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Analysing the use of interactive technology to implement interactive teaching

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Abstract

Recent policy initiatives in England have focused on promoting 'interactive' teaching in schools, with a clear expectation that this will lead to improvements in learning. This expectation is based on the perceived success of such approaches in other parts of the world. At the same time, there has been a large investment in Information and Communication Technology (ICT) resources, and particularly in interactive whiteboard technology. This paper explores the idea of interactive teaching in relation to the interactive technology which might be used to support it. It explains the development of a framework for the detailed analysis of teaching and learning in activity settings which is designed to represent the features and relationships involved in interactivity. When applied to a case study of interactive teaching during a lesson involving a variety of technology-based activities, the framework reveals a confusion of purpose in students' use of an ICT resource that limits the potential for learning when students are working independently. Discussion of relationships between technical and pedagogical interactivity points a way forward concerning greater focus on learning goals during activity in order to enable learners to be more autonomous in exploiting ICT's affordances, and the conclusion identifies the variables and issues which need to be considered in future research which will illuminate this path.

Keywords activity, affordance, case study, constraint, interactive, pedagogy.

Introduction

The introduction of ICT resources to schools is one of the most significant developments in the UK during the last 20 or so years; yet it seems to have had relatively little effect on the ways that teachers teach (Watson 2001). Indeed, there is an apparent mismatch between the National Strategies for England (DfEE 1998b, 1999, 2001), which are designed to raise standards in basic skills of literacy and numeracy through an emphasis on whole-class teaching, and the expectation that Information and Communication Technology (ICT) has the most benefits for learners when they are working more autonomously (Somekh & Davies 1991). Furthermore, there is considerable evidence concerning the extent of student learning with ICT through study and leisure activities in the home (Harrison *et al*. 2002; Facer *et al*. 2003); yet this independent approach to learning has not been a feature of recent government programmes for schools in the UK. Consequently, the National Strategy literature makes little reference to ICT and the ICT literature makes little reference to the teaching approaches promoted by the National Strategies.

It is of interest, therefore, to consider the effects of particular technologies which seem to be more closely aligned with a teacher-centred pedagogy, such as interactive whiteboards (IWBs). This technology, together with related resources, allows the user to prepare material in advance or construct it in front of a class, quickly retrieve it for display to the whole class when required, and manipulate items directly on the display in a way that corresponds to what can be achieved with an

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individual PC. IWBs have become very widespread in school classrooms in England & Wales. In 2005, a national survey in England found that nearly half of primary teachers (49%) had use of dedicated IWBs; in secondary schools, 77% of math teachers, 67% of science teachers and 49% of English teachers said they had dedicated IWBs (Becta 2005). While such large-scale adoption is very much a UK phenomenon, there is increasing interest in the potential of this technology worldwide (Bell 2002; Kent 2004; Hodge & Anderson 2007)

A review of the limited research literature currently available (Smith *et al*. 2005) identifies the following reasons given by teachers for the adoption of IWBs:

- flexibility and versatility;
- multimedia/multisensory presentation;
- saving and printing work;
- efficiency;
- planning and saving lessons;
- teaching ICT;
- interactivity and participation.

Many of these points do not require direct interaction with a board, however, and are equally valid for any large projected image of the computer screen. The last point is the only purpose for which IWB technology clearly offers special features. However, in the context of IWB use, the term 'interactive' is used to describe both the technical interactivity of the board as an interface between the user and the computer, and pedagogical interactivity as a teaching strategy (Smith *et al*. 2005). It is the interactivity of teaching, and its association with participation by learners, that seems to us to be the essential framing idea when investigating the impact of the IWB.

This paper will therefore focus on the idea of interactivity and how its role in teaching and learning can be analysed in a way which illuminates the influence of ICT in general, and the distinctive contribution made by IWBs. We adopt a holistic perspective in which teaching is taken to mean 'teaching-and-learning' (Mercer 1992), and refers to the whole range of activities by teachers and learners which are designed to bring about learning. Our framework for analysis provides sufficient generality to deal with whole-class teaching, group work and individual activity, and sufficient sensitivity to characterize the differences in the process and outcomes of learning when ICT assumes various roles in the interactions involved. This framework is used to characterize interactivity in a way which embraces and clarifies the use of the term in both pedagogical and technical discourse. We conclude by looking forward to the improvements in understanding of ICT's impact on learning that this sort of analysis can provide.

While the issues which have stimulated the writing of this paper arise from the curriculum and pedagogical cultures in England and Wales, our analysis develops ideas which are general in scope and which will have value in the embedding of ICT into any educational system and culture.

The nature of interactivity in teaching

In England, the National Literacy Strategy (DfEE 1998b) and parallel National Numeracy Strategy (DfEE 1999) advocate direct, interactive teaching as one of the factors contributing to success, along with discussion, pace, confidence and ambition. They characterize teaching as interactive when 'students' