Paper 9: ICT and Student assessment

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Abstract

The role of student assessment in ICT is often seen by teachers as problematic. This paper will explore the relationship of the two and will argue that research in assessment has not kept up with the opportunities offered by ICT. Conversely, some of the new developments in 'assessment for learning' have not yet found their way into ICT. The paper will explore the various roles and relationships that ICT has in assessment, for example, the assessment of ICT skills, the assessment of curriculum learning when work is done with the aid of ICT, assessment within computer-assisted learning, and ICT as a tool in supporting the assessment process in general. It will then go on to explore the new opportunities offered by ICT (e.g. in terms of collaboration) that the assessment processes may not have come to terms with. An example of collaborative activity will be presented and some thoughts on the assessment issues will be outlined. The paper will also explore ways forward including 'assessment for learning' (with its concern for questioning, feedback, sharing assessment criteria and self/peer assessment,), and new outcomes that could be incorporated into ICT.

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Introduction

The relationship between assessment and ICT is not straightforward, it being open to many interpretations. McFarlane (2001), in her important article on this relationship, devotes most of it to the issue of assessing the impact of ICT on student learning outcomes, one of the most contentious issues in relation to ICT. Although this is where most of the discussion in the literature is focused, my concern in this article is with assessment as part of the teaching and learning process, where such a process involves ICT. This involvement of ICT can take a variety of forms, and in the next section I will examine these forms.

Not only is the relationship complex, but those dealing with ICT rarely deal with assessment, and not surprisingly teachers feel more insecure in relation to this aspect of their ICT competence. In the UK teachers have all undergone government-funded training in the use of ICT in the curriculum (funded by the New Opportunities Fund).[1] The largest such training programme, the Learning Schools Programme (LSP), was provided by The Open University and a commercial company RM (a large supplier of ICT services and products to education). This training aims to bring teachers up to competence in a variety of 'expected outcomes' covering the use of ICT in planning, teaching, assessing students and evaluating in the area of the curriculum for which the teachers are responsible. In addition they are expected to be able to use ICT to support their work as a teacher (e.g. to obtain and produce material to support teaching). Figures 1 and 2 show the achievement of these expected outcomes as rated by primary and secondary teachers when they have completed the training on LSP (based on a sample of over 10,000 teachers). Achievement is consistently high in almost all areas (90-95% of teachers feel they have achieved the expected outcomes), except for in the area of assessment (where teachers are asked if they can Take full advantage of ICT in developing appropriate and effective strategies for assessment by yourself and learners). This may of course reflect in part the difficulties teachers encounter with assessment in general, but the difference from other outcomes is very striking.

Figure 1: the achievement of expected outcomes of ICT training by primary school teachers

Figure 2: the achievement of expected outcomes of ICT training by secondary school teachers

Assessment has always been an aspect of the use of ICT in education, although in the early days of computer-assisted learning (CAL), this was limited to relatively straightforward testing of content as a learner progressed through a program. Despite this enduring concern, and the importance of assessment more generally in education, it is perhaps surprising that there is relatively little work on the area. For example, a search for 'education AND assessment AND computer' on ArticleFirst, a large database of journal articles, listed 57 articles in the years 1990-2003. Of these only six dealt with school-level ICT and assessment, the rest being mainly in higher education, with a few in industrial or training contexts post school.[2] In recent years the development of the web has renewed the interest in assessment, if only because the use of web sites as a learning environment in itself has required the simultaneous development of ways of assessing learners, especially if they are remote from the teacher. Indeed it is this interest that accounts for the bulk of the higher education assessment articles noted above. An ERIC Practitioner File (2000) on Assessing Learners Online illustrates this focus on higher and adult education, often in the context of distance education.

As I will show, most of the work in this area ignores the developments in the field of assessment, particularly with regard to 'formative assessment', what has now become known as the field of 'assessment for learning'. This development has

focused on how learners can benefit from assessment, rather than simply providing a summative assessment that has a limited role in improving the student's learning. There are a number of possible ways of seeing how assessment can help learning but four have become important: improving the quality of questions that will encourage thinking and reflection on the part of students; focusing assessment feedback on those aspects that will help students improve (e.g. comments and not grades); sharing with students the criteria of assessment such that they will understand the quality they are try to achieve; encouraging the use of student self-assessment and peer assessment. (These will be examined in more detail later.)

I shall argue in this paper that the field of ICT in education at school level has much to learn from the 'assessment for learning' literature.[3] I will also argue that, conversely, the assessment field has something to learn from the developments in ICT, especially those that concern new educational outcomes produced by ICT.

Roles and Relationships of ICT and Assessment

As noted earlier, there is a limited literature that discusses the relationship of ICT and assessment. In a special issue of the Journal of Computer Assisted Learning (No. 17, in 2001), the editorial distinguished 'assessing learning with ICT' (i.e. the impact of ICT on learning) and 'assessing learning with ICT' McFarlane (2001). In this latter aspect, which McFarlane only deals with the towards the end of the article, she distinguishes computer-based tests to replace paper-based (etc.) assessment, and the testing of new competences as a result of using the computer. In addition, she discusses the use of the computer to mark essays, where the computer is acting as a tool. Thelwall (2000) considers computer-based assessment as an educational tool in higher education. He starts with the use of computer-based assessment online and the creation of item banks, along with assessment in CAL packages. He goes beyond the traditional summative assessment uses to consider its role in formative assessment, though these are largely tests that act as exercises to allow students to test themselves when they are ready. The provision of feedback, he argues, is important as the assessment is formative, an issue I will return to when I consider the help ICT can be to the learner. He considers why ICT might be used: to improve the learning experience; where it is of necessity part of the learning experience (using ICT); where it might improve efficiency of assessment or cope with large numbers (expediency).

These two authors provide some of the rationale for the range of relationships I will use, namely:

- assessing ICT skills and understanding;
- the task of assessing students' curriculum understanding when ICT is used as part of the learning;
- assessment as part of computer-assisted learning (CAL);
- ICT as a tool in the assessment process.[4]

I will consider each of these in turn.

ICT skills and understanding

This in some ways is simply to treat ICT as a subject much as any other subject in the curriculum. However, where it is also promoted as a tool for use in everyday life (e.g. to write, calculate, draw etc.) and as an aid to learning, then it is not an abstracted skill or understanding, but must be embedded in other activity. Thus it is possible to learn the skill functions of editing related to a word processing software package, but it is more important to know how to combine

these functions with the drafting and redrafting of text. This is a part of literacy. In those countries, like the UK, where ICT is taught as a separate subject, then it is likely that it will be treated as a de-contextualised skill at a time when ICT is being promoted to teachers as integrated into the curriculum. (McFarlane [2001] notes that this makes it difficult to know just what the ICT skill is and how progression should be viewed.) This is illustrated in UK primary schools where teachers teach ICT separately from its use in numeracy, literacy etc., exacerbated by the fact that this teaching is done in separate ICT suites. Thus the teacher takes the class down to the suite perhaps once a week for an hour for the ICT lesson. This militates both against the use of ICT to support learning across the curriculum and the development of learners' capacity to know when and how to use ICT as an everyday tool and as a support to their learning.

There is also a grey area, where the development of so called 'information skills' leads to the development of capabilities that extend curriculum work, but may require unique approaches to the likes of research. Thus, searching the web for information on a geographical topic opens up a new dimension in investigation or research connected with the subject. Similarly searching through electronic public records in history can extend the meaning of historical investigation in a way not available, nor envisaged, before the advent of access to computerised databases of this kind. I will come back to this when I consider the Curriculum use and again when I look at the possibility of assessing new outcomes. The problem for assessment in this situation is to take account of the curriculum context of use of ICT, a problem that needs different views of learning than ICT specialists have traditionally had. I will return to this problem when I briefly consider how views of learning relate to new outcomes.

Much of the discussion above has focused on the skill element of ICT, but skill cannot usefully be developed devoid of any conceptual understanding. When it is, then the blind following of procedures breaks down as soon as something unexpected happens; a common occurrence with a computer! The assessment of conceptual understanding is even more dependent upon an understanding of how learning in this area progresses (McFarlane's concern about ICT assessment). Problems of such assessment are compounded if there is a focus on skills in the use of specific software functions. Being able to carry out basic operations in a spreadsheet is of limited use if a student has no concept of modelling and of 'what if' possibilities. It is often reduced to a record sheet or a simple way of creating tables.

