A CONSTRUCTIVIST APPROACH TO EDUCATIONAL COMPUTING

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There is a considerable gap between rhetoric about educational computing and classroom reality. This paper offers a brief review of some of the recently fashionable theories in education, and applies them to teachers’ — rather than pupils’ — learning. This analysis shows not only how these theories account for the bad practices which are usually associated with educational uses of IT, but also why traditional educational theory is almost useless to teachers concerned with classroom learning in general, and IT in particular. It sketches some ideas for teacher development which are grounded in constructivist theories, set in a broader context of educational change, and based upon our ongoing work supporting technology across the curriculum. It concludes with some aphorisms for progress in IT in education.

COMPUTERS IN EDUCATION: PROMISES, FAILURES, GOALS
It is common for educational innovations to be associated with grand claims about their potential benefits, usually supported by some evidence gained from small-scale studies conducted under almost ideal circumstances, such as teaching by enthusiastic experts who have generous resources. It is no exception; early claims were quite outrageous (e.g. Papert, 1980) and have not been substantiated by subsequent research. Nevertheless, there is a considerable body of opinion that believes in the real contribution which IT might make to education, tempered with an awareness of the barriers to educational change which exist, and the likely slow rate of progress. This paper is dedicated to action-oriented pioneers who do not underestimate the problems they face. A major thrust of the paper will be to defend the proposition that learning is a constructive process which is socially mediated, and that teaching involves the transmission of culture and value systems. It follows that we should begin by sketching some of our beliefs about the potential educational value of IT.

INTENDED INTELLECTUAL BENEFITS
It is possible to list some benefits which can be associated with the use of IT, in some circumstances. None is guaranteed to flow from IT use; many can be achieved without it. It is hoped that there will be student access to learning resources and sources of information which do not depend upon the teacher; an increase in the variety of styles of teaching and learning; greater metacognitive awareness in students; more student planning of and implementation of their own work programmes; greater student IT capability, for example accessing information, communication (such as data presentation, persuading and reaching agreement); and skills such as self-monitoring, generalising, theorising and verifying concepts.

A number of commentators have offered the view that the experiences which pupils are offered in schools conform to the school culture, and not to the intellectual tradition they purport to teach about. So pupils learn how to perform a set of mathematical procedures, not how to function like mathematicians (Schoenfeld, 1985), or learn scientific ‘facts’, not how to function like scientists (Edwards & Mercer, 1985). IT offers the chance for pupils to learn how to be mathematicians and scientists, as well as about the products of these disciplines.

THE REAL USE FOR IT IN EDUCATION IS...
One might draw an analogy between the introduction of the computer and early motor cars. Each of these opened up new social worlds in which to function, and require the development of appropriate skills. Many of the social changes now associated with the car were impossible to foresee, such as sexual emancipation, huge employment opportunities, and environmental damage. Major educational and social changes are also likely to be a consequence of the increased use of computers in schools. We should accept that we don’t know what the ‘real’ uses for IT in education will be, and should adopt a style of research which allows us to capitalise upon its as yet undetermined potential in an opportunistic fashion (e.g. Ridgway et al, 1984).

EVIDENCE OF OUR CURRENT FAILURES
IT has been around in school systems for over a decade, and IT use is now widespread. The latest survey by the Department of Education and Science (DES) shows for England and Wales an average computer: pupil ratio in primary schools of 1:40, and an average ratio of 1:18 in secondary schools (POST, 1991). Schools in England and Wales are required to use IT in every subject for which statutory guidance has been published (for example, Statutory Orders for Mathematics, 1989).

An unpublished survey of 26 secondary schools in one Local Education Authority indicated that there were no schools where IT was used in every subject of the curriculum, using the weak criterion of ‘any use of IT in a subject’. IT was only used in Art departments in 50% of the schools; IT use in Music, Modern Language and Physical Education departments was rarer still. The dominant use was in English, Mathematics, Science and Technology. Even here the picture is rather poor, with IT use occurring rarely in lessons, and only by one or a small number of teachers in a department. Over one-third of the IT coordinators in the schools were given no time at all to support colleagues in the school, and...
where time was allocated, this amounted on average to only one or two hours each week. Many IT coordinators and specialists are regarded as being over-concerned with technical matters by their colleagues. IT is often considered as an educational gimmick.

