to test it more times anyway

Notes (refer to CI numbers)

1. Chatroom (1 student) – presentation of results.
2. Chatroom (teacher + 3 students) – experimental procedures and measurement.
3. Chatroom (researcher + 3 students) – experimental procedures and measurement.
4. Chatroom (3 students) – experimental procedures and measurement.

5. Forum (2 students) – presentation of results.
6. Forum (1 student) – presentation of results.
7. Forum (1 student) – experimental procedures.

Study 2 critical incident recall – interview 1

Students: Alan, Karen, Martin, Linda, Steven, Sally

researcher I'd like to talk to you a bit about the investigation you've been doing, and particularly to pick up on some of the things your wrote when you were writing in the online discussions. First of all. lets have a think about the two investigations that you read ... [Martin and Valerie] ... the first question I want to try and investigate with you is ... what do you think makes a good science investigation? I don't mean a good one to do, but a good report [emphasis].

Sally It has to be clear, and well understood and it has to have lots of scientific words.

researcher Right ... lots of scientific words – like what? What are you thinking of when you say that?

Linda Mass and volume

Alan Yeah, sort of weight and, like, amount of water.

researcher OK. So, when you're reading ... a report, what makes you think "this is good"?

Linda The way it's set up.

researcher What do you mean by that ... ?

Linda Kind of pictures to explain what's going on and things in it.

researcher Yes, OK are there any other kind of things that you look for when you're trying to work out whether you think a report's good?

Steven Presentation.

Alan Whether it's nice and clear and you can read it well and it's all nicely put together – makes it easier ...

researcher OK, so it makes it easy for you ...

Alan ... to understand.

researcher OK ... so, you looked at Martin's report ... and you looked at Valerie's report. Now the first thing we asked them to do was to say to you why they thought their investigation was the one that gave the best explanation for the behaviour of the jumping jiminy. [Reads out what they wrote as opening statements in the forum...]

researcher OK, so Martin, can you tell us a bit about how you did your investigation – you talked about a camera – can you just tell us a bit about that?

Martin Yes ... well there's already rulers, metre rulers, stuck to the wall, and then we put the jumping jiminy on the floor and started off at zero and pulled it down the stick one centimetre at a time. And every time we let go we would film where it went to so we could play it back to see if it ... definitely seeing where it got to correctly.

researcher And do you think that enabled you to get results that give you a really good ... understanding of where the jumping jiminy got to?

Martin Yes, we could keep playing it back as many times as we wanted until we were definitely sure where it went.

researcher You said in one of the discussions that you had four people checking each one more than three times so you didn't misread the numbers ...

Martin Yes.

researcher	... can you explain how that worked?
Martin	Well we did the investigation – we measured it – with four people, and when we played it back we had four people watching to see where it went to, and we played [it] back at least three times every time just in case.
researcher	So did all four people agree where the thing got to, or ... did you have any arguments about the height between the four of you?
Martin	Occasionally, but then we'd play it back a few times until we could tell which one was right, definitely.
researcher	Right, OK, so that was the way, if you had any differences of opinion about the height to which it rose, you'd keep playing the video back?
Martin	Yes, until we could definitely say which one was right.
researcher	So ... you were trying to get an agreement between you – OK, that's interesting. How did you find the video camera, did ... that make it easy?
Martin	Sort of, it was ... the only thing we found that was quite hard to deal with was that sometimes it [the jumping jiminy] would actually jump out the screen so you'd actually miss it – you'd see this thing fly past and fly right down ...
researcher	[laughs] Yes.
Martin	... so sometimes you'd have to do it again to see where it went [laughs].
researcher	I was wanting to ask Valerie if she was here – so I wonder whether any of you will be able to answer for [her] – Valerie says she thinks that Martin's report is more scientific – and I wonder if any of you have got any idea of ... what you think she might mean by that.
Linda	Use more science words.
Steven	Background knowledge of the actual project and the forces involved in it.
researcher	Right – and how do you show that then?
Steven	Um – they did, like, a page like background knowledge and it was like information that affects the jumping jiminy.
researcher	So if one report has got more background knowledge in it than another one, do you think that report is more scientific?
Linda	I think it is, because it's kind of giving you evidence to show what you found out, and it's like explaining why you've decided to do this method and why you think what's going to happen.
researcher	OK. So ... Martin in his statement says "My results could be proved to be valid." Now what do you understand by the word "valid"?
Martin	Correct?
Karen	In Valerie's experiment we just sprung it and then measured how high it went ...
researcher	You were working with Valerie, were you?
Karen	[nods] ... but in Martin's one he could, like, replay it, so where we could just see it at that moment so we'd have to make sure it was there, Martin could, like, replay it and make sure it was there. So more like specific ... make it to the millimetre if he wanted to.
Linda	It's more reliable.

82	researcher	Oh, it's more reliable [emphasis]? Now what does that mean, Linda?
83	Linda	Well, it's like – I don't know ... Valerie and Karen said they were marking it by the eye,
84		and like the camera can like never lie, so ...
85	researcher	Right, OK, so because they used a camera you think that's going to make it ...
86	Linda	It's gonna like be more accurate, accurate.
87	researcher	It's got to be more accurate because they used a camera?
88	Linda	Well, yeah!
89	researcher	OK, that's fine. One of the things that someone's written about the camera ... Karen
90		said "how were you [Martin] sure that you read the number correctly".
91	Karen	Oh no, I was thinking differently, I thought that they were plugging it into the computer
92		and reading it off the screen ...
93	researcher	Oh, right ...
94	Karen	...cos if you go into the computer it gets like blurrier as it gets bigger.
95	researcher	Oh, right, because you said when you zoom in on the number the photo gets blurrier
96		... and then Steven seems to have replied "no it doesn't Karen, because it's digital" ...
97		you were thinking [Karen] about the digital camera going on to the computer ...
98	Karen	Yes, I thought they'd put it in the computer and [indistinguishable] a bigger picture or
99		something.
100	researcher	Right, OK, that's fine. Let's just have a look at some more of these [reports] and let's
101		just think about the investigations ... did you all have a look at the graphs? [Shows
102		students graphs produced by Valerie and Martin.] When you do [an investigation] why
103		do you plot a graph?
104	Steven	So your results make more sense; see it more clearly. Cos, like, in a graph, [corrects
105		himself] a results table it's just a jumble of numbers.
106	researcher	OK. That seems reasonable does it Linda, you'd agree with that?
107	Linda	It also makes it easier to see if there's a pattern between the numbers.
108	researcher	OK, so what sort of pattern did you think you might be looking for in the investigation?
109	Karen	A straight line going upwards ...
110	researcher	[repeats] A straight line going upwards ...
111	Karen	... like equally.
112	Linda	Hooke's law.
113	researcher	[repeats] Hooke's law ... Valerie's report mentioned Hooke's law; did yours as well
114		Martin, I can't remember?
115	Martin	Not much, it mentioned it once but not much!
116	researcher	OK, do you know what Hooke's law is, means? Sally, yes?
117	Sally	Yes, double the extension you get double the, er, I can't remember, height.
118	researcher	Double the extension you get double the ... [waits]
119	Martin	... mass
120	researcher	[repeats] mass
121	Martin	... weight
122	Karen	can't remember!
123	Alan	Double the mass double the extension isn't it?

researcher Yes, OK, I'll buy that – if you've got a rubber band and you hang masses on it – if you double the mass you get double the extension, OK. So you might think it's got something to do with that, so if you double the amount you pull the rubber band down it doubles the height that the thing [jumping jiminy] goes to. So what do the two graphs tell you then?

Sally Don't follow Hooke's law.

Linda It looks like one of them's more accurate than the other, cos they're not the same kind of pattern.

researcher They're not the same shape at all, are they? [Shows graphs]. So ... you think Martin's provides the better explanation ... for the behaviour of the jumping jiminy – can you tell me why?

Linda Does Valerie's [report] have more anomalous results?

researcher What makes you think it might have more ...

Linda Cos it's like not in a straight line, she's had to go through a funny shape to try and get all of the ... [tails off]

researcher What convinces you about – is it just the graphs?

Sally Well, knowing how they got the results you can tell, it makes it, that Martin's one looks more accurate because he's got a still image.

researcher Let's just check Martin's [report] to see whether he did a graph on Excel as well ... no you didn't did you, I think it was Valerie who did a graph on Excel ... there's Valerie's graph on Excel ... [shows graph] it certainly does look different to Martin's, doesn't it ... how did she get these bits down here [towards the origin of the graph] Mrs Wright?

Mrs Wright She extrapolated them ...

researcher Right

Mrs Wright ... and I did ask her when I marked it "why did you choose these figures?" She started in fact at six centimetres [extension of the rubber band] whereas Martin's team I think started at one centimetre didn't you?

Martin Yes.

researcher OK, so you didn't have to project your results backwards Martin, because you'd collected results down here [points to region near origin of graph].

Martin Yes.

researcher So just tell me again, which one are we going for as the best explanation of the behaviour of the jumping jiminy?

[inaudible]

researcher We're going for Martin's? And we're going for Martin's because? Why are we going for Martin's Karen?

Karen Because it's more like valid evidence that he can see so he can like look back at it and make sure that it's correct and then he explains it in more like specifically.

researcher OK ... so can I just see whether I've understood you correctly? You think Martin has explained to you how he's got his evidence ... and that you think that the way he's got his evidence means that his results are more – what's the word you'd use here, they are?

166	Alan	Valid.
167	researcher	More valid, or ...
168	Karen	Reliable.
169	Sally	Sir, can I have a look at that one [points to report] for a moment?
170	researcher	You can, of course.
171	Linda	I think it's a graph
172	Sally	This one's on a larger range than that one ...
173	researcher	This one's on?
174	Sally	A larger range, what it is, it goes up to 15 and that one doesn't, it only goes up to 10.
175	researcher	That one goes to 10, that's right, so the scales on the graph ... are a little bit different.
176	Sally	So it looks about the same, cos if you look from there to there [points to graph] it's
177		about the same.
178	researcher	Right. [To whole group.] So is it possible that you could have got similar results but
179		plotted different graphs?
180	Karen	You'd have to look at the results table.
181	researcher	Yes, you would. Shall we just do that quickly? Let's just have a quick look at the
182		results tables. [Displays to students.] Valerie's starting with [an extension of] 6 – let's
183		have a look at your {Martin's] results for 6. Pulled down six centimetres, jumps to an
184		average height of 64.3 [centimetres]. Pulled down six centimetres – gosh – jumps to
185		an average height of 18.6 [centimetres]. Isn't that interesting. Let's have a look and
186		see what happens if we go up to nine centimetres ... what's that as a percentage can
187		anyone do that?
188	Sally	Fifty percent.
189	researcher	So what might we expect the height to do?
190	Sally/Linda	Go up ... a half.
191	researcher	Go up 50%, yes. Shall we have a look and see? So six is 64.3 [centimetres], nine is
192		115.3 [centimetres] – not quite double.
193	Sally	Sir, could they have had, like, different size elastic bands?
194	researcher	Right ... so ... there's elastic bands that might be different. Let's just have a look in
195		Martin's group and see what six to nine is – six is 18.6, nine has gone up to 47.6, gosh
196		that's two and a half times higher.
197	Linda	One of them could have, like, marked from the top of the cotton reel to pull it down and
198		one of them could have marked from the bottom so it could be different – depends
199		how they marked it from the stick.
200	researcher	Yes ... the method of measuring it might have been different, in which case one of
201		those is not measuring extension really, are they.
202	Linda	But of you, like, measured from the bottom of the cotton reel it wouldn't be as high as
203		if you measured from the top.
204	researcher	Right, right, OK.
205	Linda	[laughs] [quietly] I think it's the other way round actually. If you pull it down from the
206		bottom it'll go [inaudible, bell goes]

207	Mrs Wright	SO you think that, Valerie and Karen's one, when it's six, is in fact the equivalent of
208		Martin's group's one?
209	Sally	Like if Martin measured it a centimetre down from the bottom of the cotton reel ...
210	Mrs Wright	... and they measured the whole stick, so their six is Martin's one, their seven is
211		Martin's two.
212	Karen	One of them could be marking down the stick and the other could be marking up the
213		stick.
214	researcher	Yes, OK ... that was the bell going for the end of lunch I think ... thank you ever so
215		much!

Study 2 critical incident recall – interview 2

Students: Tim, Scott, Andrea, Adam, James, Julian

researcher So let's all think a bit about the two reports. Could you decide between you which report you thought gave the better description of the jumping jiminies' behaviour?

Students Scott's ...

researcher Right, OK ... what was it, James, that ... made it better?

James I think it was written in more detail, it was longer.

researcher Right, OK. So what is it that makes a good science report then? You can all join in on this one!

Andrea How much detail there is.

researcher What kind of detail ...

Andrea The way you explain it.

researcher What kind of detail do you need to put in to make other people believe what you've written?

James Why you think, why you think what you got is true.

Andrea You've got to use science.

Adam You need evidence to back it up.

James Research.

researcher What kind of evidence, what kind of research do you need to put in?

James Of how other people, if they've done these tests, how they can, how they done it and all that. You see what's different between their tests and your tests.

researcher So do you compare what you've done with other people?

James Yes, sometimes ... say they done, they pulled it [the jumping jiminy] down differently ... say you pulled it down really long, some people might not have gone that far then you can think if you want to do it again, if you want to pull it down that far.

researcher So what was it that made this investigation particularly difficult, what was it about this investigation that you found hardest?

James Measuring the height. [sounds of agreement from others]

researcher OK. So, Tim, can you tell us how you did that?

Tim I used a camera and recorded how high it jumped ... and wrote it down.

researcher Was it a still camera or a video camera?

Tim Video camera.

researcher You used a video camera – and Scott, what did you do?

Scott Well we tried different things. We put, we tried metre stick, and we put a string on the end of it ... so it dragged the string as it rose to the highest point in the air.

researcher [generally] Can you remember the graphs that these guys plotted?

James I remember Tim's!

researcher We'll have a look at them in a minute, but let me just ask you ... why did you plot a graph of your results?

Julian So we could refer back to it. To help us write conclusions and evaluations.

39	Tim	So it looked easier so we could work it out.
40	Andrea	So it's easier to have a look at and understand – easier to interpret than writing.
41	James	Cos say you haven't got ... they look at the graph and they might be confused and
42		they look at the, no, say they look at the table you wrote out they might be confused
43		and they look at the graph and people might understand.
44	researcher	So you're using a graph to explain your idea to other people, is that right?
45	Students	[general agreement]
46	researcher	Let's have a look then at the two graphs that we've got ... there's Scott's graph ...
47		what shape would you describe that as? [pause] Is it a straight line?
48	Adam	No, it's a curve.
49	researcher	What was the shape of yours, Tim?
50	James	Tim's done a line of best fit.
51	researcher	Is this the same shape as the other graph?
52	Students	No.
53	James	He's done a line of best fit, but ...
54	Andrea	No, but he could have made it the same shape, it's just that they've done it differently.
55	researcher	What sort of shape does it look like?
56	Adam	An S-shape.
57	researcher	Well, first of all what line has Tim drawn through it?
58	Students	Straight line ...
59	researcher	You've drawn a straight line through it, OK ... why did you draw a straight line through
60		it, Tim?
61	Tim	I just thought it'd be easier to look at it like that rather than a curved line.
62	Scott	To see if there's any correlation.
63	researcher	To see if there's any correlation between what?
64	Scott	Points.
65	researcher	OK, fine. What sort of shape do the points actually follow ... it's a kind of S-shape isn't
66		it? So just remind me again, whose report do you think ... explains the behaviour of
67		the jumping jiminy best?
68	Andrea	It was a long time ago.
69	researcher	[shows the reports again] So how did you expect the jumping jiminy to behave when
70		you pulled it down, what kinds of predictions did you make?
71	Julian	I thought that the further you pulled down the cotton reel the higher it would jump.
72	James	Yeah ...
73	researcher	That seems quite reasonable, doesn't it? Could you be a bit more specific about that,
74		could you be any more accurate?
75	Andrea	Er, the difference between height increases up, so if you pulled it down like that much
76		it would be that high if you pulled it down that much it would like be getting further – I
77		know what I mean.
78	researcher	OK, I know what you mean Andrea, What kind of graph did you think you were looking
79		for, Andrea?
80	Andrea	Er, a steep line probably, going up like that, not like that but like that. [gesture]

81	researcher	OK. And which of those two graphs [Tim's and Scott's] do you think is closer to the
82		one you would have expected?
83	Andrea	[Points to one of the graphs]
84	researcher	This one? OK.
85	[bell for end of lunch]	

Study 2 critical incident recall – interview 3

Students: Jill (author), Lisa, Josie, Jeremy, Justin, Naomi, Laurel

researcher	Let's start off by thinking a bit about the reports … [shows on screen] so you looked at the two reports and I asked Jeremy and Jill to say what they thought were the best features of what they'd done … which do you think is the one that explains the behaviour of the jumping jiminy better?
Students	Jill's
researcher	Jill's?
Students	Mmm [confirmation]
researcher	Right … now why are you convinced by what Jill's written … ?
Justin	She's presented it better.
Naomi	There was a lot of detail and everything.
Laurel	Mmm [agreement] – explained in detail.
Josie	Mmm – more writing.
researcher	So when you were reading the two [reports] what were you looking for?
Naomi	Explanations.
Laurel	Yeah.
Justin	Presentation.
researcher	When you say presentation, Jeremy, what do you mean?
Justin	The way it's set out, and the order that they've done the thing in. 'Cos on Jeremy's he's done one of them in the wrong order, but I can't remember what one.
Josie	Yeah, it's, he explained about the clamp stand idea before he, sort of said that he was going to use that sort of thing. It was a bit weird.
Laurel	I don't think it really matters about the presentation.
Josie }	[simultaneous] I do, because it'll be easier to read.
Jeremy }	[simultaneous] It's got to look good!
Laurel	Yeah, it's got to be easy to read but you need the detail, that's the important bit.
Josie	Yeah, but when you look at a book or something you always look at the front cover first …
Laurel	I know, but …
Josie	… and that's presentation! [pause] And the order's got to make sense as well.
Laurel	Yeah.
Josie	Otherwise it just won't make sense at all.
researcher	So when you went into it you were looking to see … explore exactly what you mean by [presentation].
Justin	The layout.
Laurel	Yes, layout.
Josie	Layout.
researcher	The layout …
Laurel	What order's it all in and everything.

39	Justin	The way it looks.
40	researcher	The way it looks and the order things are in. OK, so Justin mentioned that Jeremy had
41		got something somewhere in the wrong order ... and you're also looking for ...
42		explanation ... so what is it about what Jill's managed to do that makes her
43		explanations better then?
44	Laurel }	[simultaneous] She kind of, like, she covered everything like. Sort of explained
45		everything in detail and covered all of the parts like, all of the parts, that we did, the
46		way that we went through the experiment.
47	Jeremy }	[simultaneous] She explained, she explained some of the words we used as well.
48	Josie }	[simultaneous] And why.
49	Laurel	And she covered everything in detail and everything.
50	researcher	Jeremy, sorry, I didn't catch what you said.
51	Jeremy	She also explained some of the word that might have been hard to understand. In the
52		experiment and stuff – she had like a bit of a dictionary.
53	researcher	Right, OK, fine. Let me just get their graphs up because they both plotted graphs. And
54		while I'm doing that, let me ask all of you the question, not just Jeremy and Jill, why do
55		you include graphs in an account of an experiment?
56	All	To show your results and material.
57		To support what you're saying.
58		It's easier to explain.
59		Clearer than a table.
60	researcher	So it's part of the explanation?
61	Laurel	Makes it more clear.
62	researcher	That's fine [shows graphs] – there's two different shapes there [in the graphs]. What
63		shape is your graph, Jeremy?
64	Jeremy	It's just a diagonal line straight up.
65	researcher	It's a straight line, OK. What shape was yours, Jill?
66	Jill }	[simultaneous] A curved one.
67	Jeremy }	[simultaneous] It's a curve.
68	researcher	So it's a curve.
69	Jill	Yeah.
70	researcher	Like that.
71	Laurel	It's more or less in the same direction though.
72	researcher	Now are you happy that Jill's got the best explanation for the behaviour of the jumping
73		jiminy?
74	Students	Yes
75	researcher	Why?
76	Laurel	Detail. She explains it and makes you understand it better.
77	researcher	Right.
78	Josie	She's also got – is this about the graph?
79	researcher	If you want to comment about the graph, do, yes.

80	Lisa	Well, I don't know about Jeremy's but, there's errors in Jill's graph which might show
81		that she actually did it properly. I don't know, I'm not saying that Jeremy didn't do it
82		properly but ... do you know what I mean?
83	researcher	Let's have a look, there's errors, tell me what you mean by errors, Lisa.
84	Lisa	Are there any anomalies?
85	Justin	Just writ [sic] little circles and said "wrong". She could have done that better though.
86		Instead of writing "odd". She could have wrote something else. It looks weird.
87	Jeremy	It's an anomaly.
88	researcher	Yes Jeremy.
89	Justin	What's an anomaly?
90	researcher	Why do you think it's good that she's got anomalous results on her graph?
91	Jeremy	'Cos it shows it's not exactly perfect .. the graph [indistinct]
92	Laurel	It shows it's not consistent, that would mean that, like ...
93	Josie	It's not reliable.
94	Laurel	... yeah, and she's, like ...
95	Jeremy	Cheating.
96	Laurel	... no, she's done it properly because it's not, it can't be consistent all the time.
97	Josie	Yeah.
98	researcher	Josie, you used the word reliable – can I ask you what you meant by that?
99	Josie	Erm, it means the results aren't always the same, so if you put a mathematical formula
100		on it, it won't work.
101	researcher	Just say that again.
102	Josie	It won't be continuous ... like, they're not following the line of best fit.
103	researcher	When you use the word reliable, was it Jeremy's results that are reliable or is it Jill's
104		results that are reliable?
105	Josie	Erm, I don't know, Jeremy's I think because he didn't have any anomalies.
106	researcher	Right.
107	Josie	Did he? I don't know.
108	researcher	OK ... someone, when they were writing about the results said ... that someone's
109		results were more accurate than somebody else's ...

Guidelines for providing online support (e-moderating)

What follows is based on Gilly Salmon's book *E-Moderating: the key to teaching and learning online.*

The "Five-step model"

Salmon has built a model based on her experience of using computer mediated communication (CMC) as a tool for supporting (adult) learners – this model is shown in figure 1 below.

The five stages in the model each require the user to master certain technical skills (shown on the left of the figure) and also call for different skills in e-moderating the conference. Knowledge of our students and the outcomes of the first two studies suggest that the technical skills possessed by the majority of students can comfortably take them through the first three stages of the model so that they are quickly able to engage in knowledge construction (stage 4). Our initial introductory sessions are intended to provided the e-moderation input (on the right-hand side of the figure) to:

* welcome and encourage participation;
* provide bridges between online environments (not between "real" and "virtual" environments, but between "informal" and "formal" online environments – our students have already made the "real"/"virtual" link);
* supporting use of the online environment for learning.

Evidence from the studies so far indicates that our biggest challenge is to support the students as they engage in stage 4 – knowledge construction. (We shall also be interested in stage 5 when it comes to the part of the study where we want students to be engaged in evaluating knowledge claims – *At stage five, participants become responsible for their own learning through computer-mediated opportunities and need little support beyond that already available. Rather different skills come into play at this stage. These are those of critical thinking and the ability to challenge the 'givens'.* (Salmon, 2000:35)) In particular, we need to provide support and encouragement so that students post thoughtful and "rich" messages to the forum as well as the "quick fire" contributions that characterise some of their online exchanges. Some thoughts on this follow.

E-moderating guide (from Salmon, 2000:115-119)

The task of e-moderation to support and channel online interactions needn't be overwhelming or daunting, but it does need some ground rules. In essence, think of the online environment as an extension of your classroom. Engage with students online as you would in school, and use the same kinds of techniques to keep online interactions "on track". Here are some ideas – note that each stage subsumes the one below it, so that (eg) Stage 3 implies moderation using the guidelines for Stages 1, 2 and 3:

Stage 1 *Access/motivation.* Encourage students to log on regularly, and do so yourself. Experience suggests that students will quickly engage with the environment – the challenge is to harness this energy in order to get things moving up through the stages as swiftly as possible. Deal promptly with difficulties among participants, especially where issues such as dominance or harassment arise.

Stage 2 *Socialisation.* Aim to summarise messages often – rather as one does in the classroom, to ensure that all present understand what's been said. Encourage social interaction in

the *café* but ensure that it doesn't happen at the expense of task-oriented interaction. If necessary, access to the café can be restricted to certain times.

Stage 3 *Information exchange.* Aim to support students in making links to what others have said – the emphasis at this stage of the online interaction is the exchange of ideas about what they are going to do and what their ideas are. ("Why don't you think about ...?", "Look at what X has written about ...", "Do you know why ...?" are all useful open-ended, structured ways of directing students' thinking.)

Stage 4 *Knowledge construction.* Encourage full participation by all students so that they begin to support each other in developing understanding – just as one might use discussion to clarify understanding in the classroom.

Further help and support is available by e-mailing Patrick on `plf@soton.ac.uk`

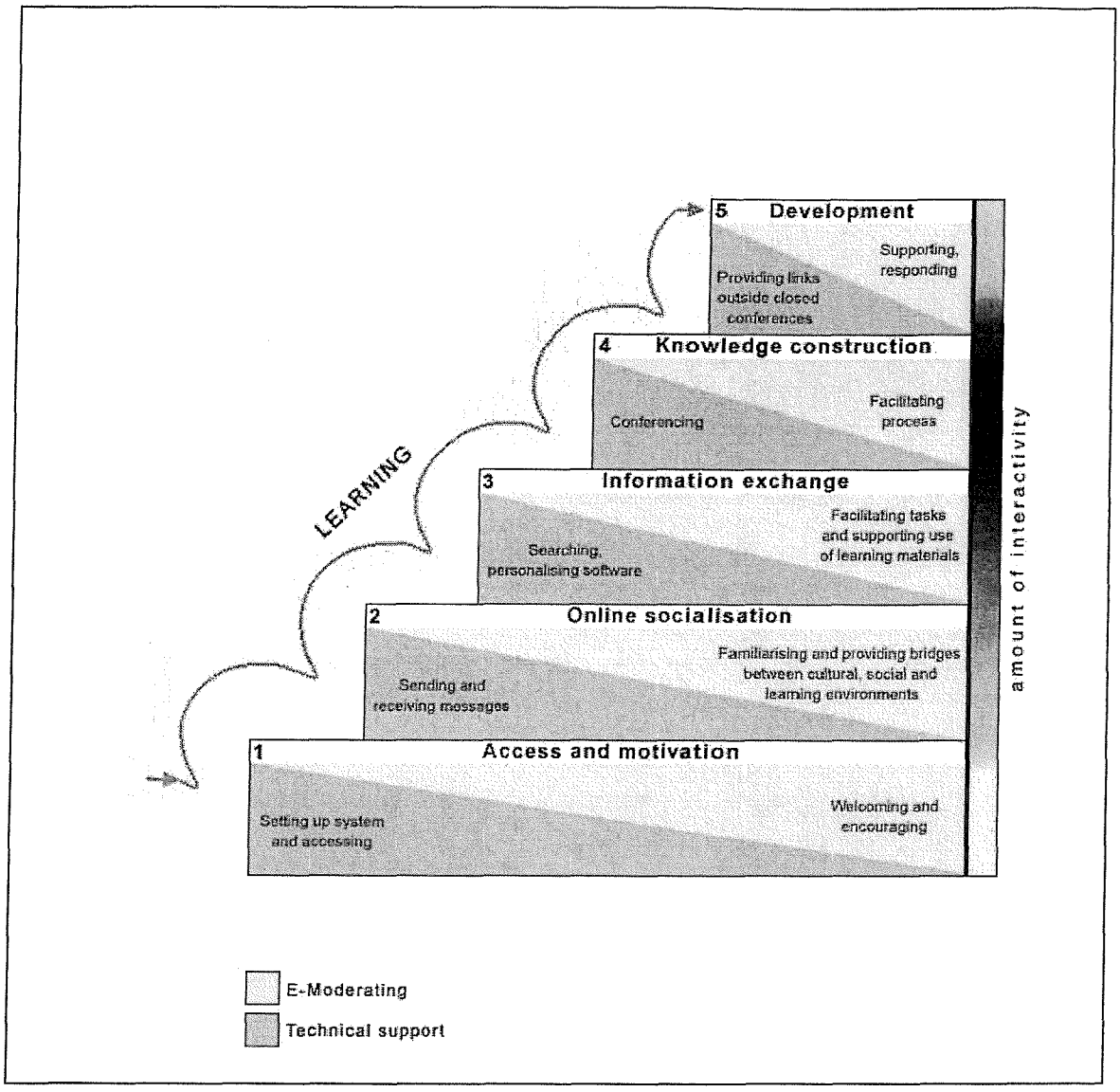


Figure 1

Reference

Salmon, G. (2000) *E-Moderating: the key to teaching and learning online.* London: Kogan Page.