Curriculum use

I am not concerned here with the impact of ICT use on students' learning in the various areas of the curriculum; the major thrust of McFarlane's article (2001).[5] Instead the question I am concerned with is an extension of the one considered in relation to the assessment of ICT skills and understanding, namely, how is the subject or curriculum learning assessed when ICT is being used? As noted earlier, this is an area that teachers feel least confident in when they were learning to use ICT in their teaching (Figures 1 and 2). In principle there is little unique about the assessment task when ICT is involved. The fact that students are using the computer to research an historical topic on the web does not on the face of it change the assessment of such a research or investigation technique. The same criteria of 'the choice and use of appropriate evidence, its analysis, and justifiable conclusions' are all the same as in situations where more traditional resources are used. Two things change:

- the nature of the evidence that the student encounters;
- the nature of the evidence of learning that the teacher can draw upon.

The first requires the students to be able to deal with potentially huge amounts of evidence, turned up by the use of a search engine, or by going to rich web sites. It also means that students must be able to judge the veracity of the information. When researching texts, assumptions are usually made about the quality of the information; no such quality assurance exists in the world wide web.

The second change, in the evidence the teacher has to draw upon, is in some senses the 'new' assessment issue. Finding and extracting information is relatively easy with ICT tools of 'search' and 'copy and paste'. The questions set must distinguish between those students who blindly copy material and those who show some understanding in its use. This means a requirement for questions directed at making students think, one of the concerns of the 'assessment for learning' movement that is developing, and again I will come back to this later. The ICT tools are also useful to the teacher. For example, it is possible for a literacy teacher who wants to assess a student's capability at writing to examine the various drafts a student has made (if these are saved as the student progresses through the drafting process). Similarly history teachers wanting to assess how students investigate sources can track the kinds of searches made and the nature of the selections from the original sources. That, at least, is the theory. Most teachers would baulk at the prospect of so much evidence from all their students.

So the situation for teachers in various areas of the curriculum is one of new territory with little research about, or development of, the new opportunities that the use of ICT brings.

Assessment as part of computer-assisted learning

This in a sense is the most well trodden road for the use of assessment with ICT. The image of much of the assessment in CAL is that found in drill and practice programs; low-level questions based on small amounts of content that have just been studied by students. This is in part a legacy of the learning ideas that underpinned early attempts at CAL (what Wood [1995, p. 13] called the 'Skinner and neo-behaviourist' approaches). In part it also reflects the limitations of the feedback that can be given by such programs. Typically a student is given a question and may choose a response, with the program telling her she is 'correct' or to 'try again', often ending by telling the student the correct answer if she fails repeatedly. Such feedback is crude and again, is based on poor models of learning and the evidence from the 'assessment for learning' movement.

In well defined areas such as arithmetic, where the domain is clear and learners' errors and misunderstandings are well known, it is possible to both give feedback that is sensitive to the learner's needs and to vary subsequent tasks based on these. This is the situation for an Integrated Learning System (ILS), but even here the results are mixed, with the impact depending upon how work on the ILS relates to other work in the classroom (see Wood, 1998). Moving outside such well defined areas, the picture of the quality of the assessment, whether to support learning or for summative purposes, is even less impressive.

Unfortunately, the advent of the web seems to have made people think that problems that dogged CAL for over 30 years are not present in this 'new' environment. It is to some of this work that I now turn in considering how ICT is now being used as a tool for assessment.

ICT as an assessment tool

Here I will look at how ICT helps:

- professionals in the assessment industry, i.e. those whose job it is to carry out large-scale testing and examining or who develop them for others to use;

- classroom teachers;
- learners;
- to provide new forms of assessment.

As I noted, the development of the web as a learning environment has been a spur to some of this work.

To help the assessment industry

This industry is involved in large-scale assessment, whether through public examination boards that organise the assessment of whole cohorts of a school population or through national programmes aimed at judging the progress of a nation's children in schools. In the UK examination boards examine children at aged 16 and 18 with hundreds of thousands taking various kinds of assessments each year. In the USA the National Assessment of Educational Progress (NAEP) and their State level programmes, adopt different sampling from examination boards, but nevertheless are large-scale enterprises. Both these kinds of organisations are concerned with the way in which ICT can act as a tool to improve the efficiency of testing or examination programmes. For example, in a review of the work of NAEP by the National Academy of Education, research is called for in the use of technology for the administration and scoring of NAEP assessments (Glaser and Linn, 1997).[6] The examination board Edexcel has onscreen testing for the assessment of adult literacy and numeracy[7] and, in conjunction with the Northern Ireland Council for the Curriculum Examination and Assessment (CCEA), plans to use this for the public examinations at aged 16.[8] The Scottish Qualifications Authority (SQA) also has a number of initiatives on computer-assisted assessment, which although they have some elements that are geared towards formative assessment (e.g. the PASS-IT Online assessment project), seem to be based on turning conventional paper tests into computer-based ones.[9] But such organisations are also interested in using ICT to assess in new ways. The National Academy of Education review of NAEP recommended the use of the computer for adaptive testing of problem-solving strategies and the self-regulation of individuals, and group problem solving.[10] In the UK the Qualifications and Curriculum Authority (QCA) held a conference in March 2004 on e-learning and e-assessment for vocational education, indicating a concern for new areas of work.[11] There is so much activity in this area, and it is changing rapidly, that some attempt to monitor this would be helpful for those who want to know what is available.[12]

Harding (2001), writing about a UK examination board, indicates that examining must keep up with, but cannot be ahead of, the development of the use of the computer in schools. Two particular uses are being tried by his examination board: examining analytical laboratory work through the use of simulations (to bypass the need for laboratory skills), and the uses of software for the likes of numerical analysis in mathematics, which require the use of the computer. He also discusses his board's uses of the computer to create adaptive tests based on item banks (and psychometric models), a straightforward efficiency use but one which also allows a more responsive form of assessment. But unlike the NAEP review in relation to technology, his concern is with supporting learning, and he notes the work of the Interactive Technologies in Assessment and Learning Unit based at the University of Cambridge,[13] and a number of on-line facilities that support teachers by providing material and assessment activities (some online for student revision).

Harding (2001) is cautious about the use of computers to complete 'standard' examinations, because they are not in use in the classroom. Similarly, in the USA, studies by Russell and Haney (2000) indicate that for written tests students will do better than on pencil and paper tests if they have a threshold level of

keyboard skills. However, they also point out that computers cannot be used as a panacea because of the expense (and of course the penalty to those with poor keyboard skills). The Educational Testing Service (ETS) is, however, developing a range of projects and applications, some of which have the potential to support teachers and others in constructing and delivering tests, including to help those with visual and hearing impairments and other disabilities. They also have a range of specific tests that are in a computer-based format.[14]

Given that many of these are still in the development phase, or are restricted to specific domains and tests, it is unlikely that, despite the pressure to use computers in schools, they will become a tool in the formal assessment system for some time.[15]

To help the teacher

Just as ICT can help the assessment industry with efficiency and volume of assessment, it is also possible for teachers to benefit in this way. However, most of the reported aids to administering assessment are at the higher education level (see Note 14). Instead, teachers are encouraged to produce their own assessment aids such as creating a record of assessment using a spreadsheet, though of course there are school management information systems that have record keeping facilities for assessment information.[16] Tools that allow them to construct assessment, such as are found in higher education (e.g. Gardner et al, 2002), are rare. Most of the tools from the assessment industry, as noted above (e.g. ETS), are for professional test developers rather than teachers. However, new tools are emerging to help the teacher, for example, Discourse developed by ETS.[17] This allows teachers to construct questions or to spontaneously ask them in class and, provided the students are networked (e.g. through handheld devices), teachers can see student responses as they are produced. This gives teachers an insight into their students understanding, and is related to some of the ideas of assessment for learning, that I will turn to later. Of course teaching packages, such as ILS, do provide assessment information on students that can be used by teachers to provide other support and to manage the students' learning process.

The use of ICT to create portfolios is recommended, but again there are few purpose-built systems or software that teachers can use. Kankaanranta (2002) reviews digital portfolios in the context of her study on early education, including a consideration of such software and the different purposes to which they can be put. Where the outputs of learning are in a digital form (e.g. a web site), then this approach may be the only medium for assessment information.

One reason why there is more evidence of help to staff in higher education from ICT is because distance learning is more common at this level.[18] Web-based courses are increasingly used in this context and they need associated ICT assessment systems (e.g. Weller, 2002).

To help the learner

Any discussion of how ICT and assessment could help learners needs to distinguish two elements. First, whether the assessment is formative or summative, i.e. helping learning (formative) or measuring/grading performance (summative). Second, it is necessary to distinguish assessment that is part of an electronic environment from its use more generally to support learners.