The picture of total use is gloomy; more worrying is the way that IT is used in class. Any survey of software catalogues from the USA shows a marked dominance of drill and practice programmes. A DES Statistical Bulletin indicates that only 33% of teachers of English in secondary schools felt confident in the use of IT with children (POST, 1991). In the UK, the predominant use of computers in classrooms is for word processing. Survey data from Her Majesty's Inspectorate (HMI) shows that in 9 out of 10 instances of using word processing the pupils were simply making a good copy of work prepared earlier. Compare this with the high-flown aspirations set out in Scardamalia, Bereiter and Steinbach (1984) which includes a consideration of the writing process, discussions of structure in compositions, and the development of reflective processes. Dunn and Ridgway (1991a) report a dominant use by student teachers of short mathematics programs irrelevant to the ongoing lesson, used by pairs of pupils.

A focus on 'Information Technology' is symptomatic of our current educational malaise. The phrase is fine as a shorthand for 'educational activities which can derive from the use of computers', but is too often taken to refer to a narrow set of activities such as the use of programmed learning, or learning about spreadsheets and databases for their own sake. Essentially, the directionality is wrong. We have a technology of considerable but undetermined power; instead of an open-ended exploration of its power, we accept a narrow set of definitions of IT, of education, of classroom practice, of student success, and thereby remain ignorant of what might be achieved. In part, this is an aspect of the human condition. We see the world through our existing constructs and find it hard to look beyond them. Other revolutionary technologies suffered in the same way in their early days, e.g. the motor car, electricity, and metal-built ships.

**REVIEW**

It is clear that a huge gap exists between our aspirations and classroom reality. Desirable educational events that can occur in some classrooms are extremely rare in classrooms in general. We have a long list of exciting 'existence proofs' related to IT, and little evidence of generalisability across classrooms.

Indeed, those IT activities which are regularly observed in class seem to be a waste of teaching time.

Nevertheless, the pace of educational change is notoriously slow, and we should establish ambitions for IT based upon the evidence of good practice we have to hand. Our personal ambitions for a pupils' IT charter can be summarised as follows:

- IT embedded seamlessly into all areas of the curriculum; coherent experiences with IT for pupils across their school careers; pupil empowerment through, for example, fluent use of word processing, modelling packages, spreadsheets, databases and other information sources; development of pupil self-awareness as learners and teachers; and taking pupils beyond what we now believe to be possible in education.

The next section will argue that many current educational theories actually explain this gap between rhetoric and reality, and predict that it will persist unless radical changes take place in our approaches to educational innovation.

**HOW DO THEORIES OF TEACHING AND LEARNING RELATE TO TEACHER DEVELOPMENT?**

The task as commonly defined in education is to enact the transfer of knowledge from experts to novices, in domains where the content is agreed, a value system is accepted (although implicitly), and where the context of learning is well understood. None of these prerequisites applies to IT in education. Teachers are rarely experts (actually, no one is). IT can be about fact and skill learning, but can also be about learning about quite different sorts of things (such as data handling and manipulation, or modelling), and different sorts of values (by setting realistic questions about say alcohol abuse, the arms race, or AIDS), in situations where children take more control over the learning, or where teachers shift the balance of their classroom activities. IT offers challenges to traditional views of teaching and learning, and will probably stimulate new theories of learning to account for its effects.

A major barrier to the effective use of IT in education is the lack of teacher knowledge. Teacher learning is likely to be at least as complex as knowledge acquisition by pupils, and so this section offers a brief aide-mémoire of current thinking about the nature of teaching and learning. It will become clear that current learning theories predict that unless teacher education is radically reconceptualised, the gap between educational ambition and educational reality will be widened, and the educational potential of IT will be rendered sterile.

A range of non-cognitive influences are important in learning, such as enthusiasm, persistence, feeling of self-worth, empowerment, a sense of personal direction, and the like (e.g. Covington, 1986; Howe, 1990; or Rogers, 1969). These are acknowledged here, then ignored throughout the paper, which focuses exclusively on cognitive development.

**LEARNING IN CONTEXT**

Glasser (1984) has argued against the belief that cognitive skills are separate from knowledge, and shows how performance on a range of cognitive tasks is influenced by the knowledge which individuals possess, and by the
way that knowledge is structured. Perkins and Salomon (1989) also addressed the concept of context independent learning, and conclude that it is not a useful notion, as do Chi and Ceci (1987) in an extensive survey.

A good deal of computer-based instructional material has been developed, such as tutorial CAL, and Intelligent Computer Aided Instruction (ICAI). These materials implicitly take a view that knowledge exists in some absolute sense, that the structures imposed upon the world by current academic frameworks are 'correct'; that knowledge is 'acquired' by individuals, who accept the structures in which it is presented; that the end point is acceptance of some abstract intellectual structure which will be similar across learners, no matter what the original context of learning, and which can be applied to a range of domains. This view conflicts with evidence from cognitive psychology—the associated pedagogic problems are discussed elsewhere (Ridgway, 1988).

PIAGET AND THE POST PIAGETIANS
The main thrust of Piaget's work has been to map out distinct stages of development, and to describe the ways in which the child constructs a view of the world which either accommodates existing cognitive structures so that they fit with new knowledge, or assimilates incoming information so that it fits existing structures. The view is strongly individualistic and constructivist; the impact of his theorising upon educational practices is best exemplified by individuals engaged in discovery learning. The wealth of writing by Piaget allows one to point to references to the significance of collaborative work (including the stimulation of cognitive conflict), and the importance of cultural contexts. Neither of these themes seemed to punctuate his research.

Others have taken up the challenge of exploring ways in which intellectual development can be stimulated by peers. Light and Blaye (1990) have studied peer tutoring situations, in which one partner takes on the role of teacher, and imparts knowledge to the other, and peer collaboration, where pupils are set the task of solving problems jointly. Both situations can produce cognitive gains. Doise and Mugny (1984) have studied cognitive conflict induced between pairs or within groups, and demonstrate that conflict can be a major source for cognitive development.

VYGOTSKY
Vygotsky (1978) has argued that learning and cognitive development result from a process which is essentially social rather than individually based. The nature of education is to share meanings and interpretations of what happens in the world by an elaborate communication process. Essentially, the skilful teacher provides tasks which lie within the learner's zone of 'proximal development' and provides enough support to allow the learner to succeed. As a result of assistance received on tasks which lie within the zone of proximal development, the child learns to internalise the processes offered by the teacher that the nature of what is learned, and the cognitive development which results, will be determined by the environment in which learning takes place.

The thrust of Vygotsky's work has been to emphasise the importance of research in naturalistic settings, such as teaching situations, and the analysis of the transactions which take place, and to stimulate renewed interest in the relationship between language and thinking. Vygotsky also talks about the zone of proximal development in interactions between a child and more able peers.

Vygotsky's approach has been contrasted both with approaches in cognitive science (e.g. by Edwards, 1990) and with Piagetian theory (e.g. by Smith, 1989). Piaget is seen to offer a 'biological' view of development, and Vygotsky a 'social' view. One might view a Vygotskian perspective as one where the learner is lead towards some view of reality held by the tutor, whilst the neo-Piagetian view is of learners who work together to negotiate a joint view.

VYGOTSKY'S FELLOW TRAVELLERS
A number of influential writers in the West have been directly influenced by Vygotsky's approach. For example, Wood, Bruner and Ross (1976) describe the sort of help which teachers provide to learners as 'scaffolding' (see also Wood, 1988), because once the initial support has done its job, it becomes unnecessary. Vygotsky's work has been further extended by research on discourse and learning by Edwards and Mercer (1987), who describe the evolution of 'common knowledge' in classrooms.

In the USA, Brown, Collins and Duguid (1989) have proposed the notion of 'cognitive apprenticeship', where the learner is likened to a craft apprentice. Cognitive apprenticeship has these characteristics: it is activity based; it is context dependent; it involves membership of a community, and so is encultured, not independent of social context. Learners see the process aspects of work, not just the product. Learning is highly directed at the outset, then control passes to the learner as learning progresses. All of these notions derive from Vygotsky. Examples of cognitive apprenticeship can be found in medicine, business, law, and graduate studies. Cognitive apprenticeship offers an attractive model for teacher development because of the need to learn facts, techniques, process skills, tactical and strategic aspects of education. It is interesting to note how few of the elements of apprenticeship are actually present in teacher education, either initially, or in professional development.

Scaffolding by an expert is not essential for learning. In peer interactions, adoption of different roles, and discussion about problem solving strategies, can all emerge from group work and can be internalised by participants.

REVIEW
All of these approaches share a view that knowledge is socially constructed, and all are consistent with general constructivist views (e.g. from Neisser, 1976 & Berger and Luckmann, 1967) who argued that humans interpret the world around them and build theories (albeit implicitly) about all aspects of their lives. At any time, these implicit theories shape the way the world is viewed and the way events are interpreted. Constructs about events or people can be changed by evidence, discussion, reflection or direct teaching, and it is almost certain that no two people will see the world identically. Failure to take account of current constructions, and the ways they might
be modified, is likely to lead to a failure to modify these constructions at all.

IMPULSATIONS FOR TEACHER EDUCATION
Constructivist views of the nature of learning predict that it will be extremely difficult to capitalise on the potential of the computer as a teaching resource, and that a major source of difficulty will be the teacher. The problems are as follows:

- studies of children's misconceptions in science show the variety of views that are held and emphasise the problems of conceptual change (e.g. Driver, 1989). These problems will be particularly marked when the topic is teacher beliefs about appropriate classroom processes. If one accepts the view that actions derive from constructions about the world, then one faces the challenge that the majority of teachers do not have constructions which are well suited to appropriate educational uses of computers;
- because teachers bring existing constructs about the nature of teaching and learning to bear when they introduce IT, they can: treat IT as if it were new content to be learned (keyboarding; use of wordprocessors or spreadsheets); or use IT to do things that they already do competently (deliver factual information; testing). These activities fail to tap the potential of IT, yet satisfy external pressures to use new technologies;
- education is predicted on the assumption that there are wise persons who 'know' and who transmit knowledge to others. This makes the system resistant to change, because teachers must step outside their traditional roles of expert, to become learners;
- changes require a shift of world view, a period of teaching which will certainly be less effective than the old style, and the gains are uncertain. Teachers may well be loath to pay such a price for uncertain rewards;
- 'satisficing' (Simon, 1957) provides inbuilt stasis. If one is already doing a competent job teaching, why should one choose to do things differently?
- if one adopts a view that learning should be a cognitive apprenticeship, the immediate problem arises that there are far too few gurus to go around;
- the practice of teacher education rarely conforms to the principles of apprenticeship, since the learning is decontextualised; teaching is not performed then analysed, and there is little scope for relevant incidental learning;
- student-teachers going into schools rarely encounter models of practice which they can base their own practice upon (Dunn & Ridgway, 1991a, 1991b);
- we are profoundly ignorant about the possible contributions that IT might make to education, and so need active exploration, discussion, and the development of new concepts. Teaching rarely provides scope for opportunities which allow cognitive conflict, tutoring, or the evolution of 'common knowledge' amongst peers.

CAN STYLES OF EDUCATIONAL RESEARCH EMERGE APPROPRIATE TO THE NEEDS OF IT?
A major problem for educational change is the heterogeneous nature of the community concerned with education — most notably the split between teachers and researchers (Ridgway & Passsey, 1991c). Educational theory is grounded outside schools. This has a number of symptoms and effects:

- the intended outcomes are statements about the nature of human learning, and human development in general. These are useful for explanation and to provide general guidance, but are only marginally useful for curriculum development, planning classroom activities, or analysing the micro-structure of particular intellectual transactions;
- the audience for the messages is usually the research community itself — theory is constructed for its creators, evaluators and modellers. It is built to satisfy the rules of an academic game, whose players rarely include practising teachers. It has none of the hallmarks of scaffolding, or cognitive apprenticeship; it is exclusively about the development of common knowledge amongst educational researchers;
- the reward systems for researchers are concerned with fame amongst other academic researchers, not with effective desirable changes in the education which pupils receive. To be a famous educational researcher means to be well known around the universities, not around the classrooms;
- the evidence base is commonly small balanced samples of children working on small-scale tasks, of an academic nature. The extent to which these results can be generalised to classroom practice is quite uncertain;
- theory is overly cognitive — it ignores organisational problems which can be crucial to innovation.