Study 3 – online support briefing

Instructions for accessing online support

Scl-Journal
The address of the Scl-Journal website is `www.sci-journal.org` – typing this into the address bar of your browser and pressing "enter" will take you to the home page of the site. From there you can

- search for reports and list all of the reports in the database
- find out how to post comments about a report
- get advice about carrying out and writing up science investigations

by clicking on the appropriate link.

Take a few minutes to look around the site, find out what reports there are, and see the comments that other people have posted.

Discussion environment
A special area of the Scl-Journal website has been set aside just for students carrying out this investigation. You can reach this area by typing `www.sci-journal.org/2003` into the address bar of your browser and pressing "enter". You will be asked for a username and password before going any further – your teacher will give you this.

For reasons of security and personal safety online, it's important that no-one outside the group of students and teachers involved in this investigation has access to the site.

- - - don't share your password with ANYONE else - - -

Once you enter your username and password correctly, you'll enter the discussion environment. At the top of the page there are some special instructions about using the environment. Please take a few moments to read these and to think about them – the rules are simple, but they're meant to make life online easier and more pleasant for everyone.

Forum
"Click **here** to enter the discussion forum"
When you click on the link you'll be taken to the discussion forum, where you'll be able to log in using your username and password. If you're doing this from home, you should be able to set the computer to log you in automatically each time you visit the page by checking the box next to the text which says *Log me on automatically each visit* (but this probably won't work on computers at school).

File upload
"Click **here** to share your files with other people"
When you click on the link you'll be taken to the file upload area. Scroll down the page until you see your username – clicking on it will take you to your personal file upload area. Here you can upload files – *Word* and *Publisher* documents, spreadsheets and image files – which you want to share with other people. (Only files relating to this investigation should be uploaded ...). Don't forget to post a message to the forum to tell people that you've uploaded something!

Chat room
The chat room will be available for online chat about the investigation at certain times. To enter the room, simply type your username into the box and click on the "connect" button. Instructions for using the chat room (and for troubleshooting if you have problems connecting to it) are available by clicking on the link just above the chat room box.

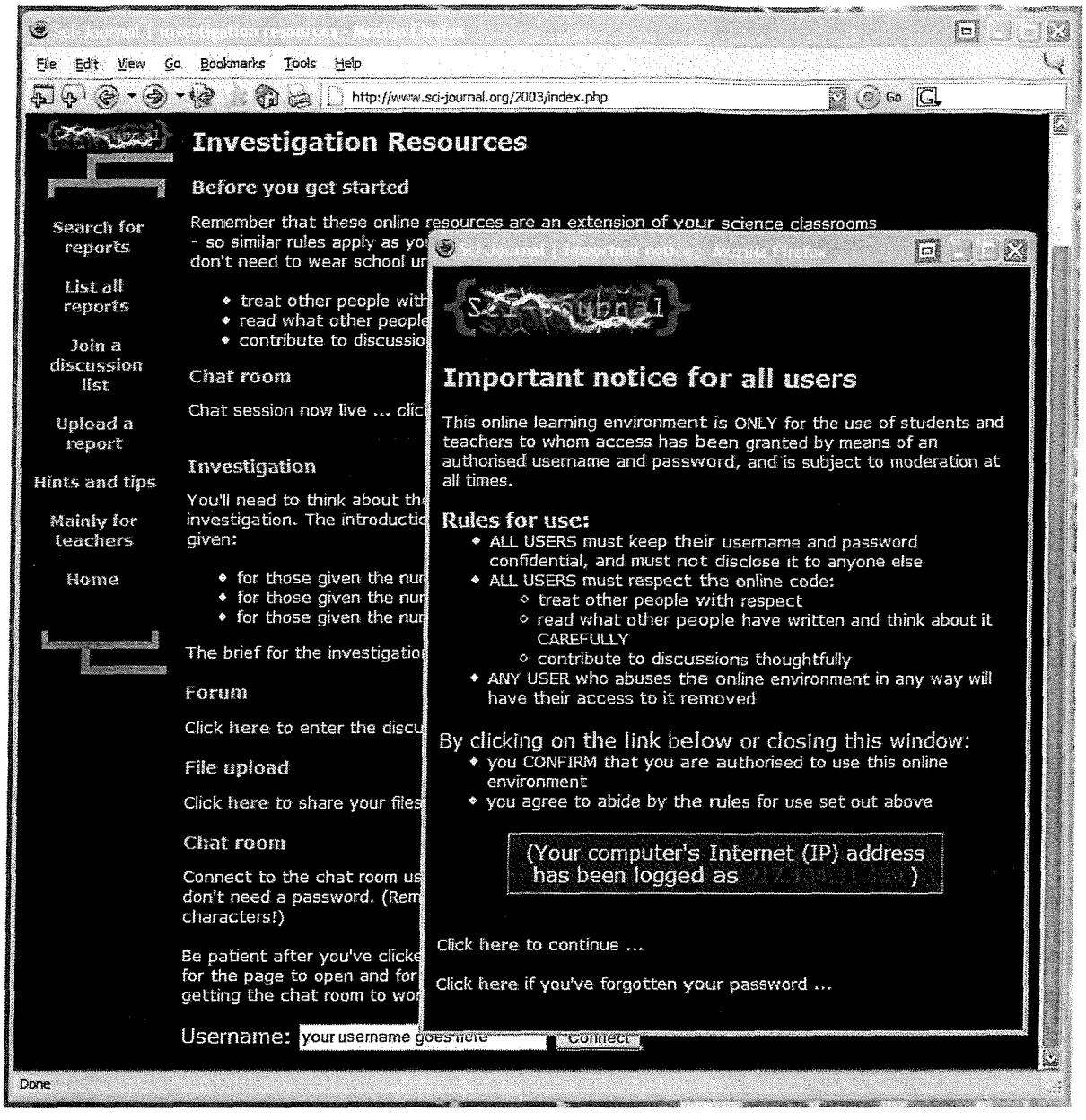
/ ... cont'd

For the security and safety of everyone, the forum, file upload area and chat room will be monitored constantly. Please treat others online (and the online resources) with respect.

Abuse of the system will be taken very seriously, and may result in access being withdrawn.

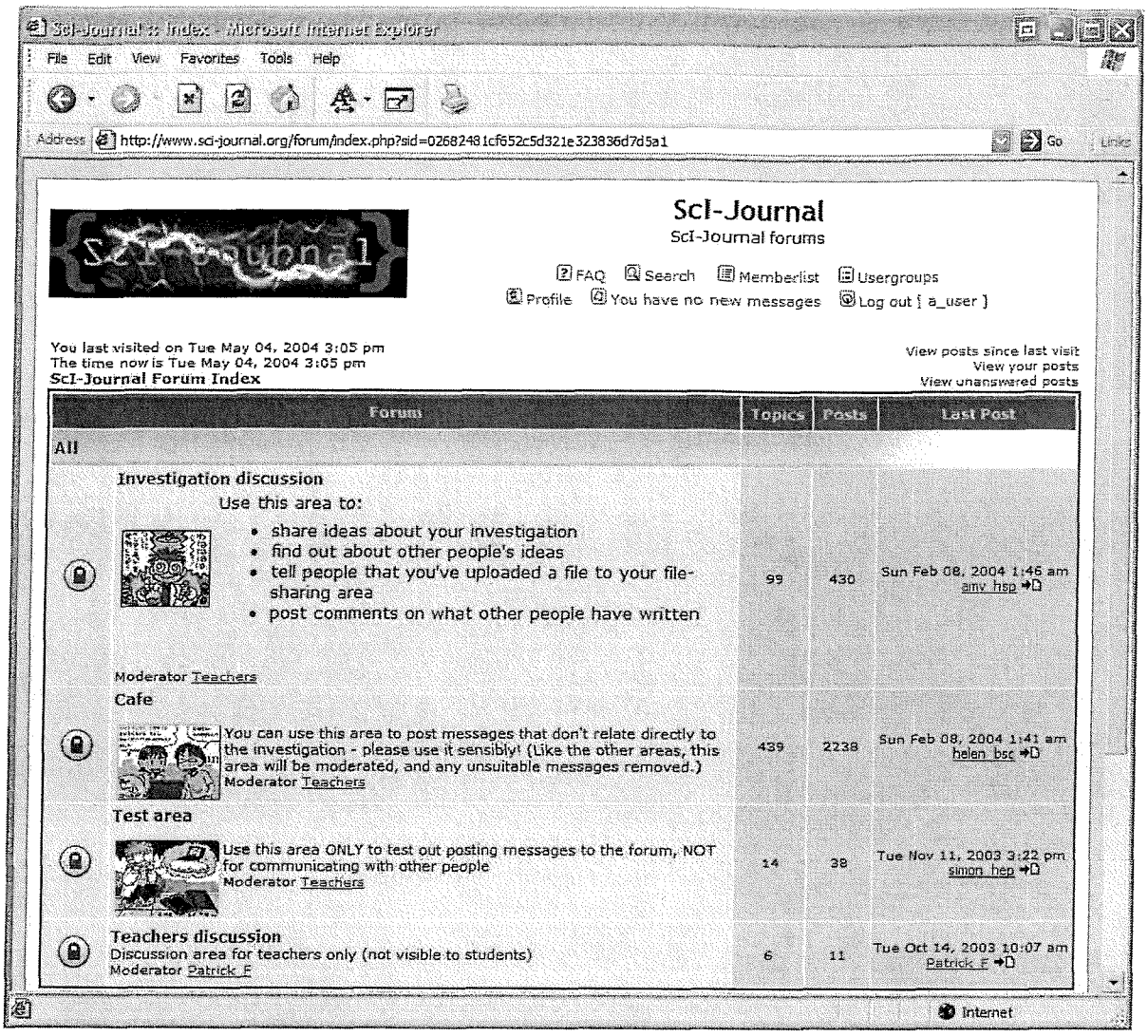
Further help and support is available by e-mailing Patrick Fullick on `plf@soton.ac.uk`

SciJournal interface (study 3, chatroom active)



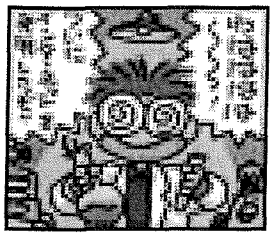
The interface to the section of the *SciJournal* web site was available only to users entering a correct username and password to obtain access. On loading, the popup window (right) appeared first and had to be closed before the user could proceed. The main page as shown was as seen by users when the chatroom was active. At other times the text box and button for logging in was absent and the "Chat session now live ..." message near the top of the page was replaced by a grey box advertising the time of the next chat session.

Sci-Journal phpBB discussion forum (study 3)



Study 3 – investigation briefing

A company producing different types of biological washing powder needs a simple way of measuring how effective its washing powders are. The test needs to be simple – so that it can be conducted outside a laboratory – and it needs to be cheap as well.



The company has employed a scientist to carry out some trials, and has decided on a test that involves measuring and recording what happens to a piece of egg white dropped into a solution made from washing powder dissolved in water. The scientist has not fully completed the work needed to make this test work properly, and more investigation is needed. This is where you come in!

From the work already done, the scientist has written the following report ...

> The investigation I have carried out shows that a piece of boiled egg white dropped into a solution of biological washing powder will come out much smaller than it went in - if you leave it for long enough.
> The conditions that seem to work best use about 3 grams of washing powder dissolved in about 30cm^3 of water. The egg needs to be left in the solution for about 20 minutes [note - this needs checking]. The solution is then poured off the egg white which is then washed several times with water and dried carefully. You can then record and measure the effect of the washing powder solution on the egg white.

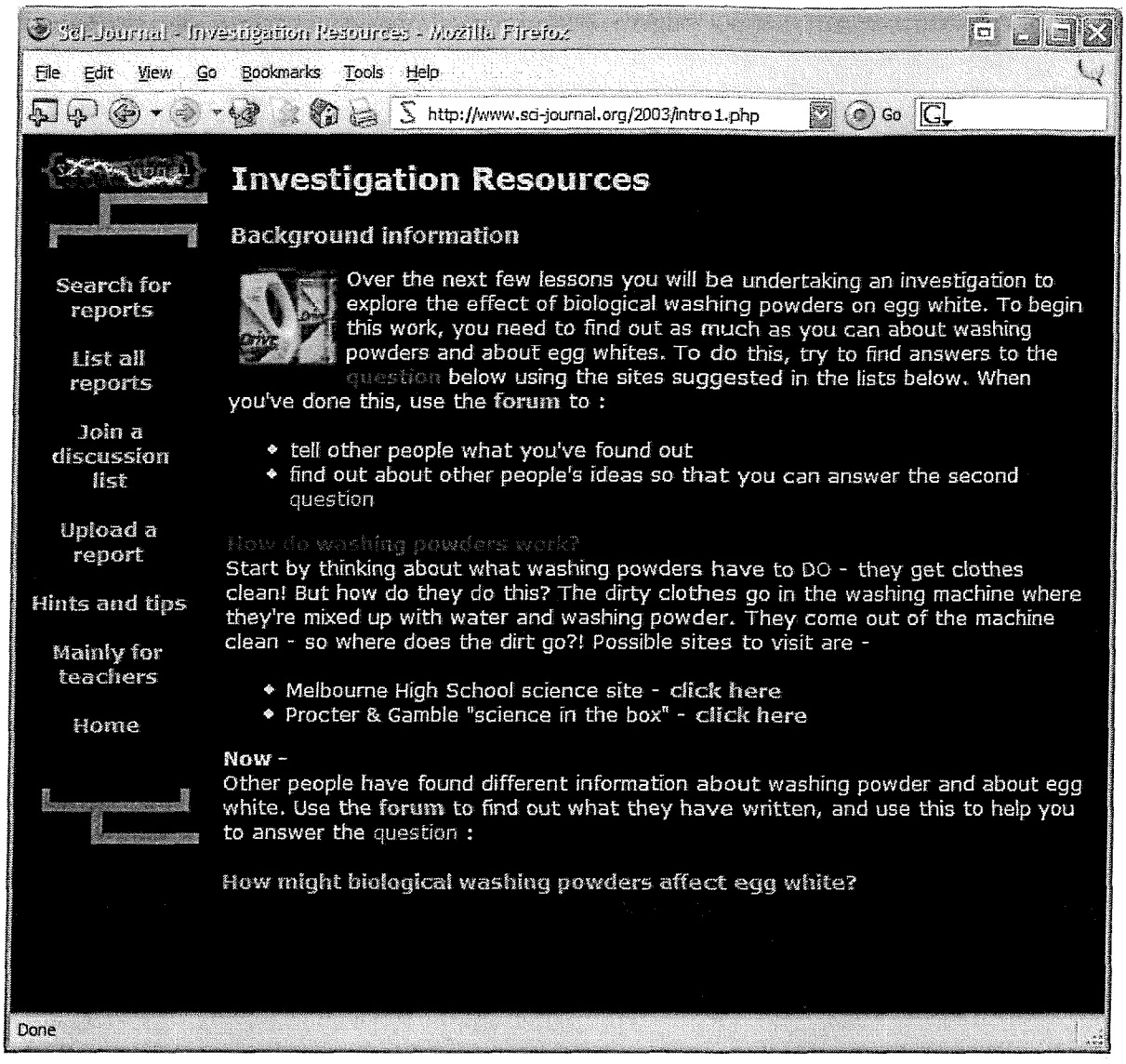
Your task ...
Apart from this information, nothing else is known about the test. The company want you carry out an investigation to explore exactly how this test works, and to produce a set of instructions for carrying it out. They also want you to produce a set of results obtained by using the test to investigate the effectiveness of a sample of washing powders – they have provided you with some samples to help you to do this. However, you will need to decide exactly what you are going to test.

You'll need to write up your report showing what you've done, how you did it and the conclusions you've reached. Using ICT to do this will enable you to share the report with others using the Web.

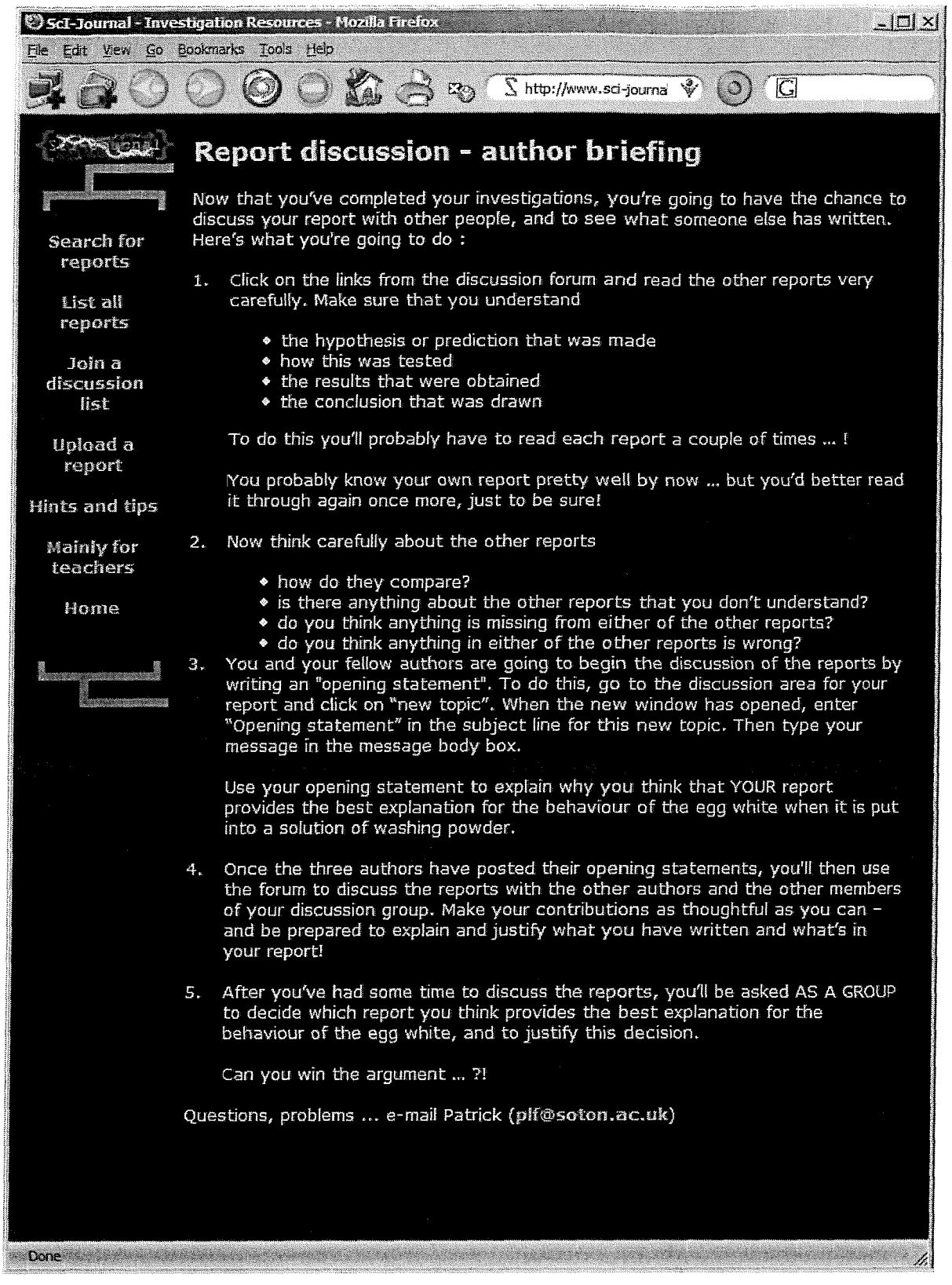
Help in carrying out the investigation and writing it up is available at

`www.sci-journal.org/hints`

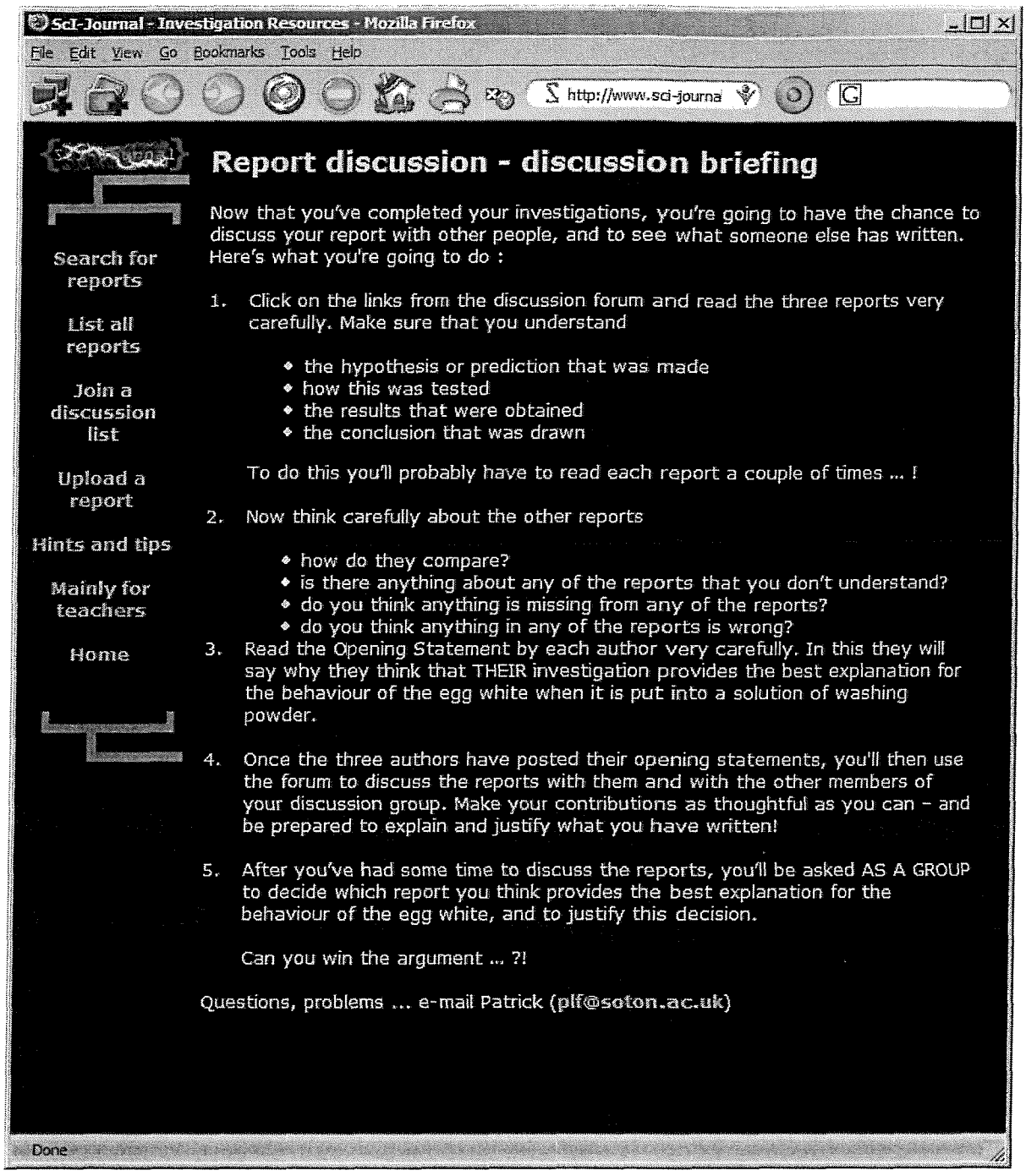
Study 3 – "research" task example



SciJournal author briefing (study 3)



Sci-Journal discussion briefing (study 3)



Study 3 – critical incident 1

source	identity	posting
choct15_150	carl_cep	alana, naomi whar results did u get 4 ur experements
choct15_152	naomi_gsp	da egg got a bit liter
choct15_153	naomi_gsp	dats all
choct15_154	alana_mtc	we have got some but they arent very good
choct15_155	carl_cep	oh i guesed dat
choct15_156	researcher	What do u mean |not very good|?
choct15_157	alana_mtc	the eggs got 1g liter in 100cm3 of 40 water with 25g of washing powder
choct15_158	researcher	How heavy were they before - ?
choct15_159	alana_mtc	5g
choct15_160	researcher	Wow!! That's a 20% reducation ...
choct15_161	researcher	*reduction
choct15_165	carl_cep	that happend in our 2 experements 2, i think its because the emzymes eat the protase and fat in the egg
choct15_166	alana_mtc	what did every1 else get
choct15_167	researcher	... pretty big I'd say!
choct15_168	researcher	Not sure who else has reults yet - Carl?
choct15_169	alana_mtc	what school are you from
choct15_170	researcher	If their username ends in p they're from Pynewood
choct15_172	researcher	If ends in c, Castleford ...
choct15_173	researcher	(And I'm from the University!)
choct15_174	alana_mtc	i am the only castleford!
choct15_175	researcher	Yup!
choct15_176	carl_cep	My books at skool i can't remrmber exactly but in one of our experements the egg reduced in mass by 0.06g
choct15_177	researcher	OK - what %age is that?
choct15_178	alana_mtc	6%
choct15_179	alana_mtc	?
choct15_180	carl_cep	Ermm i can't remember wat it started off as
choct15_181	researcher	Ok, praps you'll need to work that out later ... what do you plan to do next?
choct15_182	paula_myp	must of bin quite heavy wid da amount o eg craig woz peelin
choct15_183	researcher	?!
choct15_184	alana_mtc	did you have a different way of cutting the eggs or something?
choct15_185	paula_myp	chris peeld loads of da shels of loads o egs
choct15_186	researcher	Why?
choct15_187	naomi_gsp	sum ppl puts loads in and sum ppl only put a little bit in
choct15_188	researcher	oes that matter?
choct15_189	researcher	*Does
choct15_190	naomi_gsp	i dunno i guess dey will hav 2 test it and find out
choct15_191	carl_cep	I've got another 16 experements 2 do after dat were goin to work out the best experement
choct15_192	researcher	good point
choct15_193	researcher	16!
choct15_194	alana_mtc	because we tested and if you put a huge chunk in and it lost less mass than if we cut it up into little peices
choct15_204	carl_cep	There lots of different things u ave to test
choct15_205	researcher	like ... ?
choct15_206	alana_mtc	what other tests have you done?

source	identity	posting
choct15_210	naomi_gsp	u gotta test da concntraition of washin pwdr see if dat makes a diffrnce
choct15_212	alana_mtc	other groups have been doin that but i dont no there results
choct15_213	paula_myp	n we r doin temp o wata 2
choct15_214	researcher	praps they could upload them to the file sharing area?
choct15_215	researcher	what were ur results, paula?
choct15_216	paula_myp	same as tasha we r wurkin in a group 2 geda
choct15_217	naomi_gsp	:D
choct15_218	researcher	ok - she hasn't told us!
choct15_219	carl_cep	I've done 2 tests with water temp at 40oC with 30cm3 of water, 3g of egg, 10g of washing powder and left them 4 20mins, the first test we used Arail powder and the 2 we used bold powder
choct15_220	researcher	and ..
choct15_221	alana_mtc	what were your esults
choct15_222	alana_mtc	results
choct15_223	paula_myp	it looses more mass in a lower concentration of asda smart price in hot water
choct15_224	carl_cep	both of the eggs lost mass i cant remember which lost more
choct15_225	naomi_gsp	our 1 woz 4.07 den it went 2 like 3.85 or sumthin

Study 3 – critical incident 2

source	identity	posting
choct21_328	researcher	so ne results at all?
choct21_329	andy_agp	oy u!!! lol
choct21_330	connor_hlp	back
choct21_331	andy_agp	none other han the eggspected...
choct21_332	connor_hlp	ha ha
choct21_333	connor_hlp	lol
choct21_334	leila_jnp	egg gets smaller coz of protiease that react wid proteins/
choct21_335	researcher	hav u seen David's results in his file upload area?
choct21_400	teacher	How was the experiment today Leila?
choct21_401	leila_jnp	cool!
choct21_409	leila_jnp	i get it now . .kinda
choct21_411	teacher	get some good results?
choct21_420	andy_agp	not particularly.. noting uneggspected...
choct21_423	andy_agp	(i worked with her)
choct21_424	leila_jnp	yer asda smart price decreases the size of du egg wite at bout 60 degrees
choct21_428	andy_agp	by 1.44G!!!
choct21_429	leila_jnp	really wel
choct21_431	teacher	was that the best powder?
choct21_432	leila_jnp	lol
choct21_433	andy_agp	we think so...
choct21_435	leila_jnp	asda smart price
choct21_436	connor_hlp	posee....
choct21_437	andy_agp	cheapest and best...
choct21_438	connor_hlp	we allready sed asda is
choct21_439	leila_jnp	shut up
choct21_440	connor_hlp	:P
choct21_441	teacher	1.44g is a big decrease
choct21_442	connor_hlp	we tried different egg sizes today
choct21_443	andy_agp	was that right leila??
choct21_444	andy_agp	1.44???