Assuming that summative assessment offers limited help to the learner (a point noted earlier), I will focus on the role of formative assessment. Thelwall (2000) identifies two approaches to formative assessment, in the context of higher education. One is part of a CAL package and is seen in the questions or quizzes that are part of the teaching and learning process. The second is essentially an

open access test, where the learner can administer the test herself. The learner can therefore exercise some control over her learning, though this is not 'self-assessment' in the sense used by the assessment for learning literature. A strong argument in both of these approaches is the role of feedback to learners. Many of the articles from the higher education sector deal with this (e.g. Buchanan, 2000; Collis et al, 2001; Drew et al, 2002; Thelwall, 2000), but most do it in a very general way, with little recourse to the assessment for learning literature, where the role of feedback is well understood. Buchanan (2000) is aware of one of the points that emerges from this literature, which developed from a review by Black and Wiliam (1998), namely the need for such feedback to show the learner how she can improve; just giving a score is inadequate. (I will examine 'assessment for learning' in the next section of the article.) He recognises just giving correct answers to learners, does not fulfil this 'improvement' requirement of feedback, and so his web-based software (PsyCAL) provides guidance on what to study, based on the answers to test questions, in a test-learn-retest cycle. In a sense it is the contemporary expression of drill and practice transferred into the web environment. Examples of this exist at school level, and it sees its greatest expression in the 'revision' sites that are created by a variety of agencies. (For an example in the examination board context see Harding, 2001.)

Thus we have examples of support to learners that have underlying principles that are along the correct lines, but which are not informed by either very sophisticated views of learning or the role of assessment in learning.

The second element, to distinguish assessment that is part of an electronic environment from its use more generally to support learners, sees ICT as offering the possibility of making students more effective learners. It is this that McFarlane (2001) draws attention to in her review of the educational benefits of ICT. But underlying the contribution, she argues, is whether the learner is consuming other people's content or producing their own outcomes and hence knowledge. This latter contribution points to the role of ICT in externalising personal knowledge. An example of this is drawn attention to by ALRSG (2003) in their review of the impact of the use of ICT for the assessment of creative and critical thinking skills. They pick out the work of Osmundson et al (1999) on concept mapping, where the externalising of thinking improves learning (and the maps can be scored by the computer). But here we cannot easily distinguish the role of the ICT in the assessment per se, which of course is part of the message of those who advocate formative assessment (assessment for learning).

To provide new forms of assessment

In the sense that CAL integrates assessment into the teaching and learning process, and provides immediate feedback or feedback when the learner wants it, then ICT has produced new forms of assessment. The development of this into the web environment is not different in principle, but does allow location and time to be at the choosing of the learner, at least in higher education. At school level ideas on 'home-school work' as a replacement for 'homework', indicates the impact that the web can have for school students. As I have noted above, however, the basis of some of this assessment leaves much to be desired in terms of how well it reflects what we know of assessment for learning. Nevertheless the principle of matching closely assessment and learning leads to ideas on dynamic assessment. Wood (2001) distinguishes 'static' assessment from 'dynamic' in that the former generally measures time and incidence of success and error in answering questions or solving problems. Dynamic assessment on the other hand is formative and can emerge from one-to-one teaching, tutoring and coaching.[19] He draws on his work with computer-based assessment and tutoring systems, the latter attempt to:

- give access to help which is adapted to the learner's needs;

- allow timed interaction such that the provision of any help, feedback or explanation fits the pace of the learner's activity;
- identify tasks that serve to challenge but not to overwhelm the learner.

This sees the assessment process tightly integrated into the teaching and learning process, which in theory is the advantage of the computer in providing this on an individual basis. It therefore puts a premium on what views of learning underlie the computer program or electronic environment that is created. Two studies of dynamic assessment in the context of the use of ICT involve particular views of learning. Jensen (2001) proposes a change model of learning that contrasts with a 'stability' one (constructions of knowledge that don't change). The change model he calls 'mediated construction', which uses a specific piece of software and requires specially trained teachers who can carry out the dynamic assessment. Another approach, based on 'mediated learning experience theory', involves the use of a human mediator to help where the computer cannot cope with individual learners. At this stage these two approaches seem too specialised to be of general use in the classroom yet, but more important they rely on adopting the models underlying them, not a trivial issue when we are talking of their use in everyday classrooms with teachers who have a variety of more or less explicit views of learning.

Another new form of assessment is where complex activities can be conducted via the computer and data gathered to provide insight into cognitive processes. For example, Chung et al (2002) use Interactive Multimedia Exercises (IMMEX) to assess problem solving (see also O'Neil, 1999). This approach tries to construct a cognitive model of student learning through the observation of both moment-to-moment on-line behaviour and moment-to-moment cognitive processing (as observed through think-aloud protocols).[20] Other examples of the use of dynamic environments to assess problem solving are given in Wirth & Klieme (2003) and Bennett et al (2003). Again, promising though these types of approach are in a research context, they are too complex for classroom use (and indeed no such claims are made for them). However, this research is part of a wider programme that is effectively opening up, not just new forms of assessment, but the possibilities of assessing new kinds of learning outcomes, a topic to which I now turn.

ICT and new outcomes

One of the discourses that McFarlane (2001) addresses in her account of ICT and assessment is the extent to which ICT can be seen as an agent of change. This she sees as an alternative agenda that conflicts with a standards agenda, where the drive is to improve student achievement as measured by standard tests and similar assessment methods. In this context she sees new outcomes as being important. Politicians by and large want the improvement in efficiency or effectiveness by the use of ICT against standard measures. The result of research on this impact is mixed (as McFarlane, 2001, makes clear), and those who see the use of ICT as being unhelpful, or are sceptical politicians, wonder about the investment. Advocates of ICT are likely to resort to claiming that the problem is that ICT is not being used to its full potential when used in this way, and that what we should look for is 'new learning' or 'new ways of learning'. Apart from this being a dangerous argument (especially if this is also not proven), it also exhibits muddled thinking, as Scrimshaw (2002) indicates. He considers the variety of 'new ways of learning', which might be new ways of teaching, new participants in learning or new objectives and purposes. In the context of assessment it is new objectives and purposes that are relevant, and he sees the issue for schools as the introduction of new knowledge; in schools this is usually a process of catching up with changes in knowledge outside schools. Another way of viewing this is to see the extent to which, as McCormick and Scrimshaw (2001)

say, ICT transforms learning the subject. They give an example of the way in which literacy will be transformed when multimedia or other forms of electronic text become common currency. However, in my view the 'transformations' will only be evident when we see ICT through the lenses of contemporary views of learning, which will give a more profound understanding of, for example, collaboration. Elsewhere I have argued that some of the implications of ICT can only to be understood and implemented using such views (McCormick, 2001). Wood (1995) has already shown how different views give different types of ICT implementations, and it is evident that some of the CAL and web implementations of assessment are based on weak views of learning. For example, Cox and Clarke (1998) discuss the use of quizzes that will assess higher-order thinking, but use Bloom's taxonomy (1956), which was constructed independent of particular views of learning, and has been the subject of many empirical and philosophical criticisms.[21] This is important not only because the different views of learning have different ICT implementations, but because assessment needs to be viewed differently.

Greeno, Pearson and Schoenfeld (1997) show how different views of learning have different implications for ways of knowing and theories of achievement, and hence of assessment. They discuss four perspectives: differential (based on traits), behaviourist, cognitive and situative, focusing on the latter two as representing contemporary views. It is beyond the scope of this paper to go into the details of either the cognitive and situative perspectives or the aspects of achievement that form the basis for assessment in each, although I will highlight features of each later. Based on their analysis, they conclude that the NAEP testing deals with some aspects of the cognitive perspective, but almost none from the situative perspective, indicating that we still have a long way to go in knowing how to assess students based on our most enlightened understanding of learning.[22]

From my earlier discussion of ICT as a tool in assessment, it is evident that there is some way to go in basing such tools on what we know about how assessment might aid learning. What then are the ways we have to develop the relationship of ICT and assessment? I turn to this question now.

Ways Forward

There at least three ways forward for developing the relationship of ICT and assessment. The first concerns the developments that the assessment industry must make, to help produce routine or standard assessments that reflect contemporary views of learning and achievement, which will then form the basis for building on the new opportunities that ICT might offer. The second concerns building on the 'assessment for learning' literature to see how insights gained in the conventional classroom can be related to teaching and learning using ICT. The third concern is with the 'new outcomes' that I hinted at earlier. I will deal with the first briefly and then explore the latter two in more depth. My purpose in doing this will be to draw out some general issues, some of which act as a guide to those concerned with developing assessment in relation to the use of ICT.