The Supporting Technology Across the Curriculum (STAC) Project has adopted a systems approach to change (Checkland, 1981). Essentially, the education system is viewed as a set of interconnected actors such as pupils, teacher educators, researchers, and the State. Each affects and is affected by the others. Each actor operates within his or her own set of constraints and rewards; each has his or her own ambitions. For educational change to come about, the constraints on each actor need to be reduced, and the rewards increased. Changing the behaviour of just one set of actors is likely to induce pressures for stasis from others. Consequently, we have worked with different groups of actors to produce materials which help their development of IT, with a view to moving the whole educational system. We are not funded to develop curriculum materials, and consequently the bulk of our work has aimed to support senior staff in schools, school IT coordinators, advisory teachers, teacher trainers and INSET providers.

We aim to:
produce materials which are customised for a variety of specific applications; help develop a culture of action research amongst practitioners; communicate directly with educators; consider all problems that emerge not just ones we want to tackle; work from a broad and robust evidence base and monitor long-term change.

A brief summary of some of our work follows.

SUPPORTING TECHNOLOGY ACROSS THE CURRICULUM
Defining the new game
It is hard to know the potential of a new medium unless someone provides a rating point. The National Curriculum in the UK embeds IT in each subject. This is most welcome, but can
lead to a piecemeal approach to IT. The STAC Maps (STAC, 1990a) provide a comprehensive picture of pupil entitlement at each stage in every subject, analysed in terms of IT themes. The National Curriculum has also specified longer-term aims for IT by setting out the statutory entitlement that pupils have to IT. This entitlement is called IT Capability and embodies a view that IT applications should be available and appropriately used by all pupils in circumstances where it is felt desirable or useful. Teachers need to recognise this new imperative in the use and ambition for IT in education. These are set out clearly in STAC documents (e.g. Passey & Ridgway, 1991d).

Addressing organisational problems

Curriculum planning, coherence of pupil experience, and access to resources are but three of the challenges which schools face. If school development plans do not establish IT as a major theme, IT will remain a marginal activity for most teachers. We have produced documents to support a whole school approach to IT (Passey & Ridgway, 1991d) aimed at senior staff in school, and courses for school IT coordinators (e.g. STAC, 1990b).

Conceptual change in teachers

Teachers need to take on board new concepts routinely, and to accept innovation as a fact of life in education. They also need time to review and update classroom practices. Some approaches to teacher development are set out below.

The teacher as apprentice

A model which has been explored in the UK is the appointment of peri-patetic advisory teachers (ATS) who are recruited on the basis that they display good classroom skills (sometimes using IT), and who work with other teachers in class. The organisation of the working practices of ATS is determined on a local basis, and has been very varied (Ridgway & Shone, 1990). Such evidence on their effectiveness as we have collected is positive (Ridgway, Passey & Apter, 1991). The model of AT support in class is consistent with Vygotsky, and with the notion of cognitive apprenticeship produced by Brown and his co-workers. It suffers the practical problem about the length of time needed for the tutoring process, and that tutorial support can sometimes be divorced from other sorts of support, such as access to hardware, and coherent curriculum planning within schools. We have produced resources to support ATSs in their work (e.g. Passey & Ridgway, 1991c).

Advisory Lecturers have been proposed for initial teacher training institutions (Coulter, 1991) adopting a model which ignores the problems encountered in schools.

The uses of inservice education

Inservice education (INSET) is problematic. We have conducted a range of case studies of INSET in action (Passey & Ridgway, 1991a) on which to base some guidelines for both schools and INSET providers (Ridgway & Passey, 1991a; Passey & Ridgway, 1991b). A common theme which emerged related to the need to reconceptualise the nature of IT in education via a process of negotiation, to build in opportunities to act, and to reflect on that action with a mentor, and the need to mobilise school resources so that teachers have access to computer resources by right, as part of their professional development associated with a course.

On the nature of teacher training

Initial training is not based on cognitive apprenticeship, where a novice practises simple tasks under expert guidance. It is very rare for students to observe their tutors in expert mode in front of a class of children, and then to question them afterwards about the way the task was performed, and its outcomes. Instruction follows the school model where decontextualised knowledge is transmitted in ways that the tutor hopes will not be imitated by the students in their own classrooms. Our surveys of the IT experiences of students on teaching practice have been somewhat disappointing (e.g. Dunn & Ridgway, 1991a & 1991b).

Teacher support groups

Education is a social activity. Teachers involved in INSET often comment that the best aspects of the INSET have been opportunities to talk to colleagues, and to exchange ideas and notions. The value of this social interaction must be accepted, and opportunity for this to happen needs to be built into the system of review and updating. One mechanism is for teachers in schools within a local area to form a teacher support group. These have been used successfully, and their need has been recognised by some teachers, for example, Branfoot (1991).

Learning from students

To our knowledge, no work has been done to study the possibilities of teachers learning from pupils about the educational possibilities afforded by computers. Primary schoolteachers report anecdotally that they have learned about computer use from the work done by pupils. Some schools in the UK employ pupils in technical roles, setting up machines and software for teachers, but the prospect of teachers setting up educational environments in such a way that they learn from the activities of pupils seems remote.

Ridgway (1988) argued that one of the few sensible educational uses of Intelligent Tutoring Systems is to ask students to study them as objects, and to pose questions about the way that knowledge is represented, the ways that the user is modelled, the sorts of help offered to users, and its appropriateness. This idea can be extended to authoring systems tailored to stacks, relational databases, spreadsheets, multimedia, and the like. The teacher would ask students to use such tools to create learning situations which would be of value to pupils who are, say, five years younger. One purpose of the exercise is to provide the basis for metacognitive development, and pupil theorising (albeit implicitly) about the nature of teaching and learning. The hidden curriculum is to face teachers with these issues in a form radical — namely one in which they must respond with real opinions to the work of committed children. There are considerable practical problems with this approach.

Classroom observation studies

The model of teacher as action researcher makes good use of constructivist principles. Teachers should be encouraged to explore the potential of IT in systematic ways. The lone teacher working in class has considerable disadvantages, such as the simple problem of information overload. It is hard to teach and observe at the same time. A second problem relates to the individual nature of the knowledge which results. It can remain untapped; the teacher can easily become fatigued by the research process; the individual can easily run out of ideas to try. An approach which can overcome these problems is to use team teaching, but with a strong action research flavour.

Systematic data collection can replace the impressionistic views often formed, and subsequent analysis and discussion can serve the functions of mutual scaffolding, and negotiation over phenomena and meanings that one might expect from membership of an emerging intellectual community.

Aphorisms for progress in IT in education

This section has sketched our research activities to date. Here we identify some guiding principles for teacher development and the use of IT in education:

- conceptions of the use of IT should include the notion of IT capacity
which pupils, students and teachers can acquire and use appropriately in many environments;

- IT should become an accepted part of the social environment of the classroom;
- conceptions of education should include the notion of rolling innovation;
- teaching apprenticeship should become an integral part of every teaching career;
- a review of teaching should be a part of recognised practice, associated with observation of teaching of and by colleagues;
- a practitioner-based approach to innovation is needed, characterised by willingness to trial, opportunity to fail, and mechanisms to develop 'common knowledge' with peers.

CONCLUSIONS
Despite an exciting research literature, those educational uses of IT most commonly observed are dull. A constructivist account of learning explains the gap between ambition and actuality, and highlights the sorts of provision that needs a greater contribution from teachers, and a greater focus on issues directly related to classroom practices.

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