Study 3 – critical incident 3

source	identity	subject	posting
folg55_001	david_brp	sex sex sex	NO PORN HERE!!! now ive got ure attention!!!! IVE DONE THE EXPERIMENT AND MY RESULTS ARE IN THE FILE UPLOAD AREA TYPE THE LINK BELOW. (EXACT IT IS CaSe sEnSiTiVe) [http://www.sci-journal.org/2003/...] and click on the results.xls document
folg55_002	connor_hlp		ha ha very funny
folg55_003	james_shp	well dun	well dun u got my attention thats for shore but i did the same experiment but wiht more washing powder and 22deg water trying ariel boold s price and s price was the best

Screenshot of David's upload:

	A	B	C	D	E	F	G	H	I
1									
2									
3	WE USED :		POWDER	ariel	asda	smartprice	bold		
4	2g of egg		AFTER EXPERIMENT	1.35	1.31	1.77	1.34		
5	50 ml of water		% DECRECREACED	32.50%	34.50%	11.50%	33%		
6	15g of powder								
7	heated @ 60deg								
8	stirred for 2.5mins								
9	left in water for 2.5mins								
10									
11									
12	I have come to the conclusion that brand names are not always the ones to go for, asda was the biggest decreace. (34.5%)								
13									
14									

Study 3 – critical incident 4

source	identity	subject	posting
folg68_001	mary_lrp	ping moment !	sir i.ve had a ping moment :idea: I kinda get wat i'm supposed 2 b doing and i think that the powder containing enzymes is alot better because it will break down more stains am I right:?:
folg68_002	annie_sdp		:lol:
folg68_003	teacher		Well Done Mary
folg68_004	researcher	Well done, Mary!	Mary, you're a star! That's great! Patrick :wink:

source	identity	subject	posting
folg33_001	rachel_bec	How might biologic al washing powders effect egg white	Please can you help me find out :lol:
folg33_002	david_bsp		Rachel, they effect them by braking them down or digesting them. Because most of it is protein and fat the things which brake them down are called, protease and lipase. This is because if u look closely the begin of protease is protien so it brakes down protein and lipase brakes down fat because its lipid. Have u ever heard of lipo suction, well thats taking fat from yr body and putting it somewhere else and thats where we get lipase from Hope that helped. :D
folg33_003	mary_lrp		is this rachel [name] :?:
folg33_004	clive_shp		hi mary do u know what the whole egg thing is about.
folg33_005	mary_lrp		yeah kinda i've had a ping moment :D

Study 3 – critical incident 5

source	identity	subject	posting
folg57_001	leila_lnp	eggie eggie eggie eggie eggie eggie	I did an experiment where i placed eggwhite and asda smart price washing powder together at different temps. I used . . .1. 60ml of water 2. 4.4g of egg white 3. asda smart price bio We placed one mixture at 40 degrees and the other at 60 degrees. The experiment was most effective when the temp was higher (60 degrees) the mass of the egg that was heated to 60 decreased by 3.0g!!!! We only left the mixture in the water basin for 10 mins. I found out that the higher the temp the more the mass of the egg decreases or the the bio digests the egg quicker.
folg57_002	carrie_rsp		Yer i did the same thing with you remember! :D :wink: :D
folg57_003	clive_shp		Very nice leila :twisted:
folg57_004	darren_bsp		Wat else happen anything?
folg57_005	nadine_lnp		Hi Leila wot happened 2 ur egg ie. the mass
folg57_006	sara_grp		wat else happend? wat about the mass????/ :?: :idea: :!:
folg57_007	researcher	Looks promising!	Leila This looks promising - have u got ne ideas for further experiments? Patrick

Study 3 – critical incident 6

source	identity	subject	posting
folg49_001	julie_fep	experiment yesterday	:) smile be happy, hoz every1 does any1 know wot happened at the end of the experiment yesterday.
folg49_002	laura_mrp		dont think are experiment went wrong i just think the temp of water wasnt right. we should get better as we get more used to all this

Study 3 – critical incident 7

source	note	identity	posting
choct16_161	(privately to hayley_wnc)	annie_sdp	hi
choct16_162	(privately to annie_sdp)	hayley_wnc	hi
choct16_166	(privately to hayley_wnc)	annie_sdp	how r ya
choct16_170	(privately to annie_sdp)	hayley_wnc	fine u?
choct16_171	(privately to hayley_wnc)	annie_sdp	fine
choct16_174	(privately to hayley_wnc)	annie_sdp	have u dun the egg thing yet
choct16_179	(privately to annie_sdp)	hayley_wnc	yeh
choct16_183	(privately to hayley_wnc)	annie_sdp	ours went wrong
choct16_184	(privately to annie_sdp)	hayley_wnc	it srank
choct16_189	(privately to annie_sdp)	hayley_wnc	lol our first one did cos it grew
choct16_206	(privately to hayley_wnc)	annie_sdp	we either didnt leave it for long enough or didnt do somthing else right

Study 3 – critical incident 8

source	identity	subject	posting
folg87_001	jamie_pyc	READ THIS IT'S URGENT	I have got some results. I found out that a 4.75g egg in Biological Powder decreases by 19% going down to 4g. Also the same weight of egg white in Non-Biological Powder decreases by the same percentage. Why does this happen coz i don't think it's meant to...
folg87_002	alison_brc		Cool gd results! :D

Study 3 – critical incident 9

source	identity	subject	posting
folg70_001	elena_hec	Would the egg shrink?	Hi, me and my group decided to test wether a fully shelled egg would shrink or not when it had been tampered with. Heres a list of what we did. 1. Measured around the egg. 2. Put it in a beaker full of ice and left it for 2 miniutes. 3. Took the egg with its ice and melted the ice in water of 30 degrees. 4. When it was melted we added a non measured amout of non biological washing powder and left it for another miniuite. 5. We took the egg out and dried it. 6. Finally we measured it again. Unfourtunately the egg did not shrink but it was good to do this experiment for it out ruled some possible explanations.
folg70_002	researcher	Interesti ng, Elena	This is interesting, Elena. I'm not clear WHY you did this? And how did you measure it? Patrick

Study 3 – critical incident 10

source	identity	posting
chnov06_769	researcher	Folks - how do u know if a set of results is RIGHT or not?
chnov06_771	researcher	Wot do u mena by |right|?
chnov06_772	hayley_wnc	BECAUSE BIO CONTAIN ENZYMES AND ENZYMES ARE NEEDED TO ATTACK PROTEIN
chnov06_773	hayley_wnc	AND WITHOUT ENZYMES IT WOULD BE SLOWER
chnov06_777	chrissie_slc	u cant get right or wrong result in science coz every xperiment is different!
chnov06_778	richard_mnc	but it still worked better
chnov06_780	david_brp	i agree
chnov06_781	hayley_wnc	AND IN THE TIME IN THE WATER BATH THE BIO WOULD DESTROY MORE PROTIEN MAKING IT SHRINK MORE
chnov06_782	hayley_wnc	AM I RIGHT OR AM I STILL BLONDE?
chnov06_783	richard_mnc	that did not happen
chnov06_784	richard_mnc	blonde
chnov06_785	researcher	hayley, don't shout!
chnov06_786	david_brp	ure blond
chnov06_787	alan_gnc	Water Bath? i thought we were talkin bout eggs
chnov06_788	hayley_wnc	oi!!!!! im not blonde
chnov06_789	david_brp	u r
chnov06_790	hayley_wnc	k i wont shout
chnov06_791	richard_mnc	we puteggs in water bath
chnov06_792	hayley_wnc	david uve neva seen me
chnov06_793	david_brp	shhhhhhh
chnov06_794	richard_mnc	i have
chnov06_795	hayley_wnc	am i rite or not patrick?
chnov06_796	researcher	Chrissie, this is an interesting idea ...
chnov06_797	researcher	... bout right and wrong in science ...
chnov06_798	alan_gnc	hayley IS NOT BLONDE
chnov06_799	researcher	Can u say more bout this?!
chnov06_800	hayley_wnc	thank u andy, he wud no hes nown me 4 4 yrs! so ha
chnov06_801	researcher	hayley, what do you mean by |right|?
chnov06_802	david_brp	in a way there is a rite and rong answer
chnov06_803	richard_mnc	enjoying experiments write up boring
chnov06_804	researcher	so ...
chnov06_805	hayley_wnc	i mean rite against richard' answer
chnov06_806	chrissie_slc	thanks. ders nufing thats goin right or wrong in science coz everything different. its just ur doin the experiment differently
chnov06_807	hayley_wnc	this is so patronising
chnov06_809	richard_mnc	we put bio in first
chnov06_810	david_brp	u cant say iron is more reactive than magnesium because it no it hasent ever been and never will b!
chnov06_811	richard_mnc	david what are you on about
chnov06_812	hayley_wnc	i havent got a clu
chnov06_813	richard_mnc	its ment to be about eggs
chnov06_818	hayley_wnc	all i want to say is that sure ly in 15 mins the bio would shrink more egg as tit contains enzymes where as non bio does not
chnov06_826	hayley_wnc	*it
chnov06_827	hayley_wnc	answer me patrick
chnov06_828	hayley_wnc	plzzzzzzz
chnov06_829	alan_gnc	wats wit the * hanna
chnov06_839	researcher	Hi folks, a few technical problems here!
chnov06_844	hayley_wnc	patrick:all i want to say is that surely in 15mins bio would shrink more egg as it contains protein where as non bio does not
chnov06_845	researcher	So ignore |Patrick_F| - I'm here as |Patrick| now!
chnov06_851	hayley_wnc	answer ne patrick

source	identity	posting
chnov06_852	richard_mnc	hes not going to answer
chnov06_853	researcher	hayley, u need evidence for wot u r saying - do u hav ne?
chnov06_854	alan_gnc	no
chnov06_855	david_brp	is that rite chrissie
chnov06_856	richard_mnc	very good patrick
chnov06_857	hayley_wnc	yes that enzymes eat protein
chnov06_858	hayley_wnc	hee hee
chnov06_859	researcher	and wot is the evidence for this?
chnov06_860	hayley_wnc	and our experiment
chnov06_861	richard_mnc	as in posted on the forum
chnov06_862	david_brp	no they dont eat them they .....
chnov06_863	david_brp	i cant rember da word
chnov06_864	alan_gnc	eat them
chnov06_865	hayley_wnc	i no they react with them but its the same thing lol
chnov06_866	researcher	begins with d
chnov06_867	chrissie_slc	digest
chnov06_868	researcher	yes!!!
chnov06_869	david_brp	no its summit like dissolve
chnov06_870	david_brp	or digets
chnov06_871	richard_mnc	distroy
chnov06_872	alan_gnc	shut up david
chnov06_873	hayley_wnc	same thing wen u eat u digest its hust easier to right
chnov06_874	chrissie_slc	no its digest
chnov06_875	hayley_wnc	*just
chnov06_876	david_brp	thats wot i ment
chnov06_878	researcher	ok - so u hav evidence that enzymes digest the protein in egg white?
chnov06_879	researcher	hayley?
chnov06_880	richard_mnc	show us your results hayley
chnov06_881	david_brp	not its less charaters and letters look d-i-g-e-s-t and e-a-t- -t-h-e-m
chnov06_882	hayley_wnc	lol smart .....
chnov06_883	david_brp	lol
chnov06_884	hayley_wnc	its on the forum somewhere
chnov06_885	alan_gnc	lol
chnov06_886	david_brp	did u mean...
chnov06_887	david_brp	...smart...
chnov06_888	researcher	ok - so i'll agree that hayley has evidence that ...
chnov06_889	david_brp	bottem
chnov06_890	richard_mnc	but so do i
chnov06_891	researcher	... enzymes in bio powder digest the protein in egg white
chnov06_892	david_brp	yes
chnov06_893	researcher	But richard has evidence that suggests this is not the case ...
chnov06_894	researcher	... coz he found that non-bio digested the protein MORE
chnov06_895	david_brp	but the more surface area there is the faster or mor it will DIGEST
chnov06_900	richard_mnc	mr dunford will tell you what he said to me
chnov06_901	hayley_wnc	i no bout the surface area and we tried to get it the same each time
chnov06_902	researcher	ok hayley - but how do you explain ...
chnov06_903	researcher	... why ur results and richard's results ...
chnov06_904	richard_mnc	we used cubes that wieght a gram and used five of them
chnov06_905	researcher	... suggest different things?
chnov06_906	hayley_wnc	because we used different temperatures
chnov06_907	researcher	?
chnov06_908	researcher	Explain
chnov06_909	richard_mnc	i under stand that bio enzyims but it didnt work for ours
chnov06_910	hayley_wnc	because like i sed on tues day enzymes react differently to heat

source	identity	posting
chnov06_911	researcher	right - so why do u think that ur results r wrong, richard?
chnov06_912	richard_mnc	but temp would not have to make a diffrence
chnov06_913	researcher	hayley - in wot way?
chnov06_916	hayley_wnc	IT DOES
chnov06_917	researcher	But how?
chnov06_918	david_brp	STOP SHOUTING
chnov06_919	hayley_wnc	enzymes work faster as heat rises
chnov06_920	researcher	always, hayley?
chnov06_922	hayley_wnc	im not shoutin i just 4get to turn of caps
chnov06_923	hayley_wnc	no not always
chnov06_924	researcher	how do u know?
chnov06_925	richard_mnc	but we done 2 diffrent heats 50 and 60
chnov06_926	hayley_wnc	because u tld me hee hee
chnov06_927	hayley_wnc	yer we did 30
chnov06_929	researcher	OK richard - wot did u find?
chnov06_932	richard_mnc	that non bio works better
chnov06_933	hayley_wnc	no it doesnt
chnov06_934	alan_gnc	I DID 80'C 4 5MINS AND DA BIO ENZYMES DIGESTED THE PROTEIN QUICKER
chnov06_935	researcher	richard, that's an interpretation of your data ...
chnov06_936	hayley_wnc	u cant say that have u dun ur tests twice to confirm that?
chnov06_937	researcher	... ur results indicate that ...
chnov06_938	david_brp	no coz ova 60(deg) the enzymes or protiens (i cant remember which) denature
chnov06_939	researcher	...non-bio digests egg white ...
chnov06_940	researcher	... quicker than bio ...
chnov06_941	researcher	yes?
chnov06_942	richard_mnc	that is true
chnov06_943	david_brp	huh that makes no sense
chnov06_944	researcher	GOOD!
chnov06_945	david_brp	ya mr d told me
chnov06_946	researcher	y not, david?
chnov06_948	hayley_wnc	yer thats wot patrick tld me about them denaturing :D
chnov06_949	researcher	Good word, hayley!
chnov06_950	researcher	But here's the point i want u to answer ...
chnov06_951	hayley_wnc	.....
chnov06_952	alan_gnc	denaturingg?
chnov06_953	researcher	... richard says non-bio is best ...
chnov06_954	hayley_wnc	shut up andy
chnov06_955	researcher	... hayley says bio is best ...
chnov06_956	alan_gnc	wat did i do
chnov06_957	hayley_wnc	no i say im the best :)
chnov06_958	researcher	... so is one of them right and the other wrong?!
chnov06_961	richard_mnc	not necerseraly
chnov06_962	hayley_wnc	i dunno david?
chnov06_976	david_brp	how do u stop a baby spitting at you???
chnov06_977	hayley_wnc	tell me on msn
chnov06_981	alan_gnc	Patrick wats all da dots bout ,.....
chnov06_982	hayley_wnc	yuk!
chnov06_983	researcher	i put in some dots ...
chnov06_985	researcher	... when i want ...
chnov06_986	researcher	... to continue a message!
chnov06_987	alan_gnc	ooooooookay
chnov06_988	researcher	(Can't type quickly enuff!)
chnov06_989	david_brp	lol
chnov06_990	richard_mnc	what about my idea of not nesercraly
chnov06_991	alan_gnc	i got a joke
chnov06_992	hayley_wnc	yay chris hall is online this shud make it funi

source	identity	posting
chnov06_993	researcher	not now alan!
chnov06_995	researcher	richard, i want to follow this up ...
chnov06_997	researcher	becoz u r making an important point i think ...
chnov06_1003	david_brp	chris is cummin on
chnov06_1004	richard_mnc	thank you
chnov06_1005	researcher	So listen up folks ...
chnov06_1006	richard_mnc	im all ears
chnov06_1007	david_brp	im listenin
chnov06_1008	researcher	... let me repeat my point again
chnov06_1009	chrissie_slc	me 2
chnov06_1010	researcher	(no-one's perfect!)
chnov06_1011	alan_gnc	me 2
chnov06_1012	david_brp	wait chris is just cummin on
chnov06_1013	alan_gnc	no es not
chnov06_1014	researcher	hayley says her experiments show that bio powder digests egg white better than non-bio ...
chnov06_1015	david_brp	he is im tlkin 2 him
chnov06_1016	alison_brc	Hi im back :D
chnov06_1017	researcher	... and richard says that his experiments show the opoosite ...
chnov06_1018	richard_mnc	yes
chnov06_1019	researcher	Now ...
chnov06_1020	hayley_wnc	alison chris is gonna be online in a min cos hes on msn
chnov06_1021	alan_gnc	well cum on
chnov06_1022	researcher	... does this mean that one of them must be right and the other must be wrong?
chnov06_1023	chrissie_slc	no
chnov06_1024	alan_gnc	who hios cris hall
chnov06_1025	david_brp	no
chnov06_1026	researcher	Or can they BOTH be right?
chnov06_1027	richard_mnc	not necerseraly
chnov06_1028	hayley_wnc	alison just came online cos she noes carl is coming ;0 only jokin
chnov06_1029	researcher	Or both wrong?
chnov06_1030	hayley_wnc	YES CHRIS HALL
chnov06_1031	chrissie_slc	coz like i said ther r no rights and wrong in science
chnov06_1032	hayley_wnc	were both right arent we richard
chnov06_1033	david_brp	like chrissie sed earlier there is no rite or rong answer in this particular experiment
chnov06_1034	richard_mnc	depends

Study 3 – critical incident 11

Group 1
sara_grp (Dec 02 18:21:34)
Opening statement
i think my report is the best as i have explained how the experiment was done and recorded my results clearly and in an understanderble way. at the end i have concluded the experimaent and wrote what could be improved. at the end of the experiment i have plotted a graph to show the results of the experiment.

elena_hec (Dec 03 17:09:23)
Opening statement
Though the other write ups are extremly good i still feel that mine should come out on top due to the amount of scientific detail and explanation i have encluded. Without waffling i have managed to stress why i have various predictions and also why things turned out the way they did. I feel that another strong point of my write up was the way i displayed my results, by using both a table and a graph you get two different aspects of the same thing. The table shows every result i achieved but the graph pin points the aspects of the data wich are important and prove my theory to be correct. The only problem i could see with the over write ups was the lack of independent reasearch , i tried my best to back up almost every statement i made by looking on the internet and books. I added in these sights or authors on my report. So please vote for me :D lol

charlie_nmc (Dec 15 10:20:57)
OPENING STATEMENT
I believe that my report is the best because I tested thoroughly throughout getting accurate results and being very fair in that I did everything three times giving I think giving good results. I believe that my report was very descriptive but I think that it had to be because if someone read my report they have to know everything in detail otherwise they might not understand. I did have a graph in my report but it was not shown but I think that my graph did also display good results. But on one of the other reports they said that the weight of the egg white rose therefore they must had made a mistake but I believe I did not do this.

Responses to group 1 opening statements
Thread 1
billie_flp (Dec 04 18:37:53)
THe best Report
Hullo everbody I personally think that elenas is written best and it is gd. No offence sara :!: Well aint there nother person to do this too? :?: :?: okay

billie_flp (Dec 10 09:44:00)
i think elenas is the best because 1) it explains the investigation thoroughly 2) it is very well presented 3) she shows strong understanding of what to do 4) she knew what to do 5)it is very detailed There you are thats why i think that elena's is best

elena_hec (Dec 15 10:03:12)
thnx
Thnx again for praisin me thing lol i dint think it was that gr8 oh im plsed n e way Luv Elena 8)

billie_flp (Jan 02 13:26:32)
I think urs explained it and was quite complex but easy to understand

Thread 2
darren_bsp (Dec 12 09:29:15)
elena's report
i have just read elena's report and i found it very interesting. She has managed to include everything and has evaluated her work well, saying what she thought was wrong with it, why she thought it and what she would do better aswell as why she thought it would go well. I enjoyed reading it and found it a good guideline if i were to do another report. Darren

Thread 3
darren_bsp (Dec 12 09:37:51)
Sara's report
I thought sara's report was to the point and snappy, giving us the facts and upfrint. It also gave us evaluations of each of the results given in the report, for each different temperature, which gave it good insight into ideas. She put a in some good contructive points about the way se would do the report again if she was to. This report has good ideas in it and i would definately take some it's ideas in further reports. Darren

Thread 4
darren_bsp – (Dec 12 09:47:08)
charlie's report
Reading charlie's report was a bit hard at times as his sentences were sometimes very ong and squashed together. Maybe a point to think about in the future. He also tackle very high level concepts and gave good reasons for his ideas. he was also very descriptive about his work and sure his way was a good way of going about it. He needs to out a bit more contructive ideas about why results were hpw they were, how they came out and reasons for it. But overall a good report, nice one chris. Darren

Thread 5
jamie_pyc (Dec 15 10:07:02)
My Favourite Report
I think elenas report was the best because it was simple to read, had a good range of infomation and several good tables and graphs. it was veery detailed and she also wrote all the things she did wrong. Charlie's report however was all writing and a lot of it! sorry Charlie but it was boring to read and too long winded, but it did have a lot of good infomation. Overall i think elenas is the best, sorry charlie! :mrgreen: Jamie

Thread 6
hayley_wnc (Jan 05 18:15:53)
Elenas report
i think elenas is the best report because it contains detailed paragraphsd and other helpful informattion such as graphs.

Group 2
chrissie_slp (Dec 02 18:06:41)
Opening statement
hi! I think that my report explains the behaviour of the egg white when it is put into a solution of washing powder best because of my results. They match up with other scientists work and the research i have done. In my research it shows that temperature does affect the mass of egg white lost and that is also what my results show. Also i think that i did the experiment as accurately as can be done in the sourroundings and cirrcumstances we were given. Based on my research other scientists, both in my class and proper qualified scientists results have shown the same as my results. Also the rest of my report explains clearly how we did the experiment and what i could have done better. Thanks :)

connor_hlp (Dec 02 22:56:31)
Opening Statement
Ello! I think my report best describes the effect of biological washing powders on eggwhite because the results are all correct with a good explanation and it is set out well and easy to read. Thats basicly it, im not very good at these and i've allready had to start again as i hit the backspace key when i wasn't in the box and it deleted it all! :(Connor

No posting by alan_gnc

Responses to group 2 opening statements
Thread 1
andy_agp (Dec 10 09:46:30)
chrissies report
i think her report was well presented but she revealed a bit too much in her first paragraph. the graphs look good but are distorted. very colourful. the ending statement and her results were well

presented. if she had put a bit more detail into the variables list, it would have been better because there was no indication of what the list was for until afterwards.

chrissie_slp (Dec 14 17:56:01)
Thanks andy! :) (i think da graphs are distorted coz dey werent supposed to be dat big!!)

Thread 2
alana_mtc (Dec 14 21:14:42)
What i thought
:D :D :D :

Study 3 critical incident recall 1

Students: Carl, Paula, Naomi (Pynewood School)

researcher	The three of you were online last Tuesday ... and you were talking about the work with the eggs that you've done, and I'd just like to ask you some questions about that. At the start of the discussion you were discussing some of the results that you'd got from the work that you'd done ... I'm going to ask you a bit about [those] in a moment, but first I wonder if you can tell me a bit about how you set about the practical work to start off with ... what kinds of things did you do?
Carl	Just planned out how we tried to do it and things – it was like ...
researcher	Tell me a bit about the planning process – what sorts of things did you do?
Naomi	We had to work out what we was looking for and what we thought was going to happen
researcher	So how did you do that?
Naomi	We had to research about egg and um
Paula	and washing powder
Naomi	and washing powder – and then we had to design the tests and write what things, variables, what we could change – see what results you got.
Carl	We've got 72 different variables in our experiments, that's 72 experiments we've got to do, and we've already done 8 of them – 12 of them.
researcher	72 different variables! Wow!
Carl	Yup! different grams of washing powder, different grams of egg ... water
researcher	Did I hear you right Carl, you say you've got to do 72 different experiments?
Carl	Yup!
researcher	... how about you [the two girls], have you done anything like that, you two?
Paula	We've got just the temperature and the washing powder and the concentration difference, so we haven't got as many tests to do.
researcher	... you're setting about changing things and making measurements, is that right?
Paula	Yeah.
researcher	OK, that's fine ... everything that goes on in the chat room is recorded, and I've just printed out some bits because I thought ... there were some interesting things here ... in this little bit, Carl, you were asking people what results they'd got at this point ... and there were some people from the Isle of Wight online as well and you asked people what results they'd got; Alex on the Isle of Wight replied that her results weren't very good – she says "got some but they aren't very good". You said you'd guessed that ... I wondered what you meant by that?
Carl	I think I was actually replying to something else, but ... !
researcher	Oh, that's threaded with something else is it?! Oh that's fine, well in that case ...
Paula	Is it Naomi's one?
Naomi	Yeah, that.
Paula	It got lighter.
Naomi	[explaining thread] It got lighter – I guessed that.

40	researcher	[repeating] Oh, "I guessed that"! OK, that's fine … when Alex says "we have got some
41		[results] but they aren't very good" – several people have said things like that in the
42		chat room and in the forum, and I just wondered if you could tell me what you think
43		people mean if they say their results aren't very good.
44	Paula	That their egg didn't get very much lighter and that there weren't much change.
45	Carl	There wasn't much change, yeah.
46	Naomi	That's what we got, cos we got one that wasn't lighter.
47	Carl	Or some that added instead of reduced.
48	researcher	There are some people who've got eggs that have got heavier?
49	Carl	Yup, happened to one of ours.
50	Paula	Yeah, happened to one of ours as well.
51	researcher	So what have you done with that set of results?
52	Carl	We're going to do that test again to check it, because … it might be wrong.
53	researcher	Because that doesn't fit?
54	Carl	With the others which have all reduced.
55	researcher	… so if someone says to you "my results aren't very good" what would you think they
56		meant by that?
57	Paula	That [tentatively] other people's egg lost more weight.
58	researcher	In general … if you'd missed a piece of work because you'd been ill … so you went
59		round looking for people's results and one person said "my results aren't very good",
60		would you use their results?
61	Carl	You'd still use them …
62	Naomi	'Cos they're still their results from an experiment, so …
63	Carl	'Cos they might have done the experiment wrong or – done something …
64	Naomi	If you had … like sometimes you have to make, like, a certain thing by doing other
65		things and so if they hadn't quite made it then they would say it wasn't very good.
66	researcher	If they hadn't – yes, go on …
67	Naomi	Like if they had … you know that burning thing that we had to do and we had to get
68		crystals and metal, like some people didn't really get them?
69	Carl	Make copper.
70	Naomi	So their results wouldn't be very good.
71	Carl	'Cos nothing much happened.
72	researcher	OK … so let's just move on … there's another bit here where Pam, you were saying "it
73		must have been quite heavy with the amount of egg Craig was peeling" – what was
74		Craig up to?
75	Carl	Craig's in my group and he … if he hasn't got anything to do he just goes round
76		annoying people – he was probably just annoying you, wasn't he [to the two girls]?
77	researcher	So there's nothing significant that you were talking about Craig peeling lots of eggs …
78		?
79	All	[agreement]

researcher [Indicates chat transcript] "Some people put loads in and some people only put a little bit in" – Naomi, you started this discussion about the amount of eggs people put in and you said "I guess they'll have to test it and find out". What will they do to do that?

Naomi Well, however much egg they put in they'll have to test it and see whether it makes a difference, like how much egg or water you put in.

researcher Is that something you're doing?

Paula No.

Naomi We've got the same amount of egg, but we're putting different amounts of the washing powder in at different temperatures.

researcher And why are you doing that?

Paula } To see if the conditions will change the effectiveness of the washing powder.

Carl } ... what's the best conditions ...

researcher But why have you chosen to do it exactly that way?

Paula Because ... when you're, like, using a washing machine you put ... sometimes you put different amounts in ...

Carl } Different temperatures.

Paula } ... and you use different temperatures.

Carl Yes.

researcher ... so ... are you trying to make your tests ...

Carl ... simulate a washing machine, yeah.

researcher ... like a washing machine.

Paula } Yeah, we're mixing it as well so it, like, goes around.

Carl } 'Cos that was what would happen.

researcher So is there anything else you're doing to make the test like a washing machine?

Carl We're doing different temperatures ... 40 degrees, 60 degrees and 90 degrees in a washing machine.

Paula Mixing it up so it's ...

Carl } Could stir it so it spins.

Paula } ... like turning around like in a washing machine.

researcher Carl, you say [in the chat room] that you've got another 16 experiments to do, it sounds as though you've got more than that to do now.

Carl That's without ... 'cos each one of those experiments we've got to do four different washing powders with so that's ... we had already done two there so it was 18, so it was 72 [laughs] ... we've now done 12 so we've only got ... um ... 60 to do.

researcher Are you going to be able to finish all those?

Carl We won't get them all done!

researcher So what will that mean for the results ... are you going to be able to produce any conclusions?

Carl Not really 'cos we got all the [inaudible] experiments done, 'cos the best ... situation with the washing powders might be the one we haven't done, so we don't really know.

Study 3 critical incident recall 2

Students: Leila, Andy, Connor, Mary, David, Laura (Pynewood School)

researcher … can you tell me a little bit about the beginning of [the investigation] … how did you plan what you were going to do?

David Guesswork, I'd have said – I guessed some of it, I mean, I tried it at home and I've uploaded that file and it didn't work ' cos I used raw egg white and just washing powder and it just turned into a sticky gloop!

Leila Just seeing all the ingredients, like you had the egg and then you had heat and stuff and then you had all the washing powders and seeing how you could use them, like if you could put the egg at different temperatures with one washing powder or the same temperature with a different one.

researcher So where did you get your ideas from?

David Scl-Journal.

Andy Thinking about it, thinking about all the variables.

Leila Sir.

researcher … [repeats] Sir … Mr Davis?

Leila Yeah, and we've done some stuff before, haven't we, like just experiments, so we kind of knew what we could use and …

Andy Yeah, and the variables and stuff.

…

researcher So … when you started to do your experiments, did you have a good idea of what you were trying to do, or were you just trying things out to see what happened?

Mary Trying things out.

Leila But we all knew that we were trying to find out …

Andy Yeah, we knew what we were aiming for.

Leila … what affected, what it was that made the egg whites get smaller.

Andy We know what we're aiming for, we're just trying things out to find out what would work.

Leila Like a start and a finish and we're trying to fill in …

researcher You must have decided to do something to start off with, you decided to try doing a particular soap powder or something like that, how did you make those kinds of decisions, what did you do?

Leila Well, we only did our experiment after other people had sort of done theirs and then everyone else sort of figured out that ASDA Smartprice one [washing powder] was the best one, decreased …

Others No it wasn't!

Mary Ours has gone completely different!

David Just normal ASDA!

Leila Well, that's what Sir told us, told me anyway.

researcher Mary … what did you do?

39	Mary	We were doing, like timing the weight of the egg after every 10 minutes and we're
40		doing 50 minutes at the moment.
41	researcher	What made you decide to do it like that?
42	Mary	We just thought it would be quite an easy one to do.
43	researcher	So when you were looking for ideas about this how did you go about finding ideas to
44		help you do the practical work?
45	Leila	Mr Davis gave us, like, a few ideas to do.
46	Andy	Yeah, pointed us in the right direction and then we just stumbled along blindly until we
47		came across something that worked.
48	[general laughter]	
49	researcher	Andy ... what do you mean by that?
50	Andy	Mr Davis, like, told us what should happen and what we could change and we had an
51		idea 'cos of this work we've done before of what would affect what so we just tried a
52		few things out until it worked.
53	researcher	What work had you done before that gave you those ideas?
54	Andy	Like works on the elements and stuff, we knew that the enzymes would have affected
55		something in the egg because its full of protein so we had to find one with high
56		enzymes in it.
57	researcher	David ... you did this experiment at home ... can you tell us a bit about that?
58	David	What I did was I got an egg white and I put a skewer in the bottom just to drain the
59		pure egg white out ... drained it out and I got a biological washing tablet, crushed it,
60		and I mixed the two together, but when I mixed them together they just turned to a
61		gloop and nothing really happened ... but I only left it there for 30 seconds, I didn't
62		leave it very long or anything like that so nothing much happened.
63	researcher	But you've also uploaded some more results ... there they are [points to printed
64		version on table] ... that's the one that deals with ... four washing powders, and you've
65		described the conditions ...
66	David	And we used a water bath and heated it at 60 degrees ... and we mixed, did the whole
67		thing for five minutes, we mixed it for two and a half minutes and left it for two and a
68		half minutes 'cos Connor was saying that symbolises like a washing machine, 'cos like
69		a washing machine heats it and it mixes for so long and then it stops and then
70		whatever.
71	researcher	So you're trying to make ... the conditions of your experiment as close to a washing
72		machine as possible?
73	David	Yeah.
74	researcher	Did any of you see ... David's post [to the forum] ... about [his] upload ... did anyone
75		see that? [points to printed version on table]
76	Several	Oh yes!
77	Mary	Oh yes, sex, sex, sex! [the title of the post]
78	Leila	[reads first part of post] No porn here! Now I've got your attention, I've done the
79		experiment and my results are in the file upload area ...
80	researcher	Where did you get the idea for that, David?

81	Andy	The Simpsons!
82	David	… where he's trying to get Bart to become President or something and it said "sex,
83		sex, sex – now I've got your attention" …
84	researcher	How many people read it, do you know?
85	Andy	I did!
86	Leila	I did! – it just caught my eye when I was looking down the list!
87	David	I was tempted to put something like "******* porn" or something 'cos then some of the
88		lads would have clicked it but I thought I might get the chop for that one!
89	researcher	Yes, I think you've gone just about as far as we could expect to leave it up there on
90		the site … so, yeah!
91	…	
92	researcher	[Paraphrasing forum post] "Affecting egg white by breaking it down or digesting it" –
93		what I thought was quite interesting at the end of this [thread] was Mary's comment …
94		she says she's had a "ping moment" at the end of it. Is that Mr Davis's term?
95	Mary	Yeah.
96	researcher	What is a "ping moment"?
97	Leila	It's when you've just worked something out and a light bulb comes on in your head or
98		something.
99	Mary	If you don't understand it then you're, like, PING!
100	Connor	Like a light bulb over your head!
101	researcher	And what's it like?
102	Mary	Well, you don't really get a light bulb in your head! … You kind of like suddenly work
103		out what it is and …
104	Andy	Yeah, it suddenly comes to you.
105	Leila	Oh yeah, I get you, yeah!
106	Mary	Or come up with, like, the language to understand it or come up with an idea.
107	researcher	So what had just suddenly gone "ping" Mary?
108	Mary	I don't know, I was sat there looking at all the messages and I was looking and then I
109		just sat there like a daydream … and something just came into my head, and I just put
110		it down.
111	researcher	Is that something that happens to you often – is it something that's happened to you
112		before?
113	Laura	I've never had a ping moment.
114	Leila	I had one a couple of days ago.
115	researcher	What were you thinking about Leila?
116	Leila	This! 'Cos at the beginning I didn't understand it and I didn't see how any of it linked …
117		and then I started looking at the ingredients and washing powder and stuff and then I
118		thought it might affect the stuff that's in the egg and then, sort of, [inaudible] them
119		together.
120	…	
121	researcher	So what about … David, have you had one of these "pings"?
122	Leila	No, he knows everything! He's never not known something!

123	researcher	Is that right?!
124	David	Well, no, but if I don't understand something I kind of, use the information that I do
125		know to help me and if I can't ... if I find it too hard I just give up, 'cos I'm like that!
126	...	
127	researcher	Have you identified any of the variables that might be involved?
128	David	Heat, washing powder to water ratio, the amount of egg ...
129	Leila	You could have the same amount of ... the same washing powder and the same egg
130		but do it at different temperatures. 'Cos that's what I did, that's what Clare's doing now
131		... we got it up to, we kept it in for ten minutes and it was at 60 degrees and we had
132		4.4 grams and our egg decreased in mass by three grams.
133	Andy	It wasn't, it was one point ...
134	Leila	He was copying our experiment, he wouldn't know!
135	Andy	I wasn't, I was with you ...
136	researcher	You were discussing this online the other day, weren't you?
137	Leila	So when we were ... that's what Clare's doing now, she's trying to see how high she
138		can get the temperature to go before it denatures the enzyme.
139	researcher	'Cos ... you three – Leila, Connor and Andy – you were in the chat room weren't you,
140		earlier on this week ... [points to paper on desk] this is the log of some of the chat
141		room [session] ... Mr D says ... "get any good results?" ... and Andy says "not
142		particularly, [nothing unexpected"]. ... So if Mr Davis says "any good results" how
143		would you know what a good result was?
144	Andy	We just got the results we expected to get, so I thought ... you would be able to make
145		much of it 'cos everyone's done it before and knows what it should come out like.
146	Laura	Our experiment, we've done two now and they just don't work. The first one we did
147		was OK but I forgot how much washing powder we had. And then we writ [sic] on the
148		... glass beaker things and put them in but the pen didn't stay on so we didn't know
149		what washing powder was what. And then the other day we went into Mr Rice's class
150		to do it while the others were in the IT room, using Bunsen burners to try and, like,
151		keep it at the same temperature, and it didn't work.
152	researcher	... you said ... "this is all very new but don't worry – we'll get better once we get used
153		to doing it". What did you mean by that?
154	Laura	Well, someone writ [sic] on there that they thought their experiment went horrible 'cos
155		all the egg got heavier or something, and it did with ours as well, and it's where it's all
156		new and all the forum's new and everything and no-one really knows – we're learning,
157		we don't actually know exactly what to do, we're still learning how to use it so we'll get
158		used to it and soon we'll know what we're doing and we'll be able to use it better.
159	researcher	Do you mean as you do more of this practical you'll get better at doing this practical?
160	Laura	Yeah.
161	researcher	[To whole group] Laura was saying the more you do something like this the better you
162		get. Is that something you'd agree with?
163	Leila	You get used to, like, the terms you use.
164	Andy	And what should happen and stuff.

165	researcher	So, if I were to take this experiment back to [the] University and get a group of people
166		doing degrees in chemistry to do it, do you think they'd get the same results as you?
167	Leila	Theirs would probably be more accurate.
168	Laura	They've had more experience though, 'cos they're older than us.
169	Leila	And they might be able to do it a lot quicker than we can.
170	David	If I'm honest I think that they might get quite different results, 'cos they'd probably
171		jump in thinking "oh they're just little pipsqueaks, we're brilliant and we know what
172		we're doing" and they'd jump in and say "we're gonna do this once and we're gonna
173		do it with these variables" whereas we've tried it over a long period of time and just
174		kept doing different stuff so they might just jump in and then stumble at the first hurdle
175		if you like.
176	researcher	So ... would you think their results would be better, different, not as good as yours?
177	Leila	Less reliable.
178	researcher	As yours?
179	Leila	'Cos we've been doing it, and we've had everyone to help us and at the moment no-
180		one's really on the wrong track because everyone's been, like, saying "this is OK" and
181		everyone's been agreeing with it, and Sir keeps telling us, like, the right answers sort
182		of, so, they're all, like, thinking "big hints".
183	researcher	So [points to transcript of chat room log file] what was happening here then? Andy
184		says that there's nothing unexpected that's happened, and then Leila ... says that
185		ASDA Smartprice is the one that decreases the size of the egg white most?
186	Leila	At about 60 degrees.
187	Andy	That's the results we got.
188	David	When you were doing that Leila, were you stirring it? Or were you just leaving it?
189	Andy	No, we just left it. We stirred it and then left it.
190	David	And how long did you do it for?
191	Andy	} 10 minutes
192	Leila	} 10 minutes
193	David	Oh. 'Cos see we found that the ASDA was the best but we stirred it for half the time
194		and we only put it in for five minutes.
195	Leila	We didn't' stir it we just put it in and then put a thermometer in it and left it.
196	researcher	You seem to be having some discussions about the BEST washing powder here ...
197		what [do] you mean by "best"?
198	Andy	The one that ...
199	David	The most effective.
200	Andy	... digested it more and quicker.
201	David	I mean, we found ... we used a frozen egg, I don't know if that had any effect but ...
202		when we'd finished it all our eggs apart from one had gone green hadn't it?
203	Laura	Urghh, that's disgusting!
204	researcher	So if ... people get different results ... how can you explain the fact that Mary's got
205		one set of results and Lisa's got a different set?

206	Andy	She might have left it for longer or shorter, she might have stirred it more, there might
207		be more egg in there ...
208	Leila	Used less or more egg, more powder.
209	Andy	It could have been anything.
210	Leila	Temperature.
211	Andy	But, if we were to use exactly the same everything our results would be pretty much
212		exactly the same.
213	David	Probably be quite similar, yeah.
214	researcher	So do you think if two groups did exactly the same variables, exactly the same
215		conditions, do you think they would get the same results?
216	Leila	Yeah!
217	Andy	Possibly.
218	Leila	If the egg is, like ...
219	Andy	Very close, I reckon.
220	Leila	... the same amount old as , the same everything. 'cos it's hard to tell, if the egg's, like
221		...
222	Andy	I mean, one could be a week old, one could be a year old, so ...
223	researcher	Well, they're all coming from the supermarket, so they're all roughly the same age ...
224		are there any other differences that there might be?
225	David	Just say they said you gotta stir it, one person might stir it quite slow the other might
226		stir it really fast, which could have a difference because the egg's moving all the time.
227	Leila	It might make a difference what you stir it with.
228	Andy	There might be something on what you use to stir it with as well that could get in and
229		affect the ...
230	researcher	So do you think it would ever be possible to say "this is the best washing powder"?
231	Leila	} No.
232	Laren	} No.
233	researcher	Why not?
234	Leila	'Cos one washing powder ...
235	David	Yeah, I do.
236	Laren	Yeah, I do.
237	Leila	... might be better at cleaning a certain thing than another washing powder.
238	researcher	But using this test. If we tested all the washing powders using this test could you say
239		"this is the best washing powder"?
240	David	I think, myself that ...
241	Andy	You could say that all signs point towards it but you could never be certain or sure
242		about it because anything could have been changed.
243	Leila	'Cos they're always bringing out new stuff, aren't they.
244	David	I think that, in my opinion, that the easiest way probably would do it would be to get
245		some egg white and because we're testing how it breaks it down, 'cos it's egg white;
246		put some washing powder on some actual clothes and see if you notice a difference
247		once it's actually been in a washing machine.

248	researcher	Rather than trying to have a washing machine ...
249	David	Model – to actually physically use a washing machine.
250	Leila	But how would you get the egg white on the clothes? (If it's egg white.)
251	Laura	Blend it.
252	Leila	It's not going to stick on clothes, is it?
253	Laura	Yeah.
254	Connor	Stick it in the pocket or something!
255	Andy	No, it wouldn't have the same effect because there would be nothing actually driving it
256		round it would just be being pulled around by the clothes. Don't think that's such a
257		good idea.
258	Connor	Yes, but you'd actually stir it and stuff and you'd break it up and everything, like, gets
259		smaller and have more surface area. Kill more protein.
260	researcher	Now, let's have a look ... [shows students forum logfile extract] ... there's another one
261		you've posted, [to Leila] there's your results ...
262	Leila	Do you want me to read it out?
263	researcher	Go on then, read it out, Leila.
264	Leila	[reading] I did an experiment where I placed eggwhite and ASDA Smartprice washing
265		powder together at different temperatures. I used 60ml of water, 4.4 grams of egg
266		white, asda smart price bio. We placed the mixture at 40 degrees and the other at 60
267		degrees. The experiment was most effective when the temperature was higher (at 60
268		degrees). The mass of the egg white was heated to 60 degrees decreased by 3.0g.
269		We only left the mixture in the water basin – I think that's what they're called - for 10
270		minutes. I found out that the higher the temperature the more the mass of the egg
271		white decreases or the bio digests the egg quicker. [no longer reading] And then
272		somewhere I put here – I did put it in there – somewhere I put however, if the
273		temperature is too high then it will denature the enzyme.
274	researcher	Leila, what do you mean "denature the enzyme"?
275	Andy	It means they won't fit in, it's like a key, they won't fit properly into there so they can
276		break up the, um ...
277	Leila	Protein.
278	Mary	Like an odd-shaped thing that'll go like that and then they can't all fit in a little triangle.
279	Andy	..it wouldn't break up the ... his [Connor's] Flash movie.
280	researcher	Connor's Flash movie, yes ...
281	Andy	If they weren't little triangles, they were little circles it wouldn't work, so ...
282	Leila	[who has been reading the forum logfile] See you need to go on this thing every day,
283		because I have posts here that I didn't see!
284	researcher	Connor, you've done a very interesting Flash movie ... what made you draw it in the
285		way that you did?
286	Leila	How did you DO it?!
287	Connor	Flash.
288	Leila	How did you do it any way?!

289	Connor	Sir did one up on the board like that and then I just thought maybe I should make it
290		animated.
291	David	Did you use those shapes because last year we were doing it, weren't we, and it
292		showed those shapes for proteins, I think it was?
293	Connor	Yeah.
294	researcher	So that's what the enzymes, kind of look like?
295	Andy	} It's a model.
296	Leila	} No it's a model.
297	David	} It's a model, 'cos you don't know what they look like, but ...
298	Mary	} 'Cos you never ... yeah.
299	Andy	No-one knows.
300	researcher	When you say it's a model ... can you just explain?
301	David	It's a visual image that you can see with your eyes you don't have to look through ...
302	Andy	It represents.
303	Leila	Yeah.
304	David	... an extremely high-powered microscope to see them actually, you can just see with
305		your eye on the board or whatever what's happening. But it's not necessarily accurate.
306	Andy	It's good enough, it'll do the job.
307	David	It just shows what they do.
308	researcher	So what's the point of it then, if the enzyme doesn't really look like that?
309	Andy	} Just represents it.
310	David	} To help you learn what it looks like. Help you learn how they work.
311	Leila	} It helps you understand, like a visual image.
312	Mary	} It kind of helps you learn.
313	Andy	} It's like a caricature, it doesn't actually look like the person, but it represents them.
314	Connor	} Can't see it.
315	researcher	Can you think of any other models like that, then?
316	David	Like with electrons and protons and stuff like that, they don't actually look like a
317		nucleus in the middle and loads of rings around it ...
318	Andy	But that's how it's portrayed ...
319	David	... it hasn't actually got rings, they're just spinning in mid air, if you like, it's not actually
320		on rings.
321	Andy	It's just to show the path of the electron.
322	Connor	If you say, like, a solid isn't, like, ... made up of circles or spheres.
323	Andy	Can I just say something here?
324	researcher	Andy, go on.
325	Andy	With this experiment, when I weighed it, it was, it went down by 1.44, that's the results
326		that I got.
327	Leila	[reading from forum logfile, slowly] Three grams ...
328	Andy	It went down by 1.44.
329	Leila	... well it was, no, I think maybe you got the wrong thing, 'cos it was 4.4 grams at the
330		beginning, wasn't it ...

331	Andy	Yeah.
332	Leila	... yeah, so it went down by 3 which would leave 1.4, maybe that's where you got it
333		from.
334	Andy	No, it went down by 1.4 and left 3, that's why you got the wrong way round, 'cos it
335		wouldn't go down by 3.
336	Leila	Clare and I started doing the experiment and Andy was working with someone else,
337		then Andy said "I'm working with you guys" and Clare and I were, like, "Oh, OK", so
338		basically everything we did he sort of did, and he was asking us questions about it
339		while he was doing it, so ...
340	Andy	No, but when I weighed, when I did it again ...
341	Leila	But I think it went down by three.
342	researcher	So is this why you've got the disagreement in the chat room ... is there any way in
343		which ... can we resolve this?
344	Andy	} Do it again!
345	Leila	} Yes! Ask Clare!
346	Andy	Yeah, but what if Clare's got it wrong?!
347	Leila	Clare, Clare was ...
348	David	Clare's not biased then?!
349	Leila	... no, she wouldn't know because she doesn't know what either one thinks, so she
350		wouldn't be biased, and also she was doing the same experiment as me, so the result
351		I got she got as well, OK!
352	David	But wouldn't it be easier to do again though?
353	Andy	Wouldn't it be easier to do it again, and then you can just ...
354	Leila	Should I go ask her?
355	researcher	Not for the moment, no. If you repeated the experiment, would that be a way of solving
356		it?
357	Andy	Three grams seems a lot for it to go down in that time, 1.4 seems ...
358	Leila	Well, that's at 60 degrees, that might be on the verge of it denaturing the enzymes,
359		which means you'd get the most effective result.
360	David	It could be possible though, because when we did it, we did it for half the time and we
361		had two grams of egg, I think it was, and the most powerful one, which was ASDA,
362		took it down to 1.33. So, you've got ten minutes, so it could well take it down that
363		much.

Study 3 critical incident recall 3

Students: Hayley, Alana, Elena, Alison, Jamie (Castleford School)

researcher Alana ... this is some of the chat room [logs] ...

Alana this is when I was the only person who was on it ... Castleford person!

researcher That's right! One of the things that was happening here was that a guy called Carl from Pynewood was asking about results, and that's Naomi from Pynewood as well. But you said, when Carl said "have you got any results?" you said "we've got some but they aren't very good.

Alana Yeah.

researcher I ... wonder what you meant by "not very good".

Alana Um ... well we hadn't, I don't think we'd done very many tests so we didn't really have an accurate thing of what actually happened, so we couldn't really say what had happened.

researcher So, ... if somebody says to you "my results aren't very good" what kind of thing do you think they might mean by that?

...

Elena That you didn't try very hard or something.

Jamie You didn't do it right.

researcher Didn't do it right?

Elena } Yeah.

Alison } Mmm.

researcher Didn't do what right – what was wrong?

Jamie You've got things messed up ... got the weights wrong ... I did that – it went up.

researcher Tell us a bit about that.

Jamie It went up, it went up – I don't think we washed them properly.

Elena Yeah, we did that.

researcher Oh, your egg whites got heavier?

Alison Yeah, so did ours.

Elena Yeah, we didn't wash them.

researcher Yes, I think that I've got something, let's have a look [shows chatroom logfile transcript on paper] ... the next day [Hayley] you and Annie, a girl from Pynewood ... this shaded bit shows you this was a private chat outside the chat room that you and Annie had.

Elena Can you see them?!

researcher ... it's all logged you see, so I can see what's going on. Don't worry, there's nothing that anyone's said that's bad or anything like that! You said ... [quotes from logfile] "have you done the egg thing yet?" says Annie and you said "yes", and you said it shrank, so your egg got smaller ... so was that common, that people were finding that the egg got heavier rather than lighter?

Elena } Yeah – quite a lot.

Alison } Yeah ...

40	Alison	... 'cos we didn't dry it properly, did we and it had water on it still.
41	Elena	Quite rushed.
42	Hayley	'Cos obviously the water makes mass more, so ... we didn't wash it properly, we just
43		stuck it back on the scales!
44	researcher	What made you certain that the egg should get lighter anyway?
45	Hayley	'Cos the enzymes eat the protein.
46	researcher	Because ...?
47	Hayley	The enzymes react with the protein.
48	researcher	How did you know that?
49	Jamie	We were told!
50	researcher	Who told you that?
51	Jamie	Um ...
52	Elena	And we used the Internet – I did.
53	Alison	I got it from a book.
54	researcher	OK ... so what did you do, when you got a result that the egg white got heavier?
55	Alison	We didn't tell Mr Dinsdale! [laughs]
56	...	
57	researcher	So, when you got a result like that ... did you assume the theory was wrong or did you
58		go back and do the experiment again?
59	Elena	} We did it again and it was fine.
60	Hayley	} We did it again and it shrank.
61	researcher	And it shrank?
62	Hayley	Yeah, but we used all the same measurements.
63	researcher	So if you got one result where the egg got heavier, and you got one result where the
64		egg got lighter, which one do you use?
65	Hayley	The one that got lighter.
66	Elena	We did it again.
67	Jamie	Both of them.
68	Hayley	The lighter one we actually dried it properly.
69	researcher	Both of them, Jamie?
70	Jamie	Yeah.
71	researcher	Why do you use both of them?
72	Jamie	Because you can compare them.
73	researcher	Whereas ... Hayley says you use the one where it got lighter.
74	Hayley	Yeah, 'cos we actually made sure that we dried it properly and things like that.
75	researcher	So let's just have a look at some other results ... Jamie, you posted some stuff about
76		biological washing powders [reads from forum logfile] "biological washing powders
77		contain enzymes" ... and Alison says "not sure" – what are you not sure about,
78		Alison?
79	Alison	Er, I don't know, I think I just posted it!
80	researcher	I wasn't sure whether you weren't sure whether biological washing powders contain
81		enzymes or ...

82	Alison	Yes, that's what I said not sure about I think!
83	researcher	There's another one of Alison's posts here, look, Jamie's posted some results ...
84	Elena	I know why she wrote that one!
85	researcher	... biological washing powder you've got a 4.75 gram egg ...
86	Hayley	[Aside to Alison] I know why you posted that one!
87	Alison	[Aside to Hayley] Why?!
88	Hayley	[Aside to Alison] 'Cos you felt sorry for him!
89	researcher	... decreases by 19% going down to 4 grams ... [reads from forum logfile] the same
90		weight of egg white in non-biological powder decreases by the same percentage. So
91		you've got the same decrease whether it's biological or non-biological.
92	Jamie	Yeah.
93	researcher	And you don't think it's meant to ?
94	Jamie	No.
95	researcher	OK – so why is it a good result, Alison?
96	Hayley	[Aside, to Alison] It wasn't, you just wrote it! [laughs]
97	Alison	I don't know, no.
98	researcher	I'm interested by a result like that, because I wonder ... Jamie, what are you going to
99		do when you write this up, are you going to include both of those results?
100	Jamie	Yeah, gonna include them. We were going to do it on a graph, but we don't know how
101		to. I asked someone if they knew how to and didn't get an answer though.
102	researcher	So what would happen ... if [you've] been away for a while ... how would you decide
103		whether to use [someone's] results or not? What kinds of things would be important?
104	Hayley	If they did the experiment the same as you do it, like, say you couldn't have, like, if you
105		were comparing, if you were trying to, if you were comparing results then you'd want
106		them to be different, like different temperatures or something. But if you wanted them
107		to be the same you'd have to be sure that they used the same temperature and
108		amount of washing powder.
109	researcher	But if you hadn't done the experiment, you were just going to rely on their results, how
110		would you know ... what would make you happy about borrowing someone else's
111		results?
112	Elena	If they'd done it more than once.
113	Alison	Yeah, if they'd redone it.
114	Hayley	If the egg had got lighter! that would make it good – rather than heavier!
115	Alison	And if they did it, if they took two people's results than they could, if they were both
116		sort of the same, they could work out that it was the same. Work out if it was right.
117	researcher	You've all got different results, what do you think would happen ... if we got another
118		group of students at ... the university, who were studying chemistry, to do the
119		practical. What kind of results do you think they'd get?
120	Hayley	A lot more detailed ones, 'cos they would look into it deeper.
121	researcher	Why?
122	Alana	They've got better equipment than us to do it.
123	researcher	Because they're at a university rather than a school?

124	Alana	Yeah.
125	Elena	They'd probably know what to look for, 'cos they do these sort of things more often
126		than us.
127	researcher	So if you wanted to share results with them would you think your results were as good
128		as theirs?
129	Hayley	No.
130	Elena	Yeah, probably.
131	researcher	Hayley says ... no.
132	Hayley	I don't know why, I just ...
133	researcher	Can you think of reasons why your results from the school might not be as good as
134		the university students' results?
135	Hayley	Because you're just, like, kind of doing it on the spot, we didn't really look into it before
136		it or anything, we didn't know really what was going to happen.
137	researcher	When you say "look into it" what do you mean by that?
138	Alison	Research?
139	Hayley	Like, predicted what was going to happen and stuff, we just kind of did the experiment.
140	researcher	So you didn't make a prediction?
141	Alison	} We did, didn't we?
142	Alana	} Yeah, before it.
143	Jamie	} I did one.
144	Alana	Yeah we did one before it.
145	researcher	What prediction did you make, Jamie?
146	Jamie	That the biological one was going to make it smaller, but the non-biological wasn't.
147	researcher	Elena, you thought that your results would probably be as good as the ones from [the
148		university students].
149	Elena	Yeah, because it's the same experiment, it shouldn't matter what equipment they've
150		got or if they're older or anything. If they do it exactly the same conditions.
151	researcher	If they do it exactly the same, with the same conditions, should get the same results?
152	Hayley	} Yeah.
153	Alison	} Yeah.
154	Alana	} Yeah.
155	researcher	Let's just ask Elena ... [shows students transcript of forum logfile] ...
156	Alison	Oh yeah, we did this!
157	Elena	Me, Alison and Hayley did it!
158	researcher	The three of you did this did you?
159	Alison	Yeah, we did ... we wrote up our experiment on it as well.
160	Elena	What happened was, we did the experiment wrong, and then we thought the egg had
161		shrunk so we went to Mr Dinsdale and said "the egg has shrunk" and he said "I don't
162		think it has, try it again" so we did.
163	Alison	Yes, so we did it twice!
164	Elena	And we didn't!
165	Alison	'Cos, like, the first time we just put the egg in ice ...

166	Elena	We did it wrong.
167	researcher	Tell me about what you did here, then [points to forum logfile].You've put it in ice.
168	Alison	I've posted it on the forum yesterday.
169	Elena	Yeah, we put it in ice.
170	researcher	Oh did you?
171	Alison	} Yeah!
172	Elena	} Yeah!
173	researcher	Oh, I'm sorry, I haven't seen that.
174	Elena	} We posted it, yeah, we did it together.
175	Alison	} Yeah, we did it together, didn't we.
176	researcher	Oh, I'll go and have a look at that.
177	Alison	I've got it on paper as well ...
178	researcher	But why did you do this?
179	Alison	'Cos ...
180	Elena	Well, we thought it was an accident, but then ...
181	Hayley	We were just, like, mucking ar..., like, with the ice, the egg in the ice, and then we
182		stuck it in the water bath to make it melt.
183	Elena	'Cos we got the wrong idea.
184	Alison	'Cos we were trying to make the ice melt 'cos we weren't supposed to have it in there
185		so we just put it in the water bath but we didn't measure it before but we thought it had
186		got smaller comparing it to the other eggs.
187	Elena	'Cos it was a smaller egg.
188	Alison	And it hadn't!
189	Hayley	And we just kind of, we didn't measure the washing powder or anything...
190	Alison	No ...
191	Hayley	... we just kind of guessed.
192	Alison	... we put 10.5 or something in.
193	researcher	Why did you say ... right at the end, look it says [quotes from logfile] "it was good to do
194		this experiment"?
195	Hayley	Yeah ...
196	Alison	Yeah because ...
197	Hayley	... because it proved that it couldn't be done. 'Cos we had a fair idea that it wouldn't
198		shrink because the egg shell hasn't got protein in, but we, it was better to do it and to
199		prove that it wouldn't shrink.
200	Elena	Yeah, it proved that it is actually the egg white that makes it disappear and not
201		anything else.
202	researcher	OK, so let's be clear about this, you had the egg with the shell on.
203	Alison	} On it, yeah.
204	Elena	} Yeah, it was a complete egg.
205	Alison	It had the shell on.
206	Hayley	No cracks or anything.
207	researcher	Was it a hard-boiled egg?

208	Alison	It was, yeah.
209	researcher	So you've put this hard-boiled egg with the shell in … how did you measure it …?
210	Elena	} With … paper.
211	Hayley	We got a bit of paper …
212	Alison	} We did it with paper.
213	Alison	We drew on it and then we measured it.

Study 3 critical incident recall 4

Students: Richard, Alan, Hayley (Castleford School)

researcher I'd like to start off - without either of you two [Alan, Hayley] saying anything for a moment, OK! – can you tell me a bit about the results that you've got, not what you think they MEAN, but just purely the results that you've got.

Richard Well ... the first test we did was, we used 5 grams of egg, 20 grams of washing powder and we put them in 50 degree centigrade water, and then we measured the egg after we used the washing powder on it and Sainsbury's non-bio powder had 3.8 grams left, Sainsbury's bio powder had 4.27 grams left and Ariel bio powder had 4.27 grams left. Then we did the same, apart from we changed the water to 60 degrees centigrade and Sainsbury's non-bio had 2.68 grams left, Sainsbury's bio had 4.28 grams left, and Ariel [bio] powder 3.98 grams left.

researcher So, what does that tell us, if you wanted to sum up what you think's happened there, what do you think's happened?

Richard The Sainsbury's non-bio powder is the better looking at my results.

researcher Because – why are you saying it's better?

Richard Because it dissolved more egg.

researcher ... And you've posted some of those results into the forum, into the chat room and so on.

Richard Yes.

researcher OK, that's great ... we'll come back and discuss some of that in just a second ... this is some of the chat room logs [hands out chatroom logfile printouts] ... Hayley, can you see on the left hand side here of each page you've got numbers running down – they're line numbers ... if you look at line 767 ... Hayley, in several places, that's one example, you talk about, you ask "am I right?" ...

Hayley Yeah

researcher ... can I just ask you: do you want to be right?

Hayley No, I just, 'cos what I meant was am I right that bio should digest more of the protein because it has enzymes in it- that's what I meant, I didn't mean my results are right.

researcher No, no – I'm just really asking here, do you want to be right?

Hayley It depends what you mean by "right". If you mean "get the right answer" then yes, but if you mean – I don't know.

researcher The other two of you might want to say something about that, I don't know ...

Richard Well, everybody likes being right, so – it's just something, you want to be right.

researcher So why do you think it's important to me right then?

Richard Well, I don't think it's important, it's just something, you go through life, you're going to be right sometimes, you're going to be wrong sometimes, but when you're right you're happy!

researcher When you're right you're happy – OK. So, Hayley, if you look a bit further on, you say, line 805, "I mean, right against Richard's answer". What does that mean?

39	Hayley	Because he said that non-bio should work better but I don't see how it could because
40		it doesn't have enzymes in.
41	researcher	OK, we'll talk about that in a minute, but ... can you tell me a bit about what you think
42		a science investigation involves? A school science investigation.
43	Alan	Well ... you're just, like, looking, you sort of do an experiment to find out about
44		something.
45	researcher	And is there a particular way of doing that?
46	Alan	Not really, because you're sort of finding different ways sometimes, to try and get
47		something maybe.
48	Richard	It's like, you're given this theory type thing, you're given this thing, and then you have
49		to discover if it's right or if it's wrong by using experiments.
50	researcher	So you've got some idea what will happen before you do it?
51	Richard	Yes.
52	researcher	Hayley, does that seem reasonable?
53	Hayley	Yes.
54	researcher	If you've got a science investigation being done by two different students – both doing
55		the same investigation – a bit like you've all been doing the egg investigation ... one
56		student makes a prediction and gets a set of results that fits the prediction. ... Another
57		student makes a different prediction, gets similar results to the first student, and
58		concludes that their prediction was wrong. So they've both got similar results but
59		they've got different predictions. The first student says "OK, I'm right" the second
60		student says "No, I'm wrong". Which student is right?
61	Richard	Well, technically, emphasis on technically, the student that ... well his prediction was
62		right, his prediction was right, but I know there's going to be a catch somewhere, but
63		I'm just wondering where it is.
64	researcher	No, there's no catch here at all, I promise you!
65	Richard	Well then, it'd be the person who got the prediction right.
66	researcher	Why?
67	Richard	Well the prediction would be right because they've got the evidence there to prove that
68		it was right.
69	researcher	Do you agree with that, Alan and Hayley?
70	Alan	} Yes.
71	Hayley	} Yes, I do, yes.
72	researcher	So the student who got the results that DIDN'T confirm the prediction – you would say
73		that they were wrong.
74	Richard	Their prediction was wrong.
75	Hayley	Yeah, not they were wrong, yeah.
76	researcher	That's quite an important distinction – the student's not wrong but their prediction was
77		wrong. So imagine then that you've got to mark the work, you've got to decide about
78		the quality of the work, what student's done the better work?
79	Hayley	Both done the same.
80	Richard	They've done the same.

81	Hayley	You can't help it if you've got something, your prediction wrong. If that's what you
82		think, that's what you think.
83	researcher	So if you were a teacher marking it, you'd be happy to give them.
84	Richard	} Equal marks.
85	Hayley	} Equal marks ...
86	Hayley	... as long as they said that they'd got their prediction wrong.
87	researcher	So when they write a report, what kinds of things should they put in the report?
88	Richard	Their prediction, their results and a conclusion type thing to say if their prediction was
89		right or wrong.
90	researcher	Anything else, Alan?
91	Alan	Could put a method in.
92	researcher	Yes, I agree – I think that might be useful! Why is it important to put a method?
93	Alan	If you've got a different set of results, then if you look at the method you can see
94		where they might have, where the differences are, the results.
95	researcher	So would it be important for them both to have used the same method?
96	Richard	Yes. because then you could match results up against each other ... 'cos if you find
97		that one set of results is different from the other then you, um, you'd find that ... [long
98		pause]
99	researcher	You're looking for a word, what word are you looking for?
100	Richard	You could see whether something, there's something different between them, if
101		something must have happened or the results could never be correct.
102	researcher	Let me just check what you're saying. If the two students use different methods, can
103		you still compare their results?
104	Richard	You could, but it wouldn't make as much sense as if their results were, if their methods
105		were the same.
106	Hayley	Yeah.
107	researcher	So here we've got two students, they've done similar experiments, one says "the
108		results fit my prediction" the other student says "no, the results don't fit my prediction".
109		Should either student have done something different?
110	Richard	Do you mean "should they have done something different" or "did they do something
111		different"?
112	researcher	I mean "should they have done anything differently?".
113	Hayley	No, 'cos you don't base your experiment on your prediction.
114	researcher	What do you mean by that, Hayley?
115	Hayley	You do the experiment separately, and if you, you're just predicting what's going to
116		happen so ... I can't explain.
117	researcher	Why do you make a prediction then if your experiment isn't based on it?
118	Hayley	To – guess what's going to happen, like make an educated guess about what's going
119		to happen.
120	researcher	So what is a prediction in a science investigation?
121	Hayley	An educated guess.
122	researcher	... you said "guess" to start off with Hayley

123	Hayley	Yes, then I realised [inaudible]
124	researcher	... do you think it's more than a guess?
125	Hayley	Yeah.
126	researcher	What is an "educated guess" then?
127	Richard	It's where you have, like, facts, you have, like, data put in front of you and you read
128		through the data and you can predict something from that data.
129	Alan	Mmm.
130	Hayley	Yeah, you have to know something about what you're predicting.
131	Alan	If you know about, sort of, some – what's the word – if you know about, sort of, data
132		about the experiment you're doing – you know things about it, you can put them
133		together to get a rough idea about what might happen.
134	researcher	OK, so before you do your investigation you've probably got some idea about what
135		might happen. Did you – any of you – make any predictions before you started the
136		investigation? I've given you a copy, in the stuff that you've got, a copy of the briefing
137		sheet just to remind you, take you right back to the beginning. Did any of you make
138		predictions, and if so, what kind of predictions did you make?
139	Hayley	We put the egg was going to get bigger ... and whiter.
140	researcher	Can you just explain what you meant by "bigger"?
141	Hayley	Um – increase in mass.
142	researcher	You thought its mass would increase.
143	Alan	I thought it would decrease, I had an idea ... [inaudible].
144	researcher	Why did you think it was going to decrease?
145	Alan	Well ... I wouldn't have thought it would have increased anyway, because you can't
146		really ... wouldn't have expected it, that sort of thing to happen, so ... well I thought,
147		you know, being some sort of chemical I thought it would – it must do something, so it
148		would probably ...
149	researcher	What was some sort of chemical?
150	Alan	Well, the washing powder.
151	researcher	So it must to something too ... [pauses]
152	Alan	Yeah, it would do something to the egg, and I didn't think it would increase because
153		it's ... [tails off]
154	researcher	Why did you think it would increase, Hayley?
155	Hayley	Well I don't know. I knew about enzymes and stuff, but I just thought that ...
156	researcher	Where did you know about enzymes?
157	Hayley	Because my Mum's doing her A-level so ... she told me all about it. So I kind of knew
158		about that, but I just didn't think, I just assumed that it would get bigger because you
159		were putting it in water ... [tails off]
160	researcher	Richard, did you make a prediction?
161	Richard	I didn't make a prediction.
162	researcher	You didn't?
163	Richard	No.
164	researcher	Fine, so you just, kind of, launched into your investigation?

165	Richard	Yes.
166	researcher	OK. [Draws students' attention to printout of chatroom logfles] The bulk of what I want
167		to talk about lies between lines 900 and 960 and 1000 onwards ... Richard ... in line
168		900 you said something about "Mr Dinsdale will tell you what he said to me". What did
169		he say to you?
170	Richard	I'm not exactly sure, 'cos he believes it's not the enzymes in the washing powder
171		that's making, in the biological washing powder, that's making the eggs shrink. He
172		said something else, but I can't remember what it was.
173	researcher	OK, that's interesting ... was it just to you Richard, or to the whole class?
174	Richard	No, it was just to our group.
175	...	
176	researcher	Richard, you've told us about your results where ... the egg in the non-biological
177		powder lost more mass than the egg in the biological powder.
178	Richard	Yup.
179	researcher	So what does that result suggest then, Richard? When you INTERPRET those results
180		what do they tell you?
181	Richard	Well, that it isn't – there's something in the non-biological washing powder is more
182		effective than the enzymes in the biological washing powder.
183	researcher	Right, OK – because ... ? [prompting]
184	Richard	Well, that's what my results show.
185	researcher	So Alan and Hayley, what do your results suggest?
186	Hayley	That as temperature goes up the mass goes down.
187	researcher	As temp ... hold on, just let's look at this carefully. Alan, you said you did – I'm looking
188		at ... "I did 80 degrees C, found and a half minutes, and the bio enzymes digested the
189		protein quicker". Can you just explain a bit about your results here, before we go on?
190	Alan	What do you mean by ... ?
191	researcher	Can you just tell us ... the bio enzymes digested the protein quicker – quicker than
192		what?
193	Alan	... the non-bio enzymes.
194	researcher	So does that mean that the egg in the bio powder lost more mass than the egg in the
195		non-bio?
196	Hayley	} Right.
197	Alan	} Yeah.
198	Hayley	[Whispers to Alan] The temperature does make a difference.
199	researcher	If we go down to line 958, I was asking whether one of you was right and the other
200		one was wrong and a few lines later Richard you said "not necessarily" ... you said
201		that it didn't necessarily mean that one of you was right and the other one was wrong.
202		Is this a situation where you can both be right?
203	Richard	Yes, because we didn't test the bio and non-bio powder at the same temperature. So
204		it could be that it depends on the different temperature of the water.
205	Hayley	The temperature does make a difference, because ... yeah.

researcher	So ... you haven't necessarily got the same conditions ... so how could you decide ... what was actually happening here?
Richard	Well, we [Richard's group] done the two tests, and both times non-bio proved the better.
researcher	... what were the two tests that you did?
Richard	We had the 5 grams of egg, the 20 grams of washing powder. The first time we had the egg and washing powder at 50 degrees centigrade water, and in the second time the 5 grams of egg, the 20 grams of washing powder, but it was in 60 degree centigrade water.
Hayley	We did each test twice. But the first one was by pure accident – we did it twice just to check our results.
researcher	Why did you do them twice?
Hayley	Just to confirm that what we got was right.
researcher	And what happened when you did the tests twice?
Hayley	Both times the bio ... made it lose more mass, had digested more.
researcher	Alan, what about you, have you done things twice?
Alan	No.
researcher	Have you done similar tests to Hayley's group or to Richard's group?
Alan	Well, what I did, I worked with Jamie ... and what we did, one of the lesson that we were doing practical work he ... took most of the results into account, he copied them up on the file upload. And the second set I copied them up in the file upload, so ...
researcher	You did two sets of results then – did you do the experiment twice? Or you took two different sets of results?
Alan	Well, yeah, so he sort of did it once and then I did it once.
researcher	And was that the same temperatures and things?
Alan	No, not quite. Some of them were the same though. But really they showed this – roughly they showed the same results.
researcher	The same results as – each other?
Alan	Yeah. They proved, proved that ... they both proved, um, well, that the bio one digested ...
researcher	The bio one digested ...
Alan	... the bio enzymes digested the protein quicker than the non-bio.
researcher	Is that what you agree with, Hayley?
Hayley	Yeah, definitely, yeah.
researcher	Would you use the word "proof"?
Hayley	Um [long pause] don't know – yeah. Well, I definitely think that non-bio digests more because it has enzymes in. And needs the enzymes to digest the [tails off]. [Hayley almost certainly means "bio" here]
researcher	So how could we decide whether ... Richard's group's results suggest that the bio is less effective – the NON biological powder is more effective at reducing the mass of the egg white; and you two [Alan and Hayley], your groups have got results that suggest the opposite. So how could we ... work out who's right?

248	Hayley	He [Richard] did his temperature at 50 and 60, what did you [Alan] do your
249		temperature at?
250	Alan	80.
251	Hayley	OK, that tends to make sense then, what I was going to say.
252	researcher	What were you going to say, Hayley?
253	Hayley	'Cos I thought he did his at 40, and if he did his at 40 it might have been because, in
254		the time, that it happened, maybe the enzymes denatured before it could get to the
255		protein.
256	Richard	You could, we could have used the same temperature water, then tested to see what
257		the results would be.
258	researcher	What would we have to do – have you got enough results?
259	Hayley	we've got all the class's [results].
260	researcher	Could we use the rest of the class's results?
261	Hayley	Yeah, that's what Mr Dinsdale told us to do.
262	Richard	Some of them might not have tested bio and non-bio, some of them might have tested
263		the temperature of water.
264	Alan	Yeah, I know – well, I'm not quite sure what everyone else did.
265	Hayley	We did all our results above ...
266	researcher	Richard, a bit later on, line 1034 ... I was saying "who's right and who's wrong" and
267		Richard says "it all depends" ...
268	researcher	} ... I wonder what it depends on ... can you both be right?
269	Hayley	} On what?
270	Richard	It depends on, well, the different, the tests that we did. At the time I didn't think I knew
271		they did it at different temperatures of water to our group, so ... it just depends on the
272		conditions.
273	researcher	... I just want to ask one final question on ... who's got the "right answer". Thinking
274		about this egg experiment ... what do you think it would mean ... if you do this and
275		write it up, and let's say Mr Dinsdale reads it and says "yes, this student has got this
276		right"?
277	Alan	Well, it's probably what he predicted, it could mean that.
278	researcher	What – who predicted?
279	Alan	Well, the person who says "right" – what they think.
280	researcher	Ok, so if it's Mr Dinsdale who says "you're right", Mr Dinsdale has made a prediction
281		and you've got the same answer as him ...
282	Alan	Or he could have got research from somewhere else ... and learnt about this, sort of
283		thing ... if I've got the same as him and he says I'm right obviously what the data that
284		he has the research that he has found, same as what I've got.
285	researcher	Richard, what would you think?
286	Richard	I'd say, if someone said it was correct, they wouldn't say the results were correct, they
287		said that their conclusion would be correct.
288	researcher	And what would that mean?

289	Richard	Well, 'cos the conclusion, you look at all the data and you just put "your data means"
290		so you can – so that would be your conclusion, so they could say if the conclusion was
291		right or wrong because, in the tests that me and [inaudible] have done, our conclusion
292		would be either non-bio was better or bio would be better. And then they could mark
293		the conclusion right.
294	researcher	OK – Hayley?
295	Hayley	Yeah same. Well, I definitely think that he wouldn't mean that ... our decision was
296		right, he'd mean that our, not ideas but, like, the proof that we've got was right, if you
297		know what I mean, kind of thing.
298	Alan	The way it matches, the conclusion. If the results ... match, sort of, the conclusion, so
299		he's really saying that the conclusion is right, now I'm thinking about it.
300	researcher	The CONCLUSION is right.
301	Alan	Yeah, to what the results are saying.
302	researcher	So ... line 1031 ... Charlie says ... "like I said, there are no rights and wrongs in
303		science".
304	Hayley	There is!
305	Richard	There is!
306	Hayley	Yeah, there is!
307	researcher	Oh, so you don't agree with Charlie?
308	All	No.
309	Richard	I was trying to get that point across near the end, because if you – some metals are
310		magnetic, and if you said that one metal was not magnetic even though it was, you
311		would be wrong. And that is an experiment.
312	researcher	Right, OK, so how ... we can't imagine what Charlie might mean by [saying that there
313		are] no rights and wrongs in science – tell me a bit about what you think, Alan.
314	Alan	Yeah, you can have rights and wrongs, but there's a type where you can't have rights
315		and wrongs which is with facts, like Richard said about magnets ...
316	researcher	So if I said "iron is not magnetic" ...
317	Alan	Yeah, that's definitely wrong because that's a fact, but if you have, like an experiment,
318		an investigation, then you can't really have a right or wrong because, if you've done
319		the experiment ... well, you're trying to find out what's happening, you can't really say
320		it's right or wrong 'cos you've done it, so it can't be wrong, if you've proven ...
321	Hayley	Yeah.

Study 3 critical incident recall 5

Students: David, Chrissie (Pynebrook School)

researcher [To David] If you look at line 767 ... there's a student called Hayley ... who was asking several times whether something that she'd said ...

David Was right.

researcher ... was right or not. And a bit further down the page [line 802] ... David, you said "In a way there's a right and wrong answer".

David Yeah, but earlier on she, line 777 or something, Chrissie said "you can't get a right or wrong answer". 'Cos every experiment's different.

researcher OK, so you're both clearly involved in that discussion. Before I ask you about the right and wrong answer thing ... do you want to be right?

Chrissie Sort of, in a way.

researcher Is it important to be right?

David Yeah and no, because if you're not right then you might find something else out, if you are right then you've achieved your goal, if you like.

researcher What do you think it means if we say you're right?

Chrissie That you've done the experiment right and that you've got the results that you wanted.

researcher You got the results that you wanted ...

David That you wanted us to get.

researcher Let's just ask Chrissie what she thinks she means ... "the results that you wanted".

Chrissie After you've done all the research on what happens when protein breaks down egg white, then you sort of hypothesise what you think your results are going to be and you think you've done it right when you get those results.

researcher So ... to be right in this context would mean that the results ... that you got in the investigation would fit your hypothesis ...

Chrissie Yeah, and also the research that other scientists have done, like, on the subject before, if that's, like, the same as yours then you're along, on the right lines.

researcher It's not good enough to fit your hypothesis, it's also got to fit with ...

Chrissie Yeah.

researcher ... the knowledge that other scientists have produced.

Chrissie If you've done your research right then your hypothesis should be along the lines of what other scientists have done before.

researcher So, when you say "in a way" ... line 777, Chrissie ... says "you can't get right or wrong results in science because every experiment is different". And David later on says "in a way there's a right and a wrong answer". Let me just ask you Chrissie, what do you mean by that – that you can't get right or wrong results in science because every experiment's different?

Chrissie Well, you can have an idea of what you think is right, but it might not necessarily be right because everything changes in each experiment you do, you can't always get the exact same amount of everything and the exact same amount of time and the variables might change slightly, so ...

40	researcher	If you repeat an experiment ... what happens?
41	Chrissie	The results might become clearer 'cos you've done it more.
42	researcher	[To David, who has been looking at printout of part of chatroom logfile]. What have
43		you just seen, David?
44	David	Oh, I was just reading the bit at the bottom where Andrew said "Chrissie, are you a
45		boy or a girl"?
46	Chrissie	Did he say that to me?
47	David	There.
48	researcher	He said it to you privately – it was "no offence, are you a boy or a girl"? He was from
49		Carisbrooke and you were coming on as Charlie, so he didn't know whether you were
50		a boy or a girl! That's fair enough, isn't it?! So ... you say David that in a way there's a
51		right and a wrong answer.
52	David	Yeah, I mean like I've said just underneath where Chrissie gets asked in that private
53		thing, you can't say iron is more reactive than magnesium 'cos it has never been and
54		never will be, so in a way there is a right and wrong answer in science, but it depends
55		what experiment you're doing. So, like, if you're doing something like this [reference to
56		egg and washing powder investigation], there isn't necessarily a wrong answer or a
57		right answer, but if you're doing something like that [reference to relative reactivity of
58		iron and magnesium in previous example], that is the right answer because iron is at
59		the bottom of the reactivity series and magnesium is at the top.
60	researcher	So is it possible ... if one of your class did an experiment and the results indicated that
61		iron was more reactive than magnesium, what would that mean?
62	David	Well, it could mean that they've possibly done it wrong, or they've done something
63		different or something, 'cos we've tried that and magnesium was more reactive.
64	researcher	Could it mean that iron was more reactive than magnesium – could they have just
65		shown that the science was wrong?
66	David	Possibly - like I say, it would depend on how you did it.
67	researcher	Would it be possible for a student from ... can you see a big headline in the
68		newspaper "Student from Portchester School shows that iron is more reactive than
69		magnesium" is it possible that a student could do that?
70	David	Well possibly, 'cos I mean, like I said last time, with the scientists, they say "right,
71		we've studied of ten years or whatever doing this and we know that it should be like
72		this", so they'll try it perfectly, whereas when you're a student you don't know quite so
73		much what it's meant to be like so you experiment more. So you're more likely to
74		discover something.
75	researcher	So you think it might be possible?
76	David	Yeah.
77	researcher	OK ... so when you talk about, Chrissie, you can't get a right or wrong answer in
78		science because every experiment's different. What do you mean by different ... how
79		is every experiment different?
80	Chrissie	Everything sort of varies, the surroundings you're in, the amount of substance you're
81		using, how you do the experiment, you don't do it exactly the same way every time.

researcher	What about ... if you do the experiment and David does the experiment? Can you compare the results that the two of you get?
Chrissie	Yeah, if you use sort of maybe different amounts of things but you do it in the exact same way, then you can compare them and see ...
researcher	And it's important that you do it in the same way?
Chrissie	Yeah, although it might be, may be helpful if you did it in a different way to see which way makes the results better.
researcher	Let's just forget about the eggs and the washing powder for the moment ... imagine two science investigations done by two different students. One student makes a prediction and gets a set of results that ... fit that prediction. Another student makes a different prediction, gets pretty similar results to the first student ... that student concludes that their prediction was wrong. (Their results DON'T fit their prediction.) Which student is right? Which student has got the right answer?
Chrissie	Neither of them.
researcher	Why?
Chrissie	Because they're not necessarily right because they may have done the experiment once and ... if they did it maybe more times, then the results might show a more constant pattern.
researcher	How many times should they do it?
Chrissie	As many times as they think's right for that kind of experiment. If the results show a definite pattern, then it's more than likely that that's what it is. If they show different results and different patterns in everything that they're doing then it's not maybe [inaudible].
researcher	So ... they get one set of results and they repeat it and get another set of results. If thjose two results are similar, should they do it again or is that enough?
Chrissie	No, they should probably do it more than twice to make sure that it's not just coincidence.
researcher	So ... two sets are the same and they do it a third time and those are the same – is that enough?
Chrissie	Maybe. It depends what experiment they're doing. If it's, like, definite that, a definite pattern that you can see, then it's sort of, it's more than likely that it's going to be the same.
researcher	How would you know when you'd done it enough times?
Chrissie	When you can see a definite pattern.
researcher	OK. So you don't think either student is right – what about you, David?
David	Um, I would probably say about the same as Chrissie, because like she said, you know, you have to do it, keep doing it, but then when you saw there was like a definite pattern, if you graphed it or whatever, you kept seeing there was a definite pattern, then it would maybe symbol that you'd done it enough times. But the first time your results could be completely wrong compared to your hypothesis, you try it again and they might match your hypothesis, so then you'd have to do it a third time and find out

123		which one was right, 'cos the first time you might have done something wrong and it
124		was a fluke, or the second or whatever.
125	researcher	So, if you had to make a judgement, which student's done the better work – the one
126		who's got the results that fit their hypothesis, or the one that's got the results that don't
127		fit the hypothesis?
128	David	Have they just done the experiment once?
129	researcher	Let's say that they done this several times ... they've done it enough times to be
130		happy that they're getting the same results each time ... the other student's done the
131		same ... so who's done the better work?
132	Chrissie	The person whose prediction's the same as their results ... because they might have
133		done research on it and thought ahead of actually doing the experiment ...
134	David	Yeah, they've planned it, so they've, like, with the thing that we're doing now, they've
135		said "right this is what we're going to do, this is what we'll need to do, this is one way
136		of doing it" and then they've gone on to do it, obtaining the evidence and all the rest of
137		it.
138	researcher	Should either one of them have done something differently?
139	David	No, I don't think so, it's just, they've just both got similar results and they've both just
140		predicted a different hypothesis.
141	researcher	Thinking about the egg and soap powder investigation, did you make any predictions
142		before you started?
143	Chrissie	That the egg, the mass of the egg white would decrease because the ... enzymes in
144		the washing powder would digest the protein.
145	researcher	What about your prediction David, did you make a prediction?
146	David	Well I didn't make one as such, but thinking about it now if I had've done it a prediction
147		for me would have been something like Ariel would be the best because it's looked up
148		to and it's a good one, it's a good washing powder. When in actual fact I think the best
149		one was the Asda's own, not the Smartprice but the Asda's one.
150	researcher	Describe – don't tell me what ... you think your results mean, but just describe your
151		results to me, David, what results did you get?
152	David	I did it once at 60 degrees with some friends, we stirred it for half the time and didn't
153		stir it for half the time. And the egg decreased in all of them, we started with two grams
154		of egg and it went down in all of them, and the Smartprice was the worst and the
155		Asda's own was the best.
156	researcher	Asda biological decreased the mass of the egg the most. What about your results,
157		Chrissie?
158	Chrissie	I think we did it at 40, actually it was 60 degrees, and I think that decreased the egg
159		more than at just, like, at normal water degrees. So heat helped.
160	researcher	OK. Did you find that the biological powder decreased the mass of the egg more than
161		the non-biological powder? Did you try that?
162	Chrissie	No, we didn't have ...
163	David	No, we just used biological.

164	researcher	[At Carisbrooke] Richard had one set of results that were not the same as all the other
165		students' [results] ... is it possible that both Ross and ... Hayley ... even though
166		they've got different results, could they both be right?
167	Chrissie	Yeah.
168	David	Mmm.
169	researcher	What makes you think that ...?
170	Chrissie	Maybe they tried it in a different way or they did different mass of egg white or different
171		types ...
172	David	They used different variables.
173	researcher	What do you mean by that, David?
174	David	Stuff like changing the temperature, the amount of water, the amount of soap powder,
175		anything that you can vary. Time in the solution, stuff like that.
176	researcher	So ... if we've got two students with two sets of results like that, how might we decide
177		which student is right?
178	David	Get some, get some other students to try it with exactly the same results and see if
179		they both get the same results, or if they both get different results.
180	researcher	You said "with exactly the same results" – did you mean that?
181	David	Do the same experiment if you like ... repeat it ... some different students who, I mean
182		maybe, who don't know them or who are in, like, a different science set or whatever,
183		who they don't know as well ... because that way they're not going to try and make it
184		biased towards their friends if you like, they're going to just do it properly.
185	researcher	Is it important then, if we're going to get some other students to repeat the
186		investigation, does it matter who they are?
187	David	No, but if they're, like, best friends, then they could make it biased if they – maybe
188		they're say meant to do it at 40 but they could put it up to 45 which doesn't sound like
189		much more temperature but it would make all the difference.
190	researcher	Would you use people at another school, or could it be people from the same school?
191	David	Could be people from the same school, but that you don't get on as friends, well not
192		so much get on as well but not hang around with if you like.
193	researcher	One final question. When Mr Dean takes your work in and marks it ... what do you
194		think he might mean if he said that you've "got the right answer" in this investigation?
195	Chrissie	You've done the experiment as accurately as you can.
196	researcher	What do you mean by "accurate", Chrissie?
197	Chrissie	Based on other people's results and based on other people's research.
198	researcher	And who are those other people?
199	Chrissie	Maybe the other people in, like, your class or people at Carisbrooke that have done
200		the same experiment, if your results sort of follow theirs, and maybe people that have
201		researched it, like other scientists that have done research and results and things like
202		that.
203	David	... you've done it all as best you can then, but you've instead of just doing it a couple
204		of times you've done it loads of times, loads of different variables, so you've got the
205		results as best you can.

Study 3 critical incident recall 6

Students: Sarah, Alana, Hayley, Alison, Richard, Alan, Charlie, Jamie, Elena (Castleford School)

(Note – first part of interview missing due to technical problem with recording equipment)

1	researcher	So research includes things you find on the Internet ...
2	Hayley	Or books.
3	researcher	Where else might you find research?
4	Richard	CD-ROMs.
5	Jacob	You can ask people.
6	researcher	Why do you need to put this research in [your reports]?
7	Hayley	To show that other people have got the same ideas or they could actually work, it's not
8		...
9	researcher	Who do you mean by other people? Other students, or people other than students?
10	Hayley	Either really.
11	researcher	And is it important to compare what you've done with what other people have done?
12	Sarah	Yeah. Because then you'll know, like, if yours is roughly right, and how far out you
13		were if you were wrong.
14	Alison	In somebody's report they said they'd compared it with scientists' results that they'd
15		done before.
16	researcher	Yes that's right ... is it important to compare what you've done with what scientists
17		have done?
18	Alana	Because then you can show that it's not that however old the people are that are
19		doing it, the results may still be the same.
20	researcher	So what would be the difference between a scientist doing something and someone
21		like you doing something?
22	Alan	Well the scientist would probably be more accurately, like, they would ...sort of be
23		more, the stuff you'd use would be ...
24	Richard	They would be more controlled over the experiment.
25	Alana	They would have better equipment and they would be studying it for more time than
26		we've just, like, had it given to us, like, a few weeks ago and not have that very long.
27	Charlie	And they'd know more stuff about what is going to happen, probably their prediction
28		might probably be more right than what ours would be, 'cos they would know more
29		about enzymes and stuff like that.
30	researcher	Someone posted a message ... [in response to another message] that said "Did you
31		copy and past that or did you just know it?" Is it OK ... to copy and paste stuff?
32	Hayley	No. You might not know what you're talking about and it would just be – it might have
33		something to do with it but it might not totally be ...
34	Alan	It's alright if you read it and understand it but if you don't understand it at all and you're
35		just putting it on there, you shouldn't really do it.
36	researcher	If you come across something on the Internet and you want to put it in your report ...
37		how should you go about using it?

38	Sarah	You should put it in your own words, and explain it your own way instead of copying
39		someone else's way to do it.
40	Alison	You have to make sure you understand what it actually says and not just write it
41		because it's good or you think it's good.
42	researcher	One person wrote "My report best describes the effect of biological washing powders
43		on egg white because the results are all correct". And someone said in response to
44		that "you can't have correct answers because everybody could do the same and get
45		different answers" ... what do you think about that? Is it possible that anyone could be
46		correct?
47	Richard	Well no, not really because you could try the experiment a hundred times and the
48		results could be totally different every single time.
49	researcher	Can you get the same results more than once?
50	Alan	I would say, if you do it more accurately, it would ... how would it make it different?
51	researcher	What would doing it more accurately involve?
52	Alan	Well getting ... equal amounts of water, equal amounts of weights of the egg.
53	Charlie	Well, if you did it a few times and got the results you could make an average of the
54		results, which might be better.
55	researcher	So you repeat your experiment ... how often should you repeat a measurement?
56	Hayley	Three times.
57	Elena	Three times.
58	Hayley	Three times – for a graph, four.
59	researcher	Why?
60	Hayley	Because if you just plotted two results on a graph, because you're trying to get near
61		enough a straight line, continuous line, if you just plotted two lines they could just join
62		up in any direction, but if you plotted a third one then they can be [inaudible], and then
63		the fourth one just to check it.
64	researcher	So is it possible to say who's got the best set of results.
65	Richard	No.
66	Elena	No, not really.
67	Hayley	No.
68	Alan	Well you can say, because if someone's just gone ahead and sort of not really taken
69		any care in doing it, just pouring a bit of water in and not properly measuring it, and
70		someone else has done it really accurately ...
71	researcher	How would you know that, Alan, from what they've written?
72	Alan	Well, just them doing it, you know, taking more accurate care in doing the experiment,
73		it's going to be a bit better than someone just pouring in any amount.
74	researcher	Do you think that the person who's done it is important?
75	Alan	} Not really, no.
76	Hayley	} No.
77	Alan	But if you know they've done it complete... if you know they've done it really
78		unaccurately and someone else has done it more accurately, it's quite obvious that the
79		more accurate one would be more correct.

Study 3 critical incident recall 7

Students: Sara, Annie, Bille, Carl, Darren, David, Chrissie, Connor, Andy, Mary, Nadine (Pynebrook School)

researcher Of the reports that you've seen, which report do you think best explains the behaviour of the egg white and the washing powder?

Connor I think mine was brilliant!

PLF Apart from the fact that it was yours, why do you think it was good?

Connor No, I don't think it was that good, 'cos I didn't get the results properly.

PLF What do you mean by that?

Connor Well, we done a 60 one didn't we, yeah, and then ... the 40 one didn't work and we didn't try it again.

PLF When you say it didn't work, what do you mean?

David Well we didn't get it finished did we, 'cos we were working together and we kept doing them, but just as we were nearly there Sir said time to pack up and ... so we only got one full set of results.

PLF Billie went online and was very ... helpful and posted a number of things. Billie, you argued for Emma's (at Carisbrooke) ... let me just remind you of what Billie said about Emma's report: [reads] ... "I think Emma's is the best because ... it explains the investigation thoroughly; it's very well-presented; she shows strong understanding of what to do; she knew what to do; it's very detailed." ... how do you react to that list of things?

Darren I'd say, yes, she did seem to know what she was doing and she evaluated her own, how she did it quite well as well, that's what I thought.

Andy It's hard to do, to evaluate yourself. 'Cos, if you haven't done it before you can't really compare yourself to what you've done before.

PLF When you have to evaluate what you've done, what does that involve?

Sara Putting yourself down.

Andy Not necessarily.

Sara No, but, like, putting down your work.

Darren Constructive criticism.

Annie Rather than being biased.

Andy What you would do next time and stuff.

PLF What kinds of things have to go in an evaluation, then?

Darren The good points of how you did an experiment ...

Annie What you need to improve.

Darren ... yeah, what you need to improve, the accuracy of your results, and something like that. So you say, the good things and the bad things about it, and what you'd do next time if you did it again.

PLF How do you find the evaluation to write compared to the rest of the report?

Nadine Far harder.

Sara A lot harder.

39	Connor	You have to be, like, brave and say that you've done things wrong.
40	Andy	You have to own up ... to your mistakes, you have to accept that you've made
41		mistakes.
42	Nadine	You have to try not to be, like, biased about yourself.
43	PLF	You have to be very honest?
44	Nadine	Yeah!
45	PLF	Is there anything else that you'd want to add to Billie's list? Are there any of those
46		things that you think are not important? [re-reads list]
47	Billie	I only put five down 'cos I didn't want to put, like, twenty!
48	PLF	Is there anything you'd add, Billie?
49	Billie	I don't know ...
50	Darren	You really have to read the report through again ...
51	Andy	I haven't read that report, so ...
52	PLF	There's one word that got mentioned quite a bit in the forum discussion ... several
53		people were talking about reports containing "research", and in fact one posting said
54		something about one report had got more research init than another report which
55		made it better. What is research in a report? How would you recognise it?
56	David	On the research thing, you could have pages and pages and pages of research, but if
57		there's only, like, half a page of results then you've kind of not achieved what you're
58		trying to do, 'cos you've found out about how it all works and what's in everything but,
59		because you haven't got results, to back it up if you like, then ...
60	PLF	So what IS research, how would I know if I was looking at one of your reports, what do
61		you MEAN by research?
62	David	It, like, says what's in the egg white, says what's in the washing powder and ...
63	Andy	It's finding out.
64	Billie	Factual information.
65	Sara	You can't always use loads and loads of research, 'cos some of it you might not
66		understand fully.
67	PLF	Where does all this research come from?
68	Sara	Internet.
69	Andy	You can get it from anywhere.
70	Carl	Teachers.
71	Mary	Encarta and encyclopaedias and stuff.
72	Andy	Anywhere really.
73	David	Asking around, like teachers.
74	PLF	What about other students' work, is that OK?
75	All	[agreement]
76	Annie	Different people find out different stuff, so ...
77	PLF	How do you put it in your report?
78	Billie	You have to put it in your own words, so people can understand it as well as you.

79	Darren	And you could, like, link it in with what you're doing ... sort of knowing about the
80		different enzymes that break down the protein in the egg and stuff like that, to link in to
81		what you're doing.
82	PLF	Someone wrote in the forum, going back a few weeks ... "did you copy and paste it or
83		did you just know that?" Why do you think they posted a message like that?
84	Sara	'Cos maybe they didn't understand it.
85	Darren	'Cos sometimes it sounds like you've eaten a textbook ...
86	Sara	... 'cos you've just, like, gone on the Internet ...
87	Darren	... you've just got it out and typed it out word for word.
88	PLF	So if you've simply copied something from somewhere else is that not good, you
89		shouldn't do it?
90	Sara	You don't necessarily understand it, either. It could have words in and you don't
91		actually know what they mean.
92	Darren	If you understand it it can be alright ... if it's going to be for someone else to read, you
93		really want them to be able to understand it.
94	Andy	It should be in your own words.
95	PLF	Why should it be in your own words, Andy?
96	Andy	It's, like, an individual piece of work and if it's just copied from other people you can't
97		get the credit for it.
98	David	Copyright laws!
99	Sara	But if you put where it's from, like you say it's not your own ...
100	Andy	"Taken from ... "
101	Nadine	If people question you on what things mean, 'cos you haven't read through it and stuff
102		...
103	PLF	Other things that people mentioned about reports included diagrams and graphs. Why
104		do you include diagrams and graphs in the reports?
105	Darren	It's a visual aid almost, 'cos people learn different ways, some people can read it and
106		understand it, some people have to be able to see it.
107	Andy	Kinaesthetic and stuff.
108	Darren	And some people have to do something to be able to do it.
109	PLF	What's that, Andy?
110	Andy	It's someone who learns better by doing the stuff, experiments and trying things out
111		and hands on and stuff, rather than reading out of a book or something.
112	PLF	So where have you got these ideas about the way in which people understand?
113	Andy	From PSHE – we get a little slip that tells you what kind of learner you are ...
114	PLF	How did your tutor find out what kind of learner you are?
115	All	We did a test! We did a little test!
116	Annie	It's like "When you hear this do you see this, or feel it?" or whatever.
117	PLF	What's the reason for including graphs in a report?
118	Carl	It's a good way to show your results.
119	Connor	'Cos you can, like, show a line of best fit.
120	Andy	It's like a format of displaying results.

121	Darren	If you have, like, a graph with, like, up the side in seconds, maybe a distance-time
122		graph, and you had, like, every ten seconds and every ten metres, and then you go
123		"well I could do this better by doing a graph down size" and you do it five and keep
124		going down it's just showing your results ... 'cos if you do one graph and it has a
125		massive change, you can find where the major change is.
126	PLF	When are you suggesting you should plot the graph, then?
127	Darren	After you get the results!
128	Andy	It depends what type of results you're dealing with, 'cos you could put it in a table or in
129		a graph or anything really.
130	PLF	What happens if, when you plot your graph, you find there's a big ... change? What do
131		you do at that point?
132	Andy	I'd go back and plot the graph of smaller differences on the axes ... say I was going up
133		in tens, I'd go up in fives.
134	PLF	So does that involve going back to the investigation and taking more measurements
135		then?
136	Darren	} Yeah, you might have to take some more.
137	Andy	} Possibly. You'd probably be able to do that by looking at your results, before you
138		even had to plot the graph, by looking at what would come out.
139	Carl	Graphs are good to base your work around as well, 'cos you can draw a graph first
140		and then write and explain – it helps you to ... see what's happened instead of just
141		looking at a table of results.
142	PLF	Is it important to compare your results with other people's results?
143	Billie	Yes. Because they're not all going to be the same, and you're going to want to go and
144		find if people's got the same results as you.
145	Mary	People use different variables as well, though.
146	Annie	'Cos somebody might have done the time ones, and somebody might have done a ...
147		different amount of water.
148	Sara	If you did exactly the same experiment with someone and they did, and they got
149		different results, you could see where you went wrong or where they went wrong or
150		whatever, and do it again a different way of doing it.
151	Annie	And also 'cos they might have done it a different way, like you might have done it with
152		changing the temperature and they might have done it with changing the amount of
153		powder.
154	PLF	In what part of your report would you [make] that comparison?
155	Sara	In the bit you'd change ...
156	Annie	In the evaluation.
157	Sara	... after you'd, like, evaluated it and ...
158	Darren	If you evaluated everything ... if you did several results and then you'd write an
159		evaluation of your different results and then you'd say someone else did it this way,
160		and you'd show that and say "this could help my one".
161	Sara	"Maybe next time I could do it this way."
162	Darren	Yeah. "This would link into my results this way" or something like that.

163	PLF	Somebody wrote ... "My report best describes the effect of biological washing
164		powders on egg white because the results are all correct" ... to which somebody else
165		replied "You can't have correct answers because everybody could do the same and
166		get different ones." How do you respond to that?
167	Andy	Absolutely true! Because there's so many things that could be different that you
168		wouldn't spot, like you could have an egg that could be a day older than the other
169		person's egg, or it could have a crack in the shell or something that you hadn't seen ...
170		or you could have a different ...
171	Darren	Surface area.
172	Andy	... yeah, or different batch of washing powder or anything.
173	Sara	Different type of egg or whatever.
174	Andy	You can never have exactly the same results ... it's got to be a one in a million
175		chance!
176	Darren	There's too many variables.
177	Connor	The eggs in a box aren't laid by the same chicken.
178	Nadine	One could have, like, more protein in than the others.
179	Annie	It still doesn't mean that everything's going to be the same.
180	Sara	You can't get everything, you can't get it gram for gram everything right.
181	PLF	Do you agree with Andy, do you agree with that second person, that you just can't
182		tell?
183	All	Yeah.
184	PLF	So ... are you suggesting that it is just not possible to say how washing powder affects
185		egg white?
186	David	No, 'cos if you did the test enough times, and did enough research, then you could
187		find, you could possibly get towards the right results.
188	Connor	As long as you make it as fair as you can do.
189	Sara	But everything would always be different because you'd always be a gram or a gram
190		in or out ... or point one in or out of the mark you were doing it from.
191	David	And you'd also have to compare it with someone else's results.
192	PLF	Is this YOU doing it or is it someone else doing it?
193	David	Me and someone else, 'cos that way you can compare the results and see how our
194		results match.
195	PLF	So you're saying Dan it's POSSIBLE to do this?
196	Andy	If you get two people doing the same ...
197	David	Every time, unless you get it to a billionth of a gram, you're going to get different
198		results.
199	Sara	'Cos you're never going to get them the same ... because you could be, like, point one
200		over or point one less.
201	Andy	If you get two people doing the same experiment and they use the same amount of
202		powder as close as they can get it, the same amount of egg as close as they can get it
203		and leave it in the same temperature for the same amount of time as close as they

204		can get it, their results theoretically should be the same. But they never seem to be,
205		there's something always that you can't spot that affects it.
206	PLF	So [is it] actually impossible to ever tell exactly what's happening here? Is it ever
207		possible to say "this is exactly what's happening"?
208	Andy	} No.
209	Billie	} No.
210	Sara	} No, not really.
211	Annie	} No.
212	Connor	I think you can.
213	Sara	[quietly] I don't.
214	Mary	Depends what you use, really.
215	Chrissie	There's always something else going on that you think that wouldn't be going on and
216		that you wouldn't know was going on.
217	Andy	Up to a point it is, because ... enzymes breaking up the protein ... you don't actually
218		know what it looks like when that happens, it could like – oh I don't know how to
219		explain it!
220	Darren	It could be little men with little axes, couldn't it! [laughter]
221	Andy	Because we only use models, we use models to represent it, like Chris designed with
222		the little blue triangles coming and breaking up the hexagons.
223	PLF	So where do models fit in all this, then?
224	Billie	They're a representation ... of what will happen.
225	Sara	It represents what we think we can do.
226	Andy	It represents ... it works.
227	Darren	Unless you can use a microscope and go down to see, and watch it happening, you
228		don't exactly know what's happening.
229	Andy	It's not accurate, but it works, so we use them.
230	PLF	So where have you come across models in science then?
231	Andy	That was the first thing we did this year.
232	Darren	We use them all the time.
233	Billie	Mr Dean says about it all the time.
234	Mary	Yeah.
235	PLF	So what did you do about models?
236	Mary	Oh, the enzymes and particles fitting together.
237	Sara	Enzymes and particles and ...
238	PLF	If you had two reports that described the way they thought that egg white and washing
239		powder behaved, how would you go about deciding which report you thought was the
240		best explanation, what kinds of things would you do?
241	Sara	How it's set out and how they've explained, like, after every set of results if they've,
242		like, explained it whatever and how they've evaluated themselves at the end of it.
243	PLF	Sara mentioned presentation – what's important about presentation?
244	Sara	Does it look attractive ...
245	Annie	If it's all, like, scruffy you might not want to read it.

246	Darren	Does it make sense, is it in the right sort of order …
247	Nadine	Is it laid out in the right way?
248	Darren	… 'cos it's no good having results at the beginning and what you're going to do at the
249		end.
250	Andy	That's what I thought about charlotte's one, where I made a comment on her one I
251		said that the results, she put a lot of detail into her opening statement in her report,
252		and I thought it could have waited 'til later when she put the results in to make it more
253		effective because you learnt a little too much a little too soon, before she even
254		explained what she was going to do.
255	Annie	It sometimes can confuse you.
256	Andy	Yeah.
257	PLF	So when you sit down to write a report …
258	Annie	It's like a recipe.
259	PLF	… what are you trying to do?
260	Annie	To explain … you've got to, like, explain what you're going to do and then how you're
261		going to do it .. and you've got, like, the results and what happened when you did it …
262	Nadine	Why it happened.
263	Annie	… why it happened, why you think it happened.
264	Nadine	Would it happen again?
265	Annie	If you did it again.
266	Mary	It's the same in English. 'Cos, like, when you're doing an essay we've been told to
267		use, we've been told to always "p in our essays" [laughter] … you have to make the
268		point then you have to explain it. And you have to make sure your conclusion's at the
269		end, and you're opening paragraph's got to be at the front … it doesn't really matter
270		about [the order] … well it does in some subjects I suppose – in science it does
271		otherwise you muck it all up and it won't look right, but in English you can just put the
272		middle bit in any order, really.

Refereed papers relating to this research presented at conferences

Understanding the way in which students contribute to knowledge building and knowledge claim critiquing within a community of learners working in a computer supported learning environment

Paper presented at Networked Learning Conference, Lancaster University, 5-7 April 2004

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ABSTRACT

In this paper, the theoretical perspectives used in a study of on line learning are described. Using activity theory as an organising principle, a group of science students were brought together on line to produce a knowledge-building community. Using a methodology involving both content analysis and group interviews, the interactions between members of the community were studied, based on ideas drawn from the sociology and philosophy of science. Results from this study suggest that this methodology provides a powerful technique when exploring on line learning, producing deeper meanings from data than would be possible using content analysis alone.

Keywords

learning communities, activity theory, content analysis, epistemology

INTRODUCTION

The work described in this paper began in 1995 with the founding of *SciI-Journal* (www.sci-journal.org) as a place on the web which would enable young science students to engage in discussing reports of science investigations, with the intention of promoting a greater understanding of science concepts, and possibly of the processes through which scientific knowledge is produced too. Initially such discussion was undertaken through the use of e-mail, with authors' addresses being given at the top of each report. Issues relating to child protection led to the introduction of discussion lists in 2000, each report having its own list which is situated at the end of the report. In the current iteration of *SciI-Journal*, discussion lists are generated "on the fly" whenever a page is requested, with the comment data residing in a tsv (tab separated variable) log file. As comments are added to a report, the log file grows, and provides a record of comments and related data (not all of which is published in the discussion list). Taking Henri's definition of interactivity (Henri, 1995:150-2), analysis of these log files shows that the majority of messages in the discussion lists may be characterised as "not interactive", on the basis that, although they relate to the subject of the report, there is no evidence to suggest that there is any (re)construction of knowledge involved. The purpose of this research was therefore to establish an on line environment in which interactivity related to practical science investigations could flourish, and then to study the accounts of such interactions in order to provide some understanding of their nature. The specific questions addressed were:

- What do the on line interactions reveal about student epistemologies of science as they engage in knowledge-building?
- When students evaluate knowledge claims made by other students during an investigation, on what do they base their judgements?

This paper is concerned with the background theories used to frame the learning community in the study, to establish the nature of the data to be collected and to develop the instruments used to analyse the data.

THEORETICAL FRAMEWORK

Reports of research in which computer supported learning environments are used to examine aspects of learning in an on line community are now well-established in the literature. Much of this research is framed by the idea that members of an electronically connected group constitute a community of practice engaged in situated learning (Lave & Wenger, 1991; Wenger, 1998), and uses the analysis of computer databases containing information about interactions within the community as a means of understanding the learning processes happening within that community. Whilst at first sight it may appear quite legitimate to take a similar stance to approach the study of a group of science students engaged conducting a practical science investigation, there is good reason why one should, in fact, choose not to do so.

Social practice

Students engaged in learning in a conventional (classroom) setting generally do so under the guidance of a teacher, tutor or lecturer; in an on line setting, they may work with someone called a tutor, moderator or expert. Such an individual is sometimes said to play a rôle as a *master*, whose job it is to conduct the learning environment in such a way that the learners develop an ability to perform a *social practice* through a process that Lave & Wenger term *cognitive apprenticeship* (Lave & Wenger, 1991:29). If this view is also to be adopted when considering students learning science, then two points must successfully be argued: first, that the setting in which such science learning takes place employs the same kinds of *practices* (Wenger, 1998:45-50) as those found in authentic scientific communities undertaking research; and second, that the individual leading this process is accomplished in such practice. In the case of school science classrooms, both claims are highly suspect; and it is unlikely that learning situations in undergraduate classes in Universities are able to satisfy the first requirement even when they are able to satisfy the second. It is therefore doubtful whether it is ever possible, at a level below research studentship, to say that learning science (or more properly, learning to do science) is in accordance with theories based on common practice. Hakkarainen (1998:8) similarly notes the differences in practice between school classrooms and 'authentic scientific enquiry'.

Whilst it is problematic to frame research in which groups of students carry out practical science investigations using these kinds of models, the need to employ some kind of framework which addresses the social aspect of scientific enquiry remains. In addition, to be maximally useful such a framework also needs to address other aspects of the processes of learning through and about scientific enquiry, not least those which concern the influences which mediate these processes (such things as scientific theories and epistemological stances) and the rules whereby the processes are regulated. Of course, the model must also give due recognition to the fact that a group of students are unlikely to learn unless someone in the community acts as a "guide" to learning in some sense; another mediating influence. One possible approach to address these requirements is to employ *activity theory.*

Activity theory

Activity theory is a long-established branch of cultural-historical research with its origins in the Russia of some 80 years ago. Its name is somewhat confusing, since it is neither directly concerned with activity *per se*, nor is it a theory in the sense of being a fixed body of accurately defined statements (Kuutti, 1996:25). At the heart of activity theory lies an attempt to understand the ways in which individuals cooperate in communities in order to perform some kind of activity directed towards an object; the basic unit of study for such a process is known as an *activity unit* (figure 1). The object may be tangible (eg an aeroplane) or it may be completely

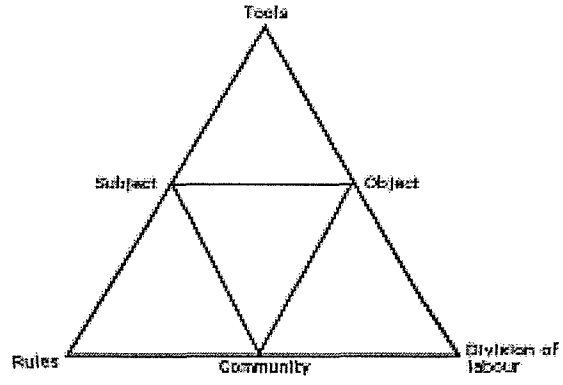

Figure 1 – an activity unit (after Cole & Engeström, 1993:8)

abstract (eg a theory); the one requirement is that it should be something that all members of the community can share for the purposes of manipulation and transformation during the activity. Working together, the *community* will employ a variety of mediating influences in pursuit of their *object*, including physical *tools* and *tools* used for thinking, and in doing so will be subject to a variety of *rules* which govern the conduct of the community (including the relations between the *subjects* making up the community) and the *division of labour* within it.

As is already apparent from the above description, although activity theory provides a framework which (potentially at least) offers a way of describing and analysing the complexity existing when a community undertakes an activity, any attempt to do this in a holistic way is likely to fail due to the large number of interdependent relationships that must be considered. One way around this is to consider *triads* taken from figure 1, an approach described by Lewis (1997). It was the use of triads which informed the approach to understanding collaborative work during practical science investigations described here.

Applying activity theory

In this study of a group of student scientists undertaking a practical science investigation, three triads were used as a theoretical basis for the empirical work in order to seek answers to the two research questions described at the start of this paper. The triads were labelled SCO, RCO and TCO in relation to the labels in figure 1 – the three triads themselves are shown in figures 2a-c. Triad SCO has its importance in the way in which the study itself was set up, whilst triads RCO and TCO guided thinking about the collection and analysis of data.

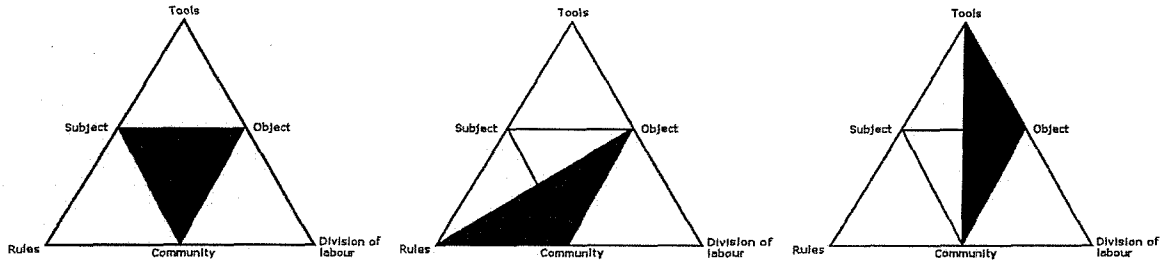

Figure 2

a) triad SCO b) triad RCO c) triad TCO

Triad SCO

The first of the three triads (figure 2a) describes the relationship between subject, community and object. Lewis considers that this triad plays an important rôle in the establishment of a learning community because "there must be space for interpretation, negotiation and the establishment of group ownership of the motive [the object of collaboration]" (Lewis, 1997:214). Here this was also judged an important triad due to the rejection (in this specific context) of the notion of social practice described earlier. Bereiter and Scardamalia also reject the idea that education below a certain level embodies social practice, noting that "children enter school at the age of five or six, but it is usually not until they are close to 20 that they encounter any serious effort to develop them into experts" (Bereiter & Scardamalia, 1993:184). Yet Bereiter and Scardamalia also note the enormous success of research groups in finding answers to problems and in generating new knowledge (which they term *knowledge building*) and suggest that knowledge-building communities could be employed to help students develop enhanced understanding, based on the idea that, although students are not actually constructing new knowledge, they **are** constructing new meanings for themselves. Sutton (1992) too argues for a focus on the social construction of meaning rather than on the interpretation of phenomena in order to enhance the quality of science learning.

The community of student scientists on which this study is based was brought together to constitute a knowledge-building community which would be encouraged and managed in such a way so as to encourage the development of nine characteristics of such a community:

1. sustained study of topics in depth rather than superficial coverage;
2. focus is on problems rather than on categories of knowledge;
3. inquiry driven by students' questions;

4. explaining is the major challenge;
5. day-to-day focus is progress toward collective goals of understanding and judgement;
6. students typically work in small groups, each with a different task;
7. discourse is taken seriously;
8. teachers can contribute what they know to the discourse, but there are other sources of information;
9. teacher's role shifts to leading it by virtue of being a more expert learner

(adapted from Bereiter & Scardamalia, 1993:210-11).

Based on this, the object of this particular activity unit is the social construction of an agreed (scientific) way of understanding the particular phenomenon under investigation through a process involving peer discourse and review.

Triad RCO

This triad (figure 2b) is associated with the protocols used by the community in rejecting or accepting knowledge claims made within the community during knowledge-building. As such these protocols may be *explicit* or *implicit*.

Explicit protocols are those which are agreed and adhered to by members of the community as they go about their tasks, whether as part of the wider social arrangements that exist in the institution within which they work or in society as a whole (eg 'treat other people's ideas with respect'), or as part of the knowledge-building community. In the case of a community engaged in building science knowledge, such protocols can usually be traced back to Merton's four norms of science (Merton, 1973), which ascribe to science (and to scientists) the characteristics of *communalism* (science as public knowledge), *universalism* (science as a collective activity), *disinterestedness* (science as emotionally neutral) and *organised scepticism* (science as involving rational procedures and reserved judgement); these are sometimes abbreviated in the acronym *CUDOS*.

Implicit protocols are those which the group may operate without ever making their basis clear; or perhaps even without any discussion. In the context of science knowledge-building, of particular interest are the non-technical reasons which may be given for the acceptance or rejection of knowledge claims from within the community. Through extensive interviews with practising scientists, Collins and Pinch have explored the non-technical criteria these individuals say that they use when deciding the validity of a particular piece of work, and have produced a list which includes: personal knowledge of a scientist's experimental capabilities and honesty; whether or not a scientist worked in industry or academia; a scientist's style and presentation of results; a scientist's 'psychological approach' to experiment; the size and prestige of the scientist's university of origin (Collins & Pinch, 1994:101). This list is the basis of an instrument used to examine whether student scientists employ similar implicit protocols in scrutinising the knowledge claims of others from within their community.

Triad TCO

The third triad (figure 2c) involves the tools used by the community in addressing the object of the activity – the joint construction of an explanation for the phenomenon under investigation. In common with triad RCO, the tools may be regarded as explicit or implicit.

The term *explicit tools* relates to those which are applied through general agreement within the community and which are derived very largely from sources within the community of professional scientists. Such tools include science knowledge or 'facts' (eg the atomic mass of sulphur or the density of water) and scientific theories that are regarded as 'proven' (eg Newton's laws of motion or the laws relating to chemical combination of elements). These tools may be acquired by the student knowledge-building community from a variety of authoritative sources which include text books, the teacher and the Internet (with especial regard to provenance I the case of the last example).

Implicit tools are similar to implicit protocols, in that they are operated by the community with little or no discussion. Especially important in this context is the approach to scientific knowledge and the relationship between evidence and theory used by the community – its *epistemological stance*. Whilst there is no agreement amongst scientists, philosophers of science and sociologists of science about what comprises a 'correct' understanding of the nature of science, there is some agreement about what may constitute an understanding that can be characterised as 'naïve'. Nadeau and Desautels have described an epistemological stance that they call naïve scientism (Nadeau & Desautels, 1984). This has five constituents: naïve realism, blissful empiricism, credulous experimentalism, blind idealism and excessive rationalism; it forms the basis of an instrument used to investigate the epistemological stance of student scientists in the knowledge-building community.

EMPIRICAL STUDY

Whilst the stimulus for this work was the original work carried out with *ScI-Journal*, there are compelling reasons for the use of computers to support knowledge-building. In establishing and maintaining a knowledge-building community of students, networked computers can play a crucial rôle in at least three respects:

1. they can provide access to records of what other students are doing, and an opportunity to comment upon it;
2. they can provide access to other sources of information (in addition to the teacher and books);
3. they can provide access to experts outside the community.

If computers are used as a means of storing students' thoughts and ideas, and as a way of recording the community's communications, then students have access to a comprehensive, searchable source of information about what others in the community are thinking, and to a record of the development of the community's progress towards their goal. This is very close to the way in which knowledge-building in an expert community is carried on; as Bereiter and Scardamalia point out "the community database serves as an objectification of the group's advancing knowledge, much like the accumulating issues of a scholarly journal" (Bereiter & Scardamalia, 1993:212).

Pilot study

Before moving to a full-scale study of a knowledge-building community based on the work described above, a small-scale study was conducted with a group of students in order to ascertain the technical feasibility of such work. Specifically, the questions asked were:

- is it technically feasible to support a science investigation using an on line discussion environment?
- will students use it?
- if so, will there be much (any) interaction of any value to research?

To obtain answers to the questions, a group of students ($N = 21$) with ages in the range 13 to 14 years in a comprehensive school were provided with continuous access over a ten day period to an asynchronous web-based discussion environment; this was in association with a practical investigation into friction that they were undertaking as part of their science work. The students were all in a "top" ability group (as defined by National Curriculum tests, nationally applied tests in such areas as cognitive reasoning, and by school science tests). The researcher and teacher acted as "experts and animateurs" (Henri, 1995) for the on line discussions. Students were introduced to the discussion environment in a short session in school at the start of the ten day period; this session had a purely social focus, and there was little or no discussion of science expected. Students were encouraged to make use of the environment both in and out of school.

At the end of the ten days, log files of the on line discussions were subjected to content analysis using a modification of Henri's model (Henri, 1991), in which contributions were classified by the researcher into three broad categories:

- social – unrelated to the science topic under discussion
- technical – concerned with use of the on line environment
- cognitive – related to the science topic under discussion

The total number of contributions to the discussions during this period was 350, of which 101 were posted outside school hours. Analysis of the classification of out of school contributions showed that 51% were social, 8% were technical, and 40% were cognitive ($\Sigma \neq 100\%$ due to rounding). Average length for social contributions was 9.3 words, for technical contributions 43.9 words (the majority of these by researcher and teacher in response to student difficulties) and for cognitive contributions 30.9 words. These figures were taken as encouraging, on the basis that a significant proportion of responses were related to the topic under investigation, and the length of these contributions suggested that students were engaged with the use of the on line discussion forum in a positive way.

Following the analysis, a group interview was conducted with a sample of students to ascertain their general feelings about the use of the on line discussion forum to support their science work, and to provide guidance about the details forum design for the main study. The teacher was also interviewed to ascertain his opinions as to the quality of the on line discussions (based on involvement in the discussion and on inspection of the log files) . Both teacher and students expressed their enthusiasm for the on line environment, and provided useful comments about its further development, leading to the conclusion that the answers to the questions posed at the start of the pilot phase were all in the affirmative.

Main study

The main study was split into two phases. The first phase involved two parallel classes from the same school as the pilot study, one of these classes including students from the pilot. This study was conducted some five months after the pilot study, in order not to interfere with preparation for National Curriculum tests. The second phase involved three parallel classes of students in the age range 13 to 14 years, taken from two schools. Although one of these schools was the school involved in the first phase and the pilot, all of the students in phase 2 were new to the research.

These phases of the study made use of a phpbb asynchronous discussion forum (www.phpbb.org) available continuously during each phase of the study, a synchronous chat room available at certain times (agreed between researcher, teacher and students) and a web-based area for file upload and download, to enable students to share such things as spreadsheets, digital photographs, word processor files and other electronic resources.

Data collection

Content analysis as applied to CMC in a formal educational setting relies on the process of categorisation to provide insight into the different kinds of contributions made by students as they engage in on line discussion. For such a process to be reliable implies not only consistency across time in the coding of contributions by a single researcher (internal reliability) but also where there are two or more researchers consistency between researchers (inter-rater reliability). However, even where studies can be shown to be reliable (and a review of 19 major studies using content analysis (Rourke et al., 2001) found that none could claim this), there must be concern over the validity of such studies, in the sense that the analysis is based on an imposition of the researcher's meaning on the text in the log file; text which has be written by a student, who could quite legitimately argue that this text is imbued with a completely different meaning. The need for an approach to the analysis of CMC-derived data which incorporates some form of triangulation is a theme also developed by McConnell (McConnell, 2000).

Given these arguments, the approach adopted when collecting data in the research was one in which initial interpretation of CMC-derived data used content analysis to categorise and sort contributions to on line discussions. This made possible further data collection through group interviews which provided participants with an opportunity to contribute to the construction of meaning from the original log files. The practical choice of a school setting in which to carry out this work made this a feasible proposition, and meant that there was also an opportunity for teachers to contribute to the process of meaning making, bringing their knowledge of the students to bear on the analysis.

Data analysis

Log files from both synchronous and asynchronous discussion forums were subjected to initial content analysis, making use of a second modification of Henri's model (Henri, 1991), in which contributions were categorised as follows:

- social – unrelated to the science topic under discussion
- technical – concerned with use of the on line environment
- cognitive – related to the science topic under discussion
- metacognitive – concerned with the nature of knowing

Selected metacognitive statements (which were always found closely associated with cognitive statements) were the subject of discussion with the students involved in the context of a group interview, in which the researcher provided the student(s) with the opportunity to expand on the on line contributions that they had made.

The implicit protocols (triad RCO) and tools (triad TCO) were explored by analysing log files and records of student interviews using instruments derived from Collins and Pinch (Collins & Pinch, 1994) in the case of implicit protocols, and from Nadeau and Desautels (Nadeau & Desautels, 1984) in the case of implicit tools. Clarification of the meaning of on line data, coupled with the use of data from the group interviews, enabled the clarification of meaning with the original authors of on line logs, together with an opportunity to explore issues in more depth. In many cases the on line logs provided a stimulus for discussion that took conversations far further than the original text-based electronic communications appeared to indicate. One such example involved students who were discussing the use of digital cameras and image manipulation software in making accurate measurements of a fast-moving object (table 1).

Karen	In Valerie's experiment we just sprung it and then measured how high it went ... but in Martin's one he could, like, replay it, so where we could just see it at that moment so we'd have to make sure it was there, Martin could, like, replay it and make sure it was there. So more like specific ... make it to the millimetre if he wanted to.
Linda	It's more reliable.
Int	Oh, it's more reliable [emphasis]? Now what does that mean, Linda?
Linda	Well, it's like – I don't know ... Valerie and Karen said they were marking it by the eye, and like the camera can like never lie, so ...
Int	Right, OK, so because they used a camera you think that's going to make it ...
Linda	... it's gonna like be more accurate, accurate.
Int	It's got to be more accurate because they used a camera?
Linda	Well, yeah!
Int	OK, that's fine. One of the things that someone's written about the camera ... Karen said "how were you [Martin] sure that you read the number correctly".
Karen	Oh no, I was thinking differently, I thought that they were plugging it into the computer and reading it off the screen ...
Int	Oh, right ...
Karen	...cos if you go into the computer it gets like blurrier as it gets bigger.

Table 1

Whilst initial indications from the on line logs were that the students involved were exhibiting a quite naïve view of the nature of knowledge, clarification in this subsequent interview showed quite the reverse. Karen and Linda's discussion in the interview showed that Karen in particular appreciated the significant differences in the nature of evidence produced by enlarging an image using a digital camera's optical zoom and enlarging it using an image-manipulating program on a computer; an understanding of the relationship between evidence and theory that was really quite impressive for this age.

CONCLUSIONS

The use of activity theory as an overarching perspective to inform the structure of this study together with the associated data collection and analysis shows that this approach has much to commend it, not least in the way in which it can focus attention on pertinent aspects of the complex interactions within a community engaged in an activity aimed at a common object. In addition, the combination of content analysis of on line logs followed by group interviews to expand on initial interpretations can provide a rich and extensive source of data, with meaning constructed by researcher working in partnership with researched.

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Understanding the Way in Which Students Contribute to Knowledge Building and Knowledge Claim Critiquing Within a Community of Learners Working in a Computer Supported Learning Environment

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Abstract: Collaborating in the production of a scientific explanation for the behaviour of a prototype toy, a group of school students was encouraged to use a Web-based environment to share their ideas and to be critical of the knowledge claims made by others, in the spirit of a knowledge-building community. The logfiles produced by online interactions were subject to content analysis and were followed by group interviews with students to allow explication of contributions. Instruments based on work from the area of science studies were then used to categorise the data, revealing patterns in the epistemological stances within the community, and highlighting the ways in which the community went about examining knowledge claims. This work suggests that content analysis of logfiles alone is insufficient to produce a deep understanding of knowledge-building and critiquing in a CSLE, which bear comparison with the processes used by professional scientists.

Introduction

The processes through which communities of scientists build theories and evaluate knowledge claims has been the object of considerable investigation by *science studiers*, the term coined by Yearley (1994) to describe the loose alliance of scientists, philosophers, sociologists, educationalists and others concerned to learn more about the processes through which scientific knowledge is produced and validated. At the same time, educational researchers have conducted work in which students' understanding of these processes has been explored using a variety of instruments, the history of which dates back over 50 years (Lederman, Wade, & Bell, 1998).

Making use of open-source software available on the Internet, an online environment was provided for a small community of school students who were undertaking a piece of science practical work. This environment was intended to support them both in and out of school as they collaboratively sought to produce explanations for the behaviour of a simple prototype of a child's jumping toy in which a stretched rubber band provided the energy for the toy to jump into the air. The processes through which this community constructed and negotiated knowledge were explored through logfiles and other data sources, and interpreted through the use of perspectives drawn from science studiers' understandings of these processes. The study was particularly concerned to address the questions:

- what does in-depth analysis of their online interactions reveal about students' epistemologies of science as they engage in knowledge-building?
- when students interact online to evaluate knowledge claims relating to practical inquiry, on what do they base their judgements?

Theoretical Framework

This study uses activity theory as a framework for understanding the interactions between students engaged in the collaborative production of understandings. Activity theory is a long-established branch of cultural-historical research with its origins in the Russia of some 80 years ago. Its name is somewhat confusing, since it is neither directly concerned with activity *per se*, nor is it a theory in the sense of being a fixed body of accurately defined statements (Kuutti, 1996:25). At the heart of activity theory lies an attempt to understand the ways in which

individuals cooperate in communities in order to perform some kind of activity directed towards an object; the basic unit of study for such a process is known as an *activity unit* (Fig. 1). The object may be tangible (eg an aeroplane) or it may be completely abstract (eg a theory); the one requirement is that it should be something that all members of the community can share for the purposes of manipulation and transformation during the activity. Working together, the *community* will employ a variety of mediating influences in pursuit of their *object*,

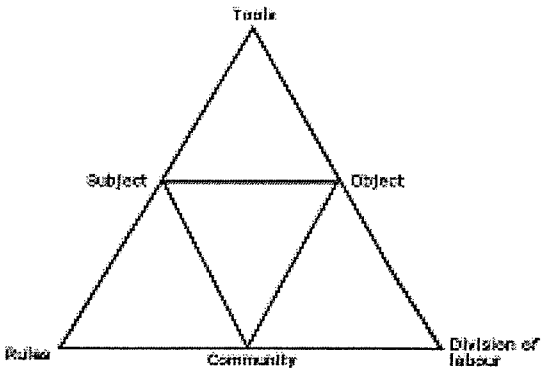

Figure 1: an activity unit (after Cole & Engeström, 1993:8)

including physical *tools* and *tools* used for thinking, and in doing so will be subject to a variety of *rules* which govern the conduct of the community (including the relations between the *subjects* making up the community) and the *division of labour* within it.

As is already apparent from the above description, although activity theory provides a framework which offers a way of describing and analysing the complexity existing when a community undertakes an activity, any attempt to do this in a holistic way is likely to fail due to the large number of interdependent relationships that must be considered. Lewis describes the use of *triads* taken from the activity triangle (Fig. 1) as a way of narrowing the focus to consider a limited range of relationships within those described by the activity triangle (Lewis, 1997). It was the use of triads which informed the approach to understanding collaborative work during practical science investigations described in this study.

Applying Activity Theory

Three triads were used as the theoretical basis for the empirical work which addressed the two research questions described at the start of this paper (Fig. 2). Triad SCO has its importance in the way in which the study itself was set up, whilst triads RCO and TCO framed the collection and analysis of data.

Triad SCO

This triad describes the relationship between subject, community and object. Lewis considers that this triad plays an important rôle in the establishment of a learning community because "there must be space for interpretation, negotiation and the establishment of group ownership of the motive [the object of collaboration]" (Lewis, 1997:214); effectively, the group of students here was set up to function as a *research group*. Bereiter and Scardamalia note the enormous success of research groups in finding answers to problems and in generating new knowledge (which they term *knowledge building*) and suggest that knowledge-building communities could be employed to help students develop enhanced understanding, based on the idea that, although students are not actually constructing new knowledge, they *are* constructing new meanings for themselves (Bereiter & Scardamalia, 1993:184). Sutton (1992) too argues for a focus on the social construction of meaning rather than on the interpretation of phenomena in order to enhance the quality of science learning.

The community of student scientists on which this study is based was brought together to constitute a knowledge-building community which would be encouraged and managed in such a way so as to promote the development of nine characteristics of such a community:

1. sustained study of topics in depth rather than superficial coverage;
2. focus is on problems rather than on categories of knowledge;
3. inquiry driven by students' questions;
4. explaining is the major challenge;
5. day-to-day focus is progress toward collective goals of understanding and judgement;
6. students typically work in small groups, each with a different task;
7. discourse is taken seriously;
8. teachers can contribute what they know to the discourse, but there are other sources of information;
9. teacher's role shifts to leading it by virtue of being a more expert learner

(adapted from Bereiter & Scardamalia, 1993:210-11).

Based on this, the object of this particular activity unit is the social construction of an agreed (scientific) way of understanding the particular phenomenon under investigation through a process involving peer discourse and review.

Triad TCO

This triad concerns the tools used by the community in addressing the object of the activity – the joint construction of an explanation for the phenomenon under investigation. Tools employed by the community may be regarded as *explicit* or *implicit*.

The term *explicit tools* relates to those which are applied through general agreement within the community and which are derived very largely from sources within the community of professional scientists. Such tools include science knowledge or 'facts' (eg the atomic mass of sulphur or the density of water) and scientific theories that are widely regarded as 'proven' (eg Newton's laws of motion or the laws relating to chemical combination of elements – such theories make up almost the entirety of school science encountered by students of the age of those studied here). These tools may be acquired by the student knowledge-building community from a variety of authoritative sources which include text books, the teacher and the Internet (with especial regard to provenance in the case of the last example).