The assessment industry

The critique mounted by Greeno et al (1997) has relevance to our understanding of assessment more generally, although these are directed at the assessment industry as represented by NAEP. They show how testing fails to tap the insights of the cognitive perspective in that testing has a simple additive model of information and skills. A cognitive perspective, on the other hand, emphasises placing learners into the 'space' of a cognitive model of concepts and procedures and being able to know what components of the space they use, and under what

conditions. This critique relates to the dimensions of achievement they call 'Strategies and schemata' (strategic procedural knowledge and conceptual knowledge) and to metacognition (e.g. self-monitoring performance on a task). They also point to the integrative and generative features of knowledge that has things to say about the kinds of assessment tasks we give learners. Finally they point to the work of dynamic assessment and the possibilities of seeing what help the learner requests, when using a computer. This allows the assessor to infer what is missing in the learner's cognitive model. The developing research work quoted earlier, on new forms of assessment that provide insight into cognitive processes, are examples of this direction.

Their critique of how NAEP matches up to the situative perspective, shows even more deficiencies, as I indicated earlier. 'Participation' is a major part of this perspective, where assessment must try to ascertain the extent to which the individual (a student) is able to sustain participation in the practices of the community that represents the domain. For example, if the community is that of mathematicians, can the learner think mathematically, work collectively and add to other's work, present arguments to others in a mathematical way? This involves the students having a sense of identity, i.e. a sense of 'self' as a mathematician. Both of these imply assessment that involves participation in interactive activities. Any assessment therefore needs to be able to place a student in terms of her progress on a trajectory of participation. Being able to participate in the community means that an individual can formulate and evaluate problems and solutions according to the standards of the community. This implies in turn that the learner needs to know what is expected, what is valued performance.[23] The situative perspective also requires a task situation that reflects action in the wider context, i.e. not in abstract situations from which it is assumed, by most assessors, it is possible to generalise performance to any situation. This goes hand in hand with such tasks being personally and socially meaningful, what is normally referred to as 'authentic' learning (Murphy & McCormick, 1997).

A number of these issues are also relevant to the next way forward, following the recommendations of the assessment for learning literature.

Assessment for learning

As I noted earlier, this literature stems from a concern to develop the role of formative assessment, and it has in some ways implicitly developed from emerging ideas from the more general literature on learning. For example, an underlying theme in a concern with the role of feedback, sharing criteria and self and peer assessment (three of the four elements of assessment for learning noted in the Introduction) is that of becoming aware as a learner, which reflects some aspects of metacognition, present in both the cognitive and situative perspectives discussed above. A seminal work in this literature was a review of research on classroom formative assessment carried out by Black and Wiliam (1998), in which they showed that there was: evidence that improving such assessment could lead to improved achievement, room for the improvement of formative assessment in classrooms, evidence of how to improve formative assessment. Through this work and a project working with teachers of mathematics, science and English (Black et al, 2002; 2003), they were able to develop principles and classroom strategies to support formative assessment. As indicated earlier, these principles covered four main areas:

- Questioning strategies. For example: increasing the wait time for students to respond to a teacher question to allow them to think and of course a corresponding change in questions that require thinking; a 'no hands up' policy, so that all students should be expected to give an answer, even if it is 'I don't know' (and of course there needs to be a supportive climate

where students are prepared to be wrong so they can improve their understanding).

- Feedback. For example: give only comments and no grades, and comments that indicate to students how they can improve; commenting on work part way through a topic (rather than at the end) so that students will have time to improve; and, rather than marking all work, focusing on some pieces and giving good feedback.
- Sharing criteria. For example: expressing the criteria used to mark work in a form students will understand; giving examples of work at different standards so that students can see what quality responses are; and giving students opportunities to construct their own tests.
- Self and peer assessment. This requires the students to have a clear sense of what they have to achieve and training in carrying out the process, and might include, for example, students giving themselves a colour rating of how well they understand a topic (green for good understanding, amber for partial and red for little understanding), and green and amber rated students pairing up to deal with problems and the teacher taking the 'reds'.

There are many specific classroom strategies that are available for each of the four areas, and the repertoire is being extended by a development of the work of Black and his colleagues.[24]

The assessment for learning literature that Black and Wiliam (1998) reviewed showed that students, who misunderstood the idea being assessed, could nevertheless choose a correct answer because they were able to use an algorithm that worked most of the time. Their concern for good questions to engage students' thinking has therefore to be applied to assessment. McFarlane, Williams and Bonnett (2000) conducted a study of children (9-10 year-olds) collaboratively using an ICT authoring tool to create multi-media hypertext documents on drugs education topics. These outputs were compared with more conventional tests, the latter of which indicated a higher-level understanding of students than was evident from an analysis of the multi-media documents. They did not argue that the production of these documents would directly improve student content understanding, but that the production would support student thinking and allow teachers to recognise actual student understanding and hence achievement. Making thinking explicit was another benefit they saw for this authoring, and this explicitness allowing the teacher, in the language used by Greeno et al (1997), to place students into the 'space' of a cognitive model of concepts and procedures. They also argue that the multi-media authoring tool will aid 'assessment for learning' by allowing students to share in the criteria of assessment and to carry out self-assessment, though they do not give specific details of how a teacher might arrange this. These elements (making thinking explicit, sharing criteria for assessment and self-assessment) see ICT as a tool for the learner, relating to the point McFarlane (2001) made about the importance of students producing their own outcomes rather than consuming other people's content.

This work by McFarlane and her colleagues is an exception and, as I have noted, little of this work seems to have found its way into the ICT literature on assessment, though clearly the ideas on feedback, in particular, are very relevant. Part of the problem of course lies in the difficulty of programming a computer to provide feedback that is sensitive to the needs of particular students and shows them how to improve. (I have already noted that only Buchanan (2000) recognised the assessment for learning function of feedback, even if the feedback of what to study further was in itself a relatively crude affair.) Given the limitations of programming ICT to allow sensitive feedback, some in higher

education have adopted a computer-mediated conference approach where teachers can give feedback using ICT as a communication device (ERIC Practitioner File, 2000; MacDonald, Mason and Heap, 1999).

Peer and self assessment seem to have been tackled more successfully, but again most of the work is in the higher education sector. Kwock and Ma (1999) use an interactive computer-based system (Group Support System) that supports peer assessment by managing the process of brainstorming, and voting on and weighting criteria. Lin, Liu and Yuan (2001) and Tsai, Lin & Yuan (2002) argue that their web-based system (NetPeas) has advantages over face-to-face systems: it is less direct and provides more of a feeling of detachment and even anonymity; the process can be monitored by the teachers as it happens (asynchronously); special-purpose programs such as NetPeas remove the difficult management and administrative load. Self-assessment under this view of assessment for learning is very much more than self-administration of the assessment, but a process of understanding what has to be achieved and determining how to improve. The use of self and peers overcomes the problem of being able to program the ICT, rather it is being used as management, administration and communication tool in the process.

As schools develop web-based systems, particularly for 'home-school work', these kinds of approaches could develop to support student learning.

New outcomes

Earlier I indicated two 'sources' of new outcomes afforded by the use of ICT in learning. The first comes from a transformation of the subject and the second from the insights that contemporary views of learning allow us. Transformations might be seen, as I suggested, in such things as views of literacy in the world of digital multimedia or electronic forms of text (such as e-mail or text messaging). I have already discussed how multi-media authoring by students allows them to externalise their thinking and to express their ideas through this media in ways that are not evident through conventional tests (McFarlane et al, 2000). In addition, McFarlane et al (2000) argue that the use of hypertext creates links among ideas that are different from the narrative sequence of text writing. They do not go as far as to argue that such multi-media authoring is a new form of literacy, but others have considered the impact of ICT on text on the digital screen (Lanham, 2001; Jewitt, 2003) and this may have implications for views of literacy.

McCormick and Scrimshaw (2001) postulate a half-way house between ICT simply replicating what is done in conventional teaching and transforming it completely, namely that it might extend what can be achieved. The obvious example is the use of the web as a source of information for research activity. Thus ICT can be seen to add a new dimension to the issue of resource-based learning, a fashion of an earlier time in schools. MacDonald et al (1999), in the higher education context, see the importance of being able to handle large amounts of material and to make sensible selections and analysis relevant to the research question etc. As I noted earlier in discussing ICT skills and understanding, this is more than information skills; it requires a context-sensitive approach to sources, and criteria for evaluating the status and veracity of knowledge, as discussed under Curriculum use. In some subjects, such as history, evaluating sources and the bias in accounts and interpretations of past events, is a part of the approach of an historian that students will be expected to learn. But this will become important across a range of subjects, and for some, such as science, will bring in new skills and approaches. While it may be standard to inculcate values of the use of evidence to support scientific ideas, in moving into the web students will be confronted by advocates who will use evidence for their own cause (environmental pollution, effects of the nuclear

industry etc.). Issues of rhetoric, and the like, may find there way into subjects that have not in the past had to deal with this. Thus we have a range of new outcomes, at least new in some areas of the curriculum.

This extension, brought out by resources available on the web, can also be found in relation to communication skills. Network technologies offer a range of opportunities for communication, across geographical areas, ethnic and religious divides, and time zones. Though these may not in themselves be new knowledge or new outcomes, they again may find their way into subjects and topics not experienced before by teachers or their students. Videoconferencing has been one of the most exciting areas where students are exploring such issues (e.g. Austin, 2003). Assessment of the learning taking place through this means has been less explored, and is not mentioned in, for example, a text documenting activities in one of the most experienced local education authorities of England (Arnold, Cayley and Griffith, 2000).

In the UK 'creativity' has become a fashionable topic, with it being one of the areas under 'thinking skills' in learning across the curriculum. In a review of creativity, new technologies and learning, Loveless (2002) indicates that ICT can be both a tool to aid creativity and provide media for the creative process. Thus ICT can support developing ideas (e.g. through the provisionality in drawing and writing with ICT) and through creating in digital media (e.g. digital video). However, she acknowledges not only the difficulties of assessing creativity, but also the difficulty of relating relevant ICT capabilities to attainment in the subjects of the curriculum (the general problem of the impact of ICT), and of providing new measures to capture the effect of ICT on creativity. In addition to the study of multi-media authoring by McFarlane et al (2000), discussed above, Loveless is able to cite only three other authors as 'useful starting points' (p. 26) for such assessment.

Interestingly there has been a review of the literature on the impact on students and teachers of the use of ICT for assessment of creative and critical thinking skills (ALRSG, 2003). Out of 103 studies that met the criteria of a systematic search, 12 were the focus of the review, from which conclusions could be drawn about impact. This review was informed by the assessment for learning literature drawing on the more general activities of the ALRSG, which includes UK researchers in this area of work. The authors note the problem of defining creativity and conclude that it can be seen as the 'divergent' element in problem solving, contrasting with the 'convergent' element of 'critical thinking'. Thus they take it to be: 'relating together principles, ideas, information and entities in new and original ways to generate new entities or ideas.' (ALRSG, 2003, p. 15). In combining thinking skills with creativity, their review takes a different view of creativity to that of Loveless (2002), who might be seen to reflect her background in the use of ICT in arts education (e.g. Loveless, 2003).[25] The results of the ALRSG review indicate three main secure findings:

- computer-based concept mapping, with automated scoring can be used for summative assessment of creative thinking;
- ICT will help teachers by storing and recording information on students' developing understanding, and provide feedback to students and allow the teacher to mediate in those areas beyond what the program can cope with;
- feedback from the computer using test material does help students to improve their later performance on the same test.[26]

Only the first of these is a unique finding, with the second and third allowing findings, well known in other areas, to be extended to creative thinking.

Thus, reflecting on what we know of ICT and assessment of these 'new outcomes' offered by the use of ICT, the picture is not one of either a thriving literature or indeed that much clarity about the nature of these outcomes. The members of ALRSG (2003) argue that priority needs to be given to conceptualising learning as involving higher-order thinking and that knowing how to use ICT goes hand in hand with understanding how to bring about this thinking. Thus, back to the message of the assessment for learning literature, and to developing teaching and learning as the route to developing appropriate assessment.

What of the second source of new outcomes, namely contemporary views of learning? I indicated earlier that these views, of the kind indicated by Greeno et al (1997), could 'create' new outcomes for assessment driven primarily by the insights such views give. Collaboration is one such area because socially-orientated views of learning can bring fresh understanding to this activity. ICT, particularly when involving network technologies, can also bring new dimensions to this, as I hope to show in the next section. Looking at the literature on new outcomes through the transforming role of ICT leads, in a number of cases, to the issue of collaboration, though once again mainly in the higher education sector (e.g. Bonamy, Charlier and Saunders, 2001).

Collaboration and learning

Contemporary views of learning throw light on collaboration in particular ways that are important for network technologies. Specifically, the social dimension in social constructivist, socio-cultural and situated views, lead us to think in new ways about the nature of collaboration and the skills associated with it.[27]

There are in fact competing views of collaboration arising from the two contemporary perspectives on learning discussed by Greeno et al (1997). (Interestingly, Greeno and his colleagues did not elaborate on the issues of collaboration in their analysis nor in what they have to say about assessment.) Those who take a cognitive perspective (focusing on an individual mind) will see peer collaboration in terms of creating and resolving cognitive conflict. The different views that individual peers bring to understanding an idea or concept create the conditions for them to rethink and construct their understanding. The promotion of individual learning through collaboration leads to individual construction of knowledge. Those who take a social constructivist or situated perspective will not look for individual creation of knowledge, but the joint creation of knowledge. This kind of approach privileges the social dimension in learning, and is the one I will consider in this paper. I will not elaborate the complete background to this approach, [28] but (below) present a selective number of ideas that are important to this view and to the collaborative example, which I will consider later.

Intersubjectivity

Intersubjectivity is a central concept in collaboration and it arises between participants from the:

> shared understanding based on a common focus of attention and some shared pre-suppositions that form the ground for communication. (Rogoff, 1990, p. 71)

It therefore requires an appreciation of the mental states of others (Crook, 1994). The elements that are part of creating intersubjectivity are:

- shared problem space;
- shared objects;
- shared or distributed cognition.

When students are collaborating, therefore, they need to establish shared thinking in these ways. Thus, for example, in a design project using a computer they would have to agree on the needs or problems they were trying to design for (this gives both shared goals and the basis for a 'shared problem space'), and to share the ways that they express them. The computer screen can be seen as a shared object, to establish shared thinking, particularly when there is a drawing or text on the screen.[29] Shared cognition is a more complex idea. The creation of an understanding in a discussion of a design can give rise to the pooling of ideas and the bringing of different kinds of expertise to bear on a design problem or need. But what is created is more than the sum of the thinking of those collaborating. Such thinking is not just working together and helping each other (this is co-operation), with the focus on the individual mind.[30] The use of electronic networks extends, and has a potential to transform, collaboration from that usually found around a computer in the classroom (the conventional view of the computer and collaboration).

Authenticity

The discussion by Greeno et al (1997) of the deficiencies of NAEP indicated authenticity as a requirement for assessment tasks. Social cultural theory focuses on the social and cultural significance of the knowledge. This leads to ideas of cultural authenticity i.e. the extent to which the learning reflects the curriculum subject in the world (outside school), which is the focus of the learning. In situated approaches this is expressed in terms of the community of practice (e.g. how the school subject, mathematics, reflects what mathematicians do in the world outside school). Authentic learning is that which enables greater participation in this community of practice, what is referred to as cultural authenticity (Murphy & McCormick, 1997). It does not mean that learning in the classroom should try to be the same as in the world outside, something impossible given the age, experience and resources available to students. However, it should be coherent, meaningful and purposeful within a social framework that is within the ordinary practices of the culture of, say, mathematical activity. Schools have particular problems in creating authentic activity because they have difficulty in setting up tasks which are meaningful, as opposed to being just ‘things you do at school.’ At one end of the spectrum of say, problem solving activities, there are the 'egg race' type activities, where students have to see how far or quickly an egg can be carried across a room without breaking it. This is an activity that has no meaning in itself unless it is put in the context of an egg-laying and packing plant etc. At the other end of the spectrum is where six year-olds are set the problem of designing a new airport for their local area. This is an activity with apparent authenticity, but where it is unrealistic to expect them to have the conception or the skills to undertake it.

However, there is a second sense in which authenticity needs to be considered, that of personal authenticity; i.e. that is personally meaningful. Without this second element no construction of knowledge or participation, which will lead to learning, can take place. These two aspects of authenticity are inter-related but they can be thought of distinctly. They are distinct in that personal authenticity relates to the view of the learners not the view of knowledge, which is what cultural authenticity refers to. In making a task that is set as a 'problem' personally meaningful, students must be involved in the context of the problem. They must also be given significant decisions to make, which allow them to create solutions. Thus, in making bridges between school learning and everyday experience, it is not essential that the situations in which school activities are set are ‘real’ (Murphy, 2000). The central requirement is that they afford the students' authentic dilemmas that, in Lave's words, ‘furnish opportunities [to the students] to improvise new practice [i.e. to learn]’ (Lave, 1992, p. 85).

Tools of learning

A situated approach also focuses on the tools and physical conditions of learning. These affect thinking; 'tools' have physical and psychological dimensions, and reflect the community of practice. So, a graph can be a tool for thinking in mathematics, and it comes with conventions and processes of use that need to be understood by students (it is not just a matter of technique). When a spreadsheet is used to create a graph, then this tool affects the way a mathematician thinks about and tackles a problem. Students have to learn to use this tool as part of authentic activity, and in doing so their learning is affected by it. When the software incorporates a collaborative element, it is likely that their thinking will have dimensions associated with the technology added.

There are two related themes that emerge from the research on social views of learning:

Collaborating to learn, where the collaboration processes aids learning. In this process the focus is on the creation of intersubjectivity and how this contributes to learning, including through guided participation. Social constructivist views of learning use the idea of guided participation, which implies a skilled person working with a less skilled person. So the learner is guided into how to participate until she is able to operate solo. One very important idea is that participation in an activity, which is part of a domain, is collaborative and learning to participate is therefore a central feature of learning.

Learning to collaborate thus follows from this learning to participate, but the focus is on the skills and understandings that are necessary to ensure successful collaboration. These skills and understandings are often overlooked in conventional collaborative activity in the classroom, and I will show how the use of ICT can create the conditions where the need to learn to collaborate becomes imperative.

Collaboration and ICT

Work on collaborative tasks with joint products (as indicated in the previous section), is still uncommon in the literature on ICT and education, despite the early grounding by socio-cultural theorists like Crook (1994) or those who have really tried to engage with the idea of collaboration through technology (e.g. Schrage, 1990). Schrage discussed joint writing to record thinking at meetings and, despite him not being a learning theorist, his ideas are very powerful in the educational context.

Teasley and Roschelle (1993) dealt with students trying to reconcile a real world of bouncing balls with a vector model (represented in software) by using the latter to predict the former. They studied synchronous collaborative activity and they tried to understand the language and actions used by student collaborators to establish shared knowledge, while recognising differences and rectifying misunderstandings. At the heart of collaboration they see the need to create and maintain a joint problem space. The software they used allowed students to establish fidelity (the match of their mental model and an external display) and mediation (the use of the external display as a tool to negotiate meaning). They identify several features of collaborative discourse:

- turn taking - sequences that indicate the degree of sharing of problem representations;
- socially-distributed productions - collaborative completion, where, for example, one student starts a sentence and the other finishes it;
- repairs - that are required because even in collaborative activity there is individual activity that can lead to conflict, i.e. a difference of view that needs to be negotiated;

- narratives – a verbal strategy to monitor each others' actions and interpretations (e.g. explicitly talk about computer mouse movements and the intentions behind them);
- language and actions - the importance of gestures, e.g. in accepting something or demonstrating an idea.

They argued that the computer forced students to spend considerable time developing their joint understanding because it:

- helped to make language less ambiguous (students can see the result);
- allowed non-linguistic conversational turn taking;
- and helped resolve impasses by allowing ideas to be tried out.

The latter element is a unique contribution of computer technology, at least in terms of speed at which these can be done (the first can be more demanding in the case of computers).

The importance of context, seen as having a socio-cultural history, leads to a need to consider students collaborating at or through the computer as integral to the classroom (Crook & Light, 1999). This means that students bring with them an experience of collaborating (or not) from their normal classroom work. In addition, the substance of the work they do at the computer relates to other work in the classroom (a point noted earlier for Integrated Learning Systems; Wood, 1998). This in turn leads to a stress on the importance of looking at the culture of collaboration that normally exists in a classroom (i.e. without the use of the computer; Littleton, 1999). In addition it is important to be aware of the culture of the subject (represented in the worlds outside and inside the classroom), in relation to both the collaborative norms and tasks.

Most of this work on collaboration focuses on 'collaborating to learn', but ICT gives unique conditions to allow students to 'learn to collaborate'. Schrage (1990) gives a powerful example of the effect of the technology on human interaction relevant to learning to collaborate. He points out the effect of long-distance telephone calls that have a significant delay in the voice travelling between the two speakers. Each has to wait a little longer than normal and hence this stresses the importance of listening to the other person. Translating this idea into the situation of remote students jointly designing, they automatically have to adopt collaborative approaches not usually found if they were working side by side at the same computer. Rather than just taking the mouse out of the hand of the other student when they want to draw something, they have to ask the other student to be able to take control of the mouse or offer control back. It also produces more explicit language that contributes to the collaborative process; the Teasley and Roschelle (1993) 'narratives'. These aspects of collaboration will be shown in the example analysed in the next section.

Collaboration: an example of new outcomes

I will use the above ideas on learning to examine an example of collaboration using ICT. The example involves two students from different schools who remotely collaborate on the design of a pen that can be manufactured from a series of plastic tubes (Open University, 2001).[31] They are using standard drawing and communications software (Micrographifx Windows Draw and NetMeeting). This allows them to have on screen the same view of the drawing and for them to each take control of the mouse in turn to work on the drawing. As they work they can also see a video picture of each other, along with an audio

link through headphones and microphone (see Figure 3). They are therefore able to talk to each other as they jointly work, with each student able to contribute.

Figure 3: students working on a pen design, showing the video link in small windows on screen.

This is an example of desktop video conferencing, with the addition of a shared common workspace. The students had been working on this project prior to the lesson in which they collaborated. They had already developed the skill of using the drawing software and individually had ideas about what pen they would design. This was the first time they had ever used this communications software, and prior to the lesson they had not communicated about what they would do (their teachers of course had). They started with a simple tube as the body of the pen, decided who would draw it, what colour, then worked on the shape of the nib, and the pen top (shape and colour).

As this was the first time they had used the communications software, inevitably the collaboration was at a primitive level. Simple decisions were taken with little discussion, but nevertheless with a regard for the other person. In addition the collaboration shows unequal participation by the students, with one student 'taking charge', but in a collaborative spirit. It illustrates some important issues, and points to the potential of this collaborative environment, which I will draw attention to below in terms of both 'collaborating to learn' and 'learning to collaborate'. From this I will then examine the assessment implications.

Collaborating to learn in the example

During the interaction a number of statements were made by the students indicating collaborative thinking and hence collaborating to learn. The first concern design decisions:

> You're going to have the nib yellow? [indicating an implicit decision made by the other student]
>
> It doesn't have to be round it can be square. [the student is checking that the other has considered this choice]
>
> I'll do the clip red? [checking that this is ok]
>
> Is that ok there, or is it a bit too big? [checking this size decision]

Of course the criteria involved in the design decisions are not yet very profound (colour, shape and size), but as the students develop they can extend these in nature and range.

There were also statements that indicate students making thinking explicit, for example:

> I'm just going to draw it [the pen top] on it [the body of the pen] and then take it off.
> [This allows the student to get the size and proportions correct.]

This procedural knowledge illustrates both the use of the software (to draw the pen in situ and then to move it to create it as a separate component) and the procedures involved. Computer-supported collaborative activity lends itself to making thinking explicit, because the students have to explain their thinking to each other (this is its 'mediation' role). Where such explicitness does not occur, it may be that students need to learn to collaborate, to ensure they create the intersubjectivity that is essential for collaboration.

Some of the elements on 'deciding what to work on' (under 'learning to collaborate' below) can also be seen as making thinking explicit.

Learning to collaborate in the example

Collaborative moves are important in learning to collaborate and are often not explicit nor negotiated between collaborators. For example, the point made earlier about students taking the mouse out of the hand of the other to carry out an operation, without asking or ensuring that the other student is happy to relinquish control. These moves become more evident in the situation where students are working remotely, because of the structuring given by the technology (in the way Schrage, 1990, describes for the long-distance telephone call). Such moves evident in the example were those associated with:

- taking control [facilitating turn taking]

  You want to control it [the mouse] and colour it [the pen] in?

- deciding what to work on ['self' regulation, where 'self' is not an individual that is being regulated, but the collective, the pair]

  Do you want to draw the rest of the pen, the tip of the pen?

  I've just drawn the lid now you can colour it.

As noted earlier, some of these moves will concern the process of collaborative thinking, and will overlap with that category. This overlap is more likely when the collaboration is extensive; indeed the fact that this is a relatively primitive level of collaboration may mask the potential of this example.[32]

Assessment implications of the example

The above analysis can provide the basis to think about assessment, and how to represent assessment criteria. These criteria may help us to define 'new outcomes', though how we actually carry out the assessment and collect evidence are more difficult issues. Below are questions relating to the possible criteria for the two areas of 'collaborating to learn' and 'learning to collaborate'; some inevitable overlap of the two occurs (as they are inter-related).

Collaborating to learn criteria

1. Design decisions: number, type and range of design criteria used
2. Intersubjectivity
    a. What shared purpose/need/problem?
    b. What shared object?
    c. What shared construction (distribution of ideas)?
    d. What shared conception of the design process?
3. Procedural knowledge
    a. What type and level of decisions in process?
    b. What is the sequence of the process?

Learning to collaborate criteria

4. Taking control
    a. Who decides?
    b. How control is taken/given?
    c. What is the balance of control?
5. Repair
    a. Who recognises it is needed?
    b. Who makes a move to repair?

   c. What response is there to the move?
   d. What is the success of the repair?