Implicit tools are operated by the community with little or no discussion. Especially important in this context is the approach to scientific knowledge and the relationship between evidence and theory used by the community – its *epistemological stance*. Whilst there is no agreement amongst scientists, philosophers of science and sociologists of science about what might comprise a 'correct' understanding of the nature of science, there is some agreement about what may constitute an understanding that can be characterised as 'naïve'. In one such characterisation, Nadeau and Desautels describe an epistemological stance that they call *naïve scientism* (Nadeau & Desautels, 1984). This has five constituents: naïve realism, blissful empiricism, credulous experimentalism, blind idealism and excessive rationalism. A simplified version of this list (Tab. 1) is used as the basis for the instrument used to investigate students' epistemology, containing the three dimensions of naïve realism, blissful empiricism and credulous experimentalism. The dimensions of blind idealism and excessive rationalism are excluded since the former is concerned with motivation (which is part of the SCO triad, and is very different for knowledge building communities involving students as compared to those comprised of scientists; and in any case, motivation would be very hard to measure from online interactions), while the latter is closely concerned

with science as an enterprise involving experts, which is not the case where a community of students is concerned. As Brown et al note:

> *It is clearly romantic to suggest ... that students in public schools be enculturated into the cultures of mathematicians, historians, and literary critics. For a start, practitioners of these callings do not as a rule populate schools; teachers of these subjects may be the consumers of the outputs of these disciplines, but they are rarely practitioners. History teachers are seldom historians. Practicing mathematicians infrequently teach [in] high school, let alone grade school.* (Brown et al., 1993:189)

Dimension		Definition	Indicators
Naïve realism	(nr)	Scientific knowledge is the reflection of things as they actually are	• statements relating to the relationships between the entities in scientific theories and models (eg atoms, taxonomic groups) and their existence in the real world • statements relating to techniques used in making and recording observation statements
Blissful empiricism	(be)	All scientific knowledge derives directly and exclusively from observation of phenomena	• statements concerning the making and interpretation of individual practical measurements and observations
Credulous experimentalism	(ce)	Experimentation makes possible the conclusive verification of hypotheses	• statements concerning the way in which data-gathering is planned to support hypothesis-testing • statements relating to the interpretation of sets of experimental results

Table 1: dimensions used in classifying students' knowledge-building epistemologies

Triad RCO

This triad is concerned with the rules used by the community in rejecting or accepting knowledge claims made within the community during knowledge-building, a process referred to here as *knowledge-claim critiquing*. In common with triad TCO, the rules used in this process may be either explicit or implicit.

Explicit rules are those which are adhered to by members of the community as they go about their tasks, whether as part of the wider social arrangements that exist in the institution within which they work or in society as a whole (eg 'treat other people's ideas with respect', a rule drawn from those imposed as part of students' social contract with the school), or as part of the knowledge-building community. In the case of a community engaged in building science knowledge, such rules may often be traced back to Merton's four norms of science (Merton, 1973), which ascribe to science (and to scientists) the characteristics of *communalism* (science as public knowledge), *universalism* (science as a collective activity), *disinterestedness* (science as emotionally neutral) and *organised scepticism* (science as involving rational procedures and reserved judgement); these are sometimes abbreviated in the acronym *CUDOS*.

Implicit rules are those which the group may operate without ever making their basis clear; or perhaps even without any discussion. In the context of science knowledge-building, of particular interest are the non-technical reasons which may be given for the acceptance or rejection of knowledge claims from within the community. Through extensive interviews with practising scientists, Collins and Pinch have explored the non-technical criteria these individuals say that they use when deciding the validity of a particular piece of work, and have produced a list which includes: personal knowledge of a scientist's experimental capabilities and honesty; whether or not a scientist worked in industry or academia; a scientist's style and presentation of results; a scientist's 'psychological approach' to experiment; the size and prestige of the scientist's university of origin (Collins & Pinch, 1994:101). This list formed the basis of an instrument used to examine whether student scientists employ similar implicit protocols in scrutinising the knowledge claims of others from within their community (Tab. 2).

Empirical work

There are compelling reasons for the use of computers to support knowledge-building. In establishing and maintaining a knowledge-building community of students, networked computers can play a crucial rôle in at least three respects:

1. they can provide access to records of what other students are doing, and an opportunity to comment upon it;
2. they can provide access to other sources of information (in addition to the teacher and books);
3. they can provide access to experts outside the community.

If computers are used as a means of storing students' thoughts and ideas, and as a way of recording the knowledge-building community's communications, then students have access to a comprehensive, searchable source of information about what others in the community are thinking, and to a record of the development of the community's progress towards their goal. This is very close to the way in which knowledge-building in an expert community is carried on; as Bereiter and Scardamalia point out "the community database serves as an objectification of the group's advancing knowledge, much like the accumulating issues of a scholarly journal" (Bereiter & Scardamalia, 1993:212).

Dimension		Definition	Indicators
personal qualities	(q)	personality and intelligence	• reference to personal characteristics having a bearing on science practical work • reference to intelligence / ability • reference to integrity / trustworthiness
private information	(i)	information divulged outside the (formal) online environment	• reference to information relevant to investigation relayed by another means (eg word of mouth, or via another online channel)
presentation	(p)	presentation of results and report of investigation	• reference to appearance, layout, clarity etc of investigation report
social	(s)	social reasons unrelated to science classroom or online environment	• reference to personal relationship(s) or qualities with no direct bearing on science practical work
technical	(t)	technical aspects in presentation of knowledge claim	• reference to scientific or technical issues connected with knowledge claim, ie scientific "fact" or theory as found in text books or other authoritative source

Table 2: dimensions used in classifying students' knowledge claim critiquing

Context

A group consisting of two classes ($N \approx 60$) of 13-14 year-old students in the third year of a comprehensive school were provided with continuous access over a period of several weeks to a web-based discussion environment, in association with a practical investigation into forces and energy that they were undertaking as part of their school science work. The students were all in a "top" ability group (as defined by National Curriculum tests, nationally applied tests in such areas as cognitive reasoning, and by school science tests). The researcher and teacher acted as "experts and animateurs" (Henri, 1995) for the online discussions. Students were introduced to the discussion environment in a short session in school at the start of the study. This environment consisted of a phpBB asynchronous discussion forum (www.phpbb.org) available continuously to students at all times and a web-based area for file upload and download, to enable students to share such things as spreadsheets, digital photographs, word processor files and other electronic resources. In addition, a chat room based on the NFC Chat software package available under the GNU Library General Public Licence (http://sourceforge.net/projects/nfcchat/) provided the facilities needed for students to interact synchronously online in a Web-based environment. This chat room was open to students at certain times (agreed between researcher, teacher and students). Students were

encouraged to make use of all aspects of the environment both in and out of school. All aspects of online interactions were logged, and informed consent was obtained from students and their parents/carers for these logs to be used, in anonymised form, in research. Access to all online resources was controlled by usernames and passwords for child-protection purposes.

Data Collection and Analysis

Logfiles of the online interactions provided an extensive dataset which was analysed initially through content analysis. Content analysis as applied to logfiles from CSLEs used in a formal educational setting relies on the process of categorisation to provide insight into the different kinds of contributions made by students as they engage in on line discussion. For such a process to be reliable implies not only consistency across time in the coding of contributions by a single researcher (internal reliability) but also where there are two or more researchers consistency between researchers (inter-rater reliability). However, even where studies can be shown to be reliable (and a review of 19 major studies using content analysis (Rourke et al., 2001) found that none could claim this), there must be concern over the validity of such studies, in the sense that the analysis is based on an imposition of the researcher's meaning on the text in the log file; text which has been written by a student, who could quite legitimately argue that this text is imbued with a completely different meaning. The need for an approach to the analysis of CSLE-derived data which incorporates some form of triangulation is a theme also developed by McConnell (McConnell, 2000).

Dimension	Definition	Indicators
social (s)	posting unconnected to science investigation	• greeting • verbal support • social conversation
technical (t)	posting related to use of forum, chatroom or other aspect of networked computers	• comment / question about using the online resources • response to such question
cognitive (c)	posting related to science investigation involving science knowledge / skills	• statement / question relating to science connected with investigation • statement / question connected directly to conduct of investigation
metacognitive (m)	posting concerned with "knowing about knowing"	• comment / question containing judgement (explicit or implicit) about investigation, conclusion, methods etc • comment / question concerning relationship between experimental data and conclusions drawn

Table 3: dimensions used for content analysis

In this light, the approach adopted was one in which initial interpretation of CSLE-derived data employed content analysis to categorise and sort contributions to online discussions in order to highlight those which were of interest for further exploration. This content analysis was based on a categorisation of messages into four dimensions (Tab. 3), of which those classified as metacognitive (Shimamura, 1994) were of possible interest for further study. This then led to further data collection through group interviews which provided participants with an opportunity to contribute to the construction of meaning from the original logfiles. The practical choice of a school setting in which to carry out this work made this a feasible proposition, and meant that there was also some opportunity for teachers to contribute to the process of meaning making, bringing their knowledge of the students to bear on the analysis, providing a rich source of data.

Results

Based on the analysis of some 8500 lines of logfiles, group interviews were conducted with students to explore and develop some of the ideas found.

One area concerned the way in which students measured the height to which the prototype toy jumped, something that many of them considered to offer considerable challenge (Tab. 4, refs a and b). Some students considered that there was, potentially, a straightforward solution to this problem, albeit one that had been denied to them (Tab. 4, refs c, d and e). There is a clear implication here that these students regard measuring instruments as a way of getting at the "real" value of a quantity without the observer getting in the way, and completely independent of any kind of theory, an epistemological position described by Chalmers as *naïve inductivism* (Chalmers, 1982:2).

Reference	Source	Statement
a	chatroom	i know that it will be very difficult 2 b accurate
b	phpBB forum	its dodgy to get accurate results on this expirment
c	chatroom	i think that measuring this was really hard, we should have been given height measurers to attach to them that automaticall tell us
d	chatroom	we should have thouse electronic height measurers to attack to them
e	phpBB forum	we could atatch a height measurement readin thing 2 it, but that probaly wont work
f	interview	Oh no, I was thinking differently, I thought that they were plugging it into the computer and reading it off the screen ... 'cos if you go into the computer it gets, like, blurrier as it gets bigger.

Table 4: extracts from logfiles and interview transcripts (original spellings and formats)

Although these, and other, online contributions from students appear to indicate the use of implicit tools conforming to the description of blissful empiricism (Tab. 1), interview data suggests that this is not always the case. In the a group interview with students, there was discussion concerning the use of digital imaging equipment to "capture" the point at which the toy reached its maximum height, zooming in on a scale so as to obtain a more accurate reading. One student (Tab. 4, ref f) saw the importance of understanding the way in which digital images are enlarged, either by using the optical zoom function on the camera (which retains the sharpness of the image) or through the use of digital image manipulation software on a computer (using which the image becomes blurred as it is enlarged). In this case, the student appears to understand that instruments do not provide a way of making absolute measurements (ie that a "height measurer" does not exist) and that care is needed in interpreting observations made with instruments in the same way as observations made with human faculties in conjunction with simple instruments such as rulers.

Conclusions

The analysis of logfiles and interview transcripts of the knowledge-building community using instruments derived from the discipline of science studies is capable of shedding considerable light on the processes involved in knowledge-building and knowledge-critiquing. This suggests that there is a wide range of epistemological positions adopted during knowledge-building, and that there are many examples of knowledge-critiquing in which student scientists use similar non-technical criteria to professional scientists when scrutinising knowledge claims. The use of group interviews to explore online interactions with students reveals meanings that would otherwise remain hidden, suggesting that content analysis of logfiles alone is incapable of producing an in-depth understanding of the processes involved in knowledge building among students working in a CSLE.

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Exploring school students' online interactions within a science knowledge-building community

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Introduction

A considerable quantity of research into online learning communities has been conducted on the assumption that the entire meaning of online interactions can be captured by the logfiles of online dialogue generated automatically by the computer. Recent work has highlighted the inadequacy of this approach, pointing out that the richness of human interactions, even when computer-mediated, makes them not susceptible to simple textual representation. This work strongly suggests that the use of more naturalistic approaches are likely to provide a deeper picture of the research setting, leading ultimately to a fuller understanding. Although the use of naturalistic methods may offer advantages in terms of the depth of description, this may be at the expense of an ability to generalise from the findings so as to be able to "search for universal laws which explain and govern the reality being observed" (Cohen & Manion, 1989:8); the adoption of a multi-method approach to data collection and analysis may go some way towards addressing these concerns.

This paper describes the methodological approach adopted in the analysis of online data gathered during a study conducted over 12 months with nearly 150 UK school students aged 13-14. In this study networked computers were used to provide students with a Computer Supported Collaborative Learning (CSCL) environment in which to engage in knowledge-building as they undertook practical science investigations as part of their school work.

Background

One of the most powerful aspects of the scientific enterprise (in its broadest sense of seeking to "understand the world") is the ability of research teams to tackle large, complex questions and to produce complex and comprehensive theories which provide powerful insights into the workings of our universe. Where the science of Newton and Galileo was generally the enterprise of individuals, modern knowledge production is a collaborative enterprise, the success of which is noted by Bereiter and Scardamalia in a review of the nature of "expertise" and the implications of this for education (Bereiter & Scardamalia, 1993).

Given the power of collaborative work in scientists' science, its use in students' science is strangely muted. For example, although the National Curriculum for Science in England and Wales is phrased in the third person plural (eg "they evaluate their work, in particular the strength of the evidence that they and others have collected" (DFEE, 1999:28)), the implication nevertheless is that learning and practising science is an individual accomplishment. Whilst the emphasis on the individual is understandable in the context of assessment, the social nature of knowing suggests that there may be much to gain by considering classrooms as communities that collaborate in producing understanding. Writing about the benefits of discussion in science classrooms, Shapiro argues

> *Much of ... more advanced science learning involves phenomena that are not immediately perceptible ... and ... that must be understood in abstract rather than concrete ways. Reflecting on this change ... [s]tudents may see that their own personal ideas are not necessarily parallel to those of the scientist in order to learn the ideas of the scientist.*
>
> (Shapiro, 1994:31)

If benefits accrue during discussions which are focused on the development of individual understandings it may be argued that, in communities where the

construction of meaning is the intended outcome of a group collaborative activity, the collective nature of the activity may enhance understanding of the individual as well as of the community through *interthinking* (Mercer, 2000). Sutton (1992) also argues for a focus on the social construction of meaning rather than on the interpretation of phenomena in order to enhance the quality of science learning. The notion of the social construction of knowledge is at the heart of Bereiter and Scardamalia's model of a *knowledge-building community* (Bereiter & Scardamalia, 1993:201). Whether a science classroom can be regarded as a knowledge-building community depends upon the nature of the activities in that classroom and upon the rôle of the teacher, as the following discussion will show.

If a science classroom is simply seen as a microcosm of the community of authentic science, then knowledge-building is certainly not one of the outcomes of whatever activities take place within it. This is due to the lack of any authentic science expertise in the classroom – by definition the students do not possess this, and the teacher is not an expert in this sense either (Brown et al, 1993:189). However, if a view is taken in which students are seen as constructing knowledge which, although not new *per se*, is new *to them*, then the idea of a science classroom which has as its intended outcome the construction of new and more powerful meanings that are in accordance with "accepted science" may be consistent with knowledge-building, under three conditions, described by Bereiter and Scardamalia as follows:

1. the process of conducting a science investigation is not regarded as one in which students simply "learn by discovery", pretending to be scientists rediscovering knowledge already known;
2. the process of conducting a science investigation is not regarded as "cognitive apprenticeship" in which the teacher pretends to be an expert scientist;
3. the teacher must play a rôle within the community which devolves control of the investigation to students whilst acting to support and lead the enquiry – "progressive discourse" as opposed to "Socratic dialogue"

(Bereiter & Scardamalia, 1993:204-9).

Bereiter and Scardamalia counter the idea that students are still "pretending to be scientists" by pointing out that the absorption of the students in the process indicates a real commitment, not just to the process but also to the end – that "they think the questions really matter, and they are right" (Bereiter & Scardamalia, 1993:215). They also make the point that

> *It is worth noting that adult scientists and scholars do not spend all their time advancing the frontiers of knowledge. For most of them, that is a rare event. They spend a great deal of their time trying to make sense of what others have found or proposed, and that is not fundamentally different from what we have reported school children to be doing.*
>
> (Bereiter & Scardamalia, 1993:215)

The study

Two groups of students conducted two practical investigations, each one lasting a period of several weeks. The first investigation was conducted by 58 students aged 13-14 years in two top-ability classes of a comprehensive school in the south of England. Working in small groups, these students were challenged to produce explanations for the behaviour of a prototype of a child's jumping toy (*Jumpin' Jiminy*) which they manufactured themselves from simple household materials. The second investigation was conducted by 88 students from two comprehensive schools in the south of England. This investigation involved the production of an explanation of the behaviour of cooked egg white in solutions of biological and non-biological washing powders, and was also conducted by students working in small groups.

The students were supported during these investigations through a CSCL environment in which they could communicate with other students conducting the investigation through both synchronous and asynchronous CMC (computer mediated communication). File-sharing facilities were also available in order that students could

share electronic documents such as digital images and word-processed accounts as part of their discussions. Students were encouraged to make use of the CSCL environment to discuss their science work out of school, homework assignments being set specifically to encourage this.

Logfiles of all online interactions were available for analysis throughout both studies. A small-scale pilot study conducted prior to the two studies described above had used content analysis to show that online interactions between students were occurring in which school science work formed the focus of discussion. This analysis showed that over one-third (35%) of online interactions occurring in the CSCL environment involved students discussing their science practical work, and indicated that online discussions were occurring in which knowledge-building was a feature.

The collection and analysis of CMC data

A positivist approach to the collection and analysis of data from CMC has formed a common approach in the last 15 years (Rourke et al, 2001; Oliver & Conole, 2004), based on the idea that the entire meaning of online interactions is accessible through logfile analysis alone. Rourke et al (2001) list 19 studies that they describe as "influential", all employing some variety of content analysis. The basis for the majority of these is the work of Henri (Henri, 1991), whose analytical framework for the categorisation of students' electronic contributions to a discussion is based on five dimensions. Content analysis can be described as a positivist research method since it is the researcher who is in complete control of determining meaning based on text alone. Concerns about the objectivity of content analysis form part of the discussion of the strengths and weaknesses of content analysis by Rourke et al, who argue that "the failure of researchers to adhere to the principles that make quantitative research valid" makes content analysis unreliable (Rourke et al, 2001). Other researchers disagree, and contend that the problem with content analysis lies not in the way it is conducted but in its positivist approach *per se*, which attempts to infer the meaning of data out of context (Hara, Bonk and Angeli, 2000; Salmon, 2002).

Researchers who argue against a positivist methodology propose a more naturalistic form of enquiry in which the study of a setting is more holistic and where the relationship between the researcher and the research subject is one of interaction rather than distance (Borg & Gall, 1989:383-4). For example, McConnell sounds a note of caution about the adoption of positivist approaches to research into CSCL, which seek to "define *how* we look at research data in advance of carrying out the research" (McConnell, 2000:242). He argues for making sense of data from a naturalistic perspective, also described by Salmon as *constructivism*, involving "participants ... [exploring] their own thinking and knowledge building processes" (Salmon, 2002). The ontological position of research of this kind rejects the notion of an external, observable reality to which the observer has direct access through objective research methods.

The implications of this epistemology for the methodology of inquiry into CSCL are the adoption of "research methods that would allow us to explore issues rather than methods which would impose a certain kind of highly structured framework on the research" and in which "we would want to relate our analysis to that of the groups' own analyses ... but we would also be analysing the transcripts [of the CSCL work] in order to examine the ways in which knowledge is negotiated, controlled, understood, etc by the learners and tutors" (McConnell, 2000:242-3). On this theme, Lally & De Laat suggest that a more appropriate approach to data collection and analysis when researching online learning communities is to avoid the use of single methods, and to make use of a multi-method approach in order to "understand a richness of learning beyond the capability of any one of the methods when used by itself" (Lally & De Laat, 2002). This is behind the idea of *critical incident recall* used in this study.

Critical incident recall is based on work by McAteer and co-workers and Lally. McAteer et al describe a study of CSCL in which this approach was employed, aimed at

identifying effective communication practices in CMC. The study used individual interviews with participants to elicit information about interactions and responses to them that was impossible to glean from logfiles (McAteer et al, 2002). These interviews were based on *critical incidents* as an aid to memory, interviewees being asked to "recall instances where communication was particularly successful and particularly unsuccessful, and to give their reasons why" (McAteer et al, 2002:316). Archives of conferences assisted in this process, which gave an interviewee the opportunity to respond freely with recollections about the conference before more targeted questions were used to focus on key issues highlighted as important by the researchers. McAteer et al consider the interview process a "fundamental part of the research" which provides "a central means of identifying successful and unsuccessful communication events and communications practices" (McAteer et al, 2002:316).

Lally outlines a somewhat similar way of eliciting data of this sort; he describes these data as holding information about the "non-expressed cognitive, affective and social processes of individuals and group" (Lally, 2002); Lally's work is based on *critical event recall*, in which "participants recall include their worries, concerns, motivation, thinking, understanding, plans and intentions, observations and conclusions in relation to the event" (Lally, 2002). Using this technique, Lally worked with participants who had used an e-learning environment some 14 months earlier, asking them to reflect on the e-learning experience with the help of logfiles and various summary tables providing information about the interactions. Discussing the value of this technique in obtaining information from a tutor reflecting on his online interactions with a group of students, Lally observes that "the tutor engaged in many reflective and analytical observations about his own facilitation of the group and the behaviours of individuals within it, yet much of this thinking was not directly observable in the transcripts of the group's work", and concludes that "critical event recall has the potential to access aspects of learning and tutoring processes that are not directly available in group discussion transcripts" (Lally, 2002). He also observes that the use of group recall provides an additional dimension, "enable[ing] the articulation of many previously unexpressed aspects of learning" (Lally, 2002).

Collecting and analysing data from science students in the study

Analysis of the logfiles of both synchronous and asynchronous online interactions between the science students in this study was conducted using two *taxonomic frameworks* based on work concerned with the epistemology and sociology of science. The purpose of this analysis was to see how students went about constructing scientific knowledge, and the ways in which they thought about knowledge claims. The first of the taxonomic frameworks draws on Nadeau and Desautels' notion of *naïve scientism*, and describes the characteristics of three dimensions of a naïve approach to building science knowledge – *naïve realism*, *blissful empiricism* and *credulous experimentalism* (Nadeau & Desautels, 1984). The three dimensions and the indicators used to identify online interactions with character reflecting one or more of these dimensions are shown in table 1.

		Definition	Indicators
naïve realism	(NR)	Scientific knowledge is the reflection of things as they actually are	• statements relating to the relationships between the entities in scientific theories and models (eg atoms, taxonomic groups) and their existence in the real world
blissful empiricism	(BE)	All scientific knowledge derives directly and exclusively from observation of phenomena	• statements relating experimental outcomes and conclusions
credulous experimentalism	(CE)	Experimentation makes possible the conclusive verification of hypotheses	• statements relating to hypothesis testing

Table 1 – dimensions of naïve scientism

The second framework uses studies by Collins and Pinch concerning the non-technical reasons given by scientists for accepting or rejecting another scientists' knowledge claim (Collins & Pinch, 1994). This framework describes the characteristics of six dimensions associated with students' acceptance or rejection of knowledge claims. These dimensions and the indicators used to identify online interactions with character reflecting one or more of these dimensions are shown in table 2.

The two frameworks were used to identify *critical incidents* in the logfiles of online interactions which indicated that students' discussions featured some aspect of interest. These critical incidents were then the subject of *critical incident recall*, during which the group of students involved in the critical incident were interviewed and asked to reflect on and analyse the critical incident themselves. This process involved the students, as research subjects, in contributing actively to constructing the meanings within the logfiles of their online interactions, providing access to understandings that would otherwise be lost if meaning was imposed by the researcher alone. This process is illustrated in figure 1.

		Definition	Indicator(s)
reputation	(r)	Personal reputation for ability in science practical work and integrity.	• reference to practical ability • reference to integrity / trustworthiness
personal qualities	(q)	Personality and intelligence.	• reference to personal characteristics having a bearing on science practical work • reference to intelligence / ability
private information	(i)	Information divulged outside the (formal) online environment.	• reference to information relevant to investigation relayed by another means (eg word of mouth, or via another online channel)
presentation	(p)	Presentation of results and report of investigation.	• reference to appearance, layout, clarity etc of investigation report
social	(s)	Social reasons unrelated to science classroom or online environment.	• reference to personal relationship(s) or qualities with no direct bearing on science practical work
technical	(t)	Technical aspects in presentation of knowledge claim.	• direct reference to scientific theory ("finished science") connected with knowledge claim

Table 2 – dimensions associated with scrutiny of knowledge claims

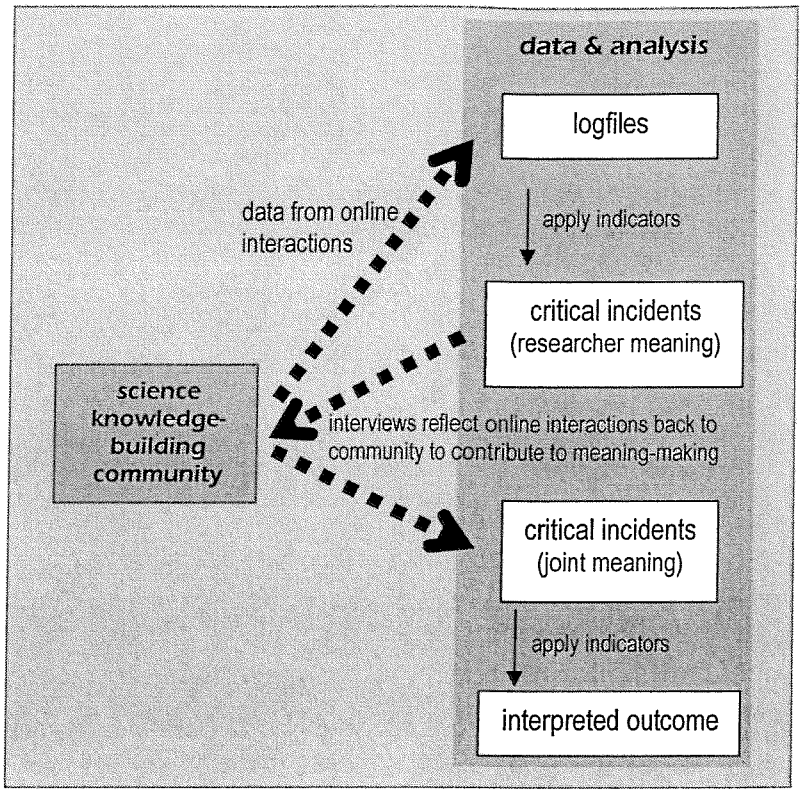

Figure 1 – the model for the analysis

Discussion

Application of this method to the data from the online interactions of school science students has shown that the added data from critical incident recall can provide depth to an analysis based on the analysis of logfiles alone, and in some cases can even show that the initial interpretation of the logfile is wrong. As an example of this, consider three online interactions between students discussing the way in which the height to which a *Jumping Jiminy* may jump, in investigation 1:

> *i think that measuring this was really hard, we should have been given height measurers to attach to them that automaticall tell us*
> *we should have thouse electronic height measurers to attack [attach] to them*
> (extract from logfiles of synchronous online interactior

By way of contrast, during critical incident recall a student from another group appears to have some insight into the rôle played by instruments in the process of making and interpreting observations based on digital imaging, and the enlargement of these images:

> *Oh no, I was thinking differently, I thought that they were plugging it into the computer and reading it off the screen ... cos if you go into the computer it gets, like, blurrier as it gets bigger.*
> (extract from critical incident rec

This student can see the importance of understanding the way in which digital images are enlarged, either by using the optical zoom function on the 9digital) camera (which retains the sharpness of the image) or through the use of digital image manipulation software on a computer (using which the image becomes blurred as it is enlarged). In this case, the student appears to understand that instruments do not provide a way of making absolute measurements (ie that a "height measurer" does not exist) and that care is needed in interpreting observations made with instruments in the same way as observations made with human faculties in conjunction with simple instruments such as rulers. This is in contrast to the extracts from logfiles alone, in which such nuances are absent.

Critical incident recall, then, can provide important data which helps to contextualise the data from online interactions alone, addressing issues of validity through triangulating initial (researcher) interpretations with interpretations agreed jointly between researcher and researched. Whilst it may be argued that such interpretations are not capable of wide generalisation, being the outcome of the explication of a very specific instance, the very richness of the interpretation when compared to that from the logfile alone may lead to knowledge claims which are not intended to reveal ultimate truth but to provide a rich description of the world in order to make sense of it (Cohen & Manion, 1989:27).

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