6. Self-regulation
   a. When are self-regulatory moves made?
   b. What is decided?
   c. What is the level of decision (i.e. of the self-regulation)?

The evidence for each of these will not be easy to collect and will require some kind of audio and perhaps even video evidence. For example, 2a, 2c, 2d, 4a-c, 5a-c (above) would require at least audio recording of the conversation (easy to do, difficult to then analyse to find evidence, at least for a busy teacher). In some instances the products of the design could be saved at different stages. For example, to determine if they have a shared object (2b) it might be possible to look at individual student initial design ideas, compared to the subsequent collaborative ideas. This could be done by saving drawings at strategic times in the process to see their growth and combinations (i.e. not just one student's ideas being used).

To overcome the problem of audio or video recording (not possible in routine assessment), then it might be possible to have the students undertake self-assessment, and at times even peer assessment. An example of self-assessment would be to ask students to record on a separate sheet the types of design decisions they made (1 above), points of disagreement experienced and how these were resolved (5a-d). This of course leads us to assessment for learning. Students will need to be able to understand the criteria and thus the ideas, concepts and procedural knowledge they are trying to learn. It may be that as part of the learning they could record their interaction and each try to make assessments of themselves. The fact that the technology makes them more explicit about their collaboration helps to make them aware of the learning to collaborate and will encourage reflection and self-regulatory behaviour, both of which will aid their learning.

Of course, initially they would not have sufficient understanding so working with an older student or an outside (expert) designer could help; this idea of guided participation would bring students to a better understanding. Given that the outside designer does not have to leave her office, this will be easier to set up than hitherto has been the case.

None of this discussion gives us workable assessment methods, particularly for summative purposes, but it does show possible directions of development and its potential for formative assessment is clear.

Conclusion

My argument has been that the relationship of ICT and assessment has not always kept up with developments in either of the separate fields of ICT or assessment. Developments in one can affect the other. In particular, the possibilities of recent ICT developments that, for example, network technologies offers for collaboration, open up new outcomes that must be assessed. By the same token, developments in assessment for learning, which have largely been ignored by the ICT field, offer useful directions for assessment and ICT. However, to exploit the relationships productively it is important to develop principles based on sound views of learning, while recognising that there are competing perspectives. Further, it is clear that the school and higher education sectors operate in isolation and need to share both models of use of ICT and assessment and understandings of the learning issues.

My focus has been on learning processes (in my example collaborating to learn and learning to collaborate), and I have not emphasised the knowledge issues. I have made the point, for example, that networked technologies allow students to confront knowledge from many sources. In some areas this will mean tolerating ambiguity or uncertainty in the knowledge encountered; teachers will have to tolerate this in their classrooms and students will need to know how to deal with it. This aspect needs to be developed to understand the associated assessment issues; another debate!

An implicit message in the argument has also been the need to avoid earlier mistakes associated with CAL, in our headlong rush to the web-based digital curriculum. In particular, we must avoid using limited views of learning and knowledge. But we must do that while exploiting the innovations that can result from improved communication and networking facilities. This may require thinking and working 'outside the black box' to deliberately misquote Black et al (2002).

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Figure 1: the achievement of expected outcomes of ICT training by primary school teachers

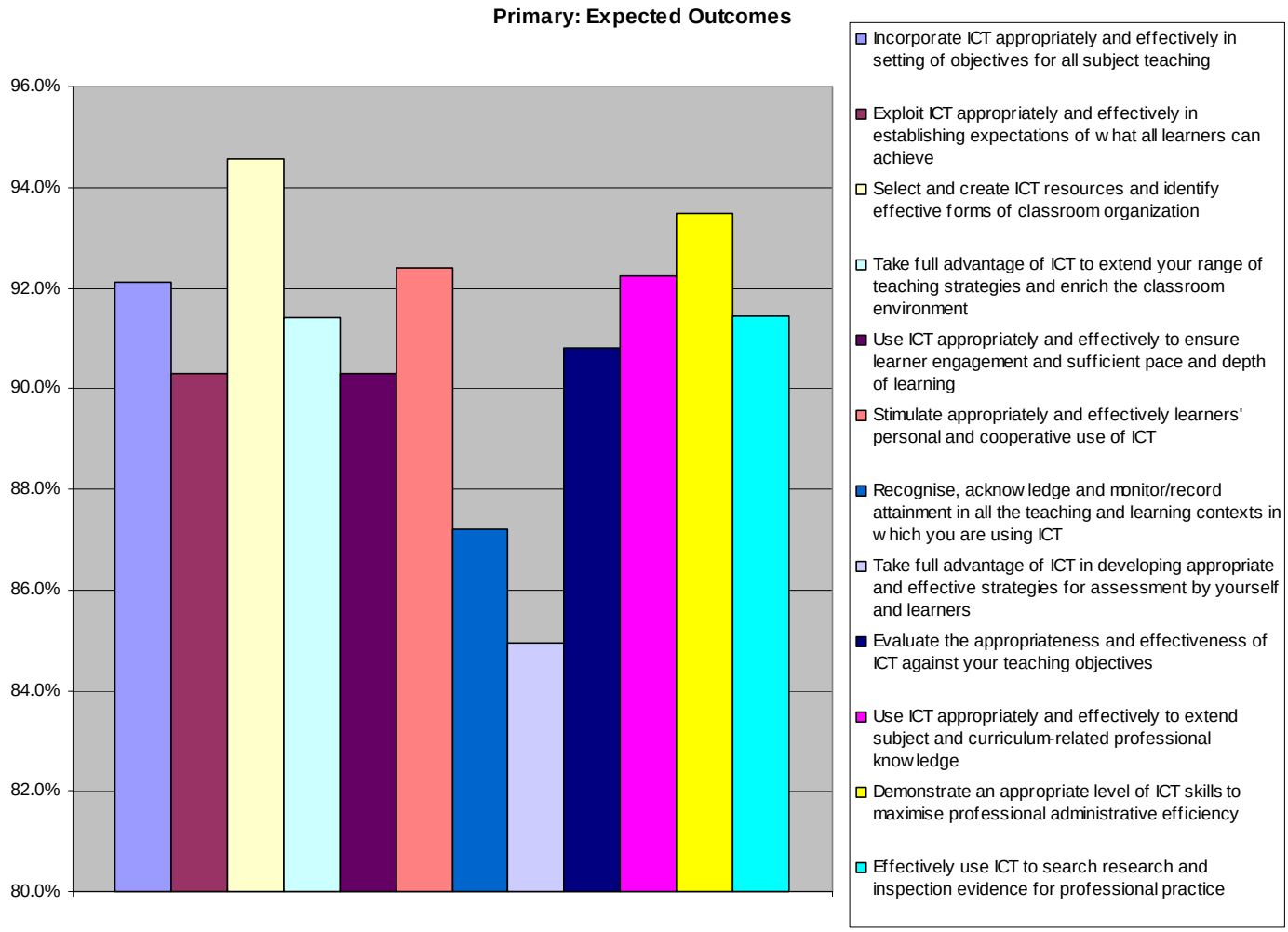

Figure 2: the achievement of expected outcomes of ICT training by secondary school teachers

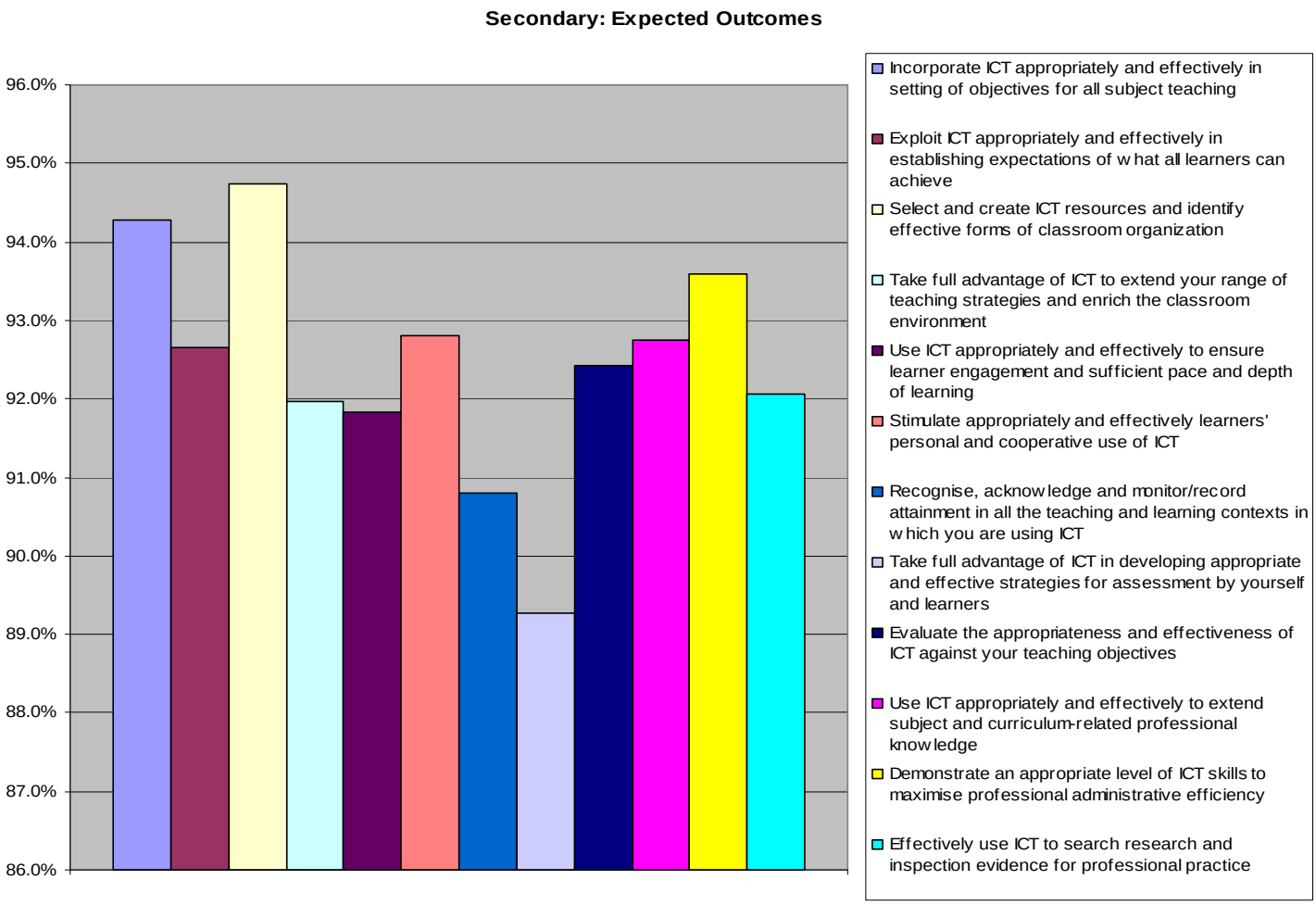

Figure 3: students working on a pen design, showing the video link in small windows on screen.

[1] This took place in the four nations of the UK, and for England see: http://www.mirandanet.ac.uk/tta/index.htm (All the web sites quoted in this article were checked in April 2004.)

[2] This search, conducted in April 2004, also brought up a number of articles that were evaluations of computer-based teaching. There were also six publications that dealt with education in general (e.g. conference proceedings) and these have been excluded. Interestingly, not all the articles in the special issue of *Assessment in Education* (Vol. 10, No. 3, 2003) on 'assessment for the digital age' were picked up by this search. So the number of school-level articles is actually slightly higher than six.

[3] My discussion reflects some of the argument of Pellegrino (2001), though I take a more cautious view than he does. He was of course considering the issues at a policy level, and so examines more general trends and implications. See also National Research Council (2002).

[4] McFarlane (2003), in the editorial for the journal issue on *assessment for the digital age*, used three themes: the use of computer-based assessment tools; the use of computer-based technologies to assess aspects that conventional (test) media find difficult or cannot assess; assessing the outcomes of computer-based technologies in learning. These cover the same set as derived from McFarlane (2001) and Thelwall (2000).

[5] As noted earlier, this is the focus of much current debate about ICT, and in the UK this has been fuelled by the publication of major studies ImpaCT2 (Harrison *et al*, 2002) and Pathfinders (Somekh *et al*, 2002). For a review of this attainment literature see Cox *et al* (2003).

[6] There is now a project to determine the feasibility and utility of conducting NAEP tests via the internet. At a state level Russel *et al* (2003) report on studies of the benefits and costs associated with using computer-based tests in place of conventional means.

[7] http://www.edexcel.org.uk/qualifications/QualificationQA.aspx?id=82075

[8] This is part of the Paperless Examination Project http://www.rewardinglearning.com/development/new/press/2004/press_010604.html and http://www.ccea.org.uk/ (see 'Teachers: Qualifications' section).

[9] PASS-IT can be found on http://www.pass-it.org.uk and general SQA computer-assisted assessment initiatives are on http://www.sqa.org.uk/ (see Research & Development section).

[10] For a theoretical basis for the latter see O'Neil, Chuang & Chung (2003).

[11] The QCA conference has a temporary web site: http://www.livegroup.co.uk/qca/index2.php but this will only be available until mid-2004. The home page for QCA is: http://www.qca.org.uk/index.html There is also an annual conference in this area: 'The e-Assessment Question Using ICT to measure skills, understanding and knowledge' http://www.e-assessment-question.co.uk/.

[12] The National Foundation for Educational Research in the UK has helpfully done this: http://www.nfer.ac.uk/research/cba.asp . This review contains both positive and cautious views of the future developments in this area.

[13] http://www.ucles-red.cam.ac.uk. In a more recent article from this unit, Raikes & Harding (2003) review the issues of computerising conventional public examinations, and look forward to the possibility of more detailed feedback to the student.

[14] http://www.ets.org/research/index.html (follow the Assessment & Technology link).

[15] The pace of development is likely to faster in higher education as assessment systems already exist (e.g. see Edwards *et al*, 2002; Frosini, Lazzerini and Marcelloni, 1998; Gardner, Sheriden and White, 2002; Ricketts and Wilks, 2002; Thelwall, 2000). In addition, software exists to carry out automated essay scoring that gives levels of reliability when compared to a human marker of the same order as exists between human markers (Foltz, Laham and Laundauer, 1999); given the relatively low level of conceptual complexity and the shorter length of school essays compared with those in higher education (and the much higher numbers), it is surprising that they are not more common at school level. Drew *et al* (2002), giving guidelines for the computerised assessments of key skills like writing, note that essay-marking tools cope well with about 500-word essays. See also Landauer *et al* (2003). Nevertheless there are advocates (Patelis, 2000), with some saying that education authorities need to start planning

now for the introduction of computer-based systems (e.g. Pellegrino, 2001; Rabinowitz and Brandt, 2001).

[16] In the UK the organisation responsible to support schools and ICT devotes almost all its advice on assessment to this aspect (http://www.becta.org.uk/leaders/).

[17] http://www.ets.org/discourse/.

[18] The *ERIC Practitioner File* on 'Assessing Learners Online', noted earlier, takes distance learning in higher and adult education as the context for its advice.

[19] A review of dynamic assessment by Elliott (2003) argues that there needs to be a shift from the traditional tool of educational psychologists, for example to classify individuals, to one where they and teachers can devise classroom-based educational interventions. The focus of the review is on those with special educational needs.

[20] This work is part of a range of studies from the National Centre for Research on Evaluation, Standards and Student Testing (CRESST): http://www.cresst.org/products/reports_set.htm.

[21] They don't even use the updated and revisited versions of the taxonomy (Anderson and Sosniak, 1994; Anderson and Krathwohl, 2000).

[22] It is important to realise that there is considerable controversy about these perspectives, with some seeing them as competing theories, and others as complementary (see McCormick, 2001). The latter is the view taken here.

[23] There is no implication that all students are trying to be mathematicians, rather that learning mathematics is to learn to participate in the community. That participation will be for most only partial, and in the school context, will actually be the participation in the school mathematics community.

[24] This is part of the agenda of the *Learning How to Learn in classrooms, schools and networks* Project of the UK Economic and Social Research Council's Teaching and Learning Research Programme: http://www.learntolearn.ac.uk/. It involves the Universities of Cambridge and Reading, King's College London, and the Open University.

[25] This can be further seen by the fact that there is a parallel report on thinking skills (Wegerif, 2002) from the same source as the Loveless (2002) review. This source can be found at: http://www.nestafuturelab.org/research/lit_reviews.htm

[26] They made a series of other findings, which, because of the nature of the evidence in the studies, are stated more cautiously.

[27] This does not imply that those who hold these different views all see collaboration in the same way.

[28] Joiner *et al* (2000) give important accounts of the socio-cultural approach, where collaboration is seen as situated.

[29] See Wegerif & Scrimshaw (1997) for research on shared thinking around text.

[30] Seitamaa-Hakkarainen *et al* (2001) use a different theoretical base to arrive at similar ideas. However, they use the term 'co-ordination' where I have used 'co-operation' and 'co-operation' and 'communication' where I have used 'collaboration'. The focus in their analysis is on knowledge construction.

[31] The data are taken from a video of both students' interaction with each other and their computers, and interviews of their teachers.

[32] Elsewhere I have elaborated the thinking behind this example and how it can be developed as a collaborative activity (McCormick, 2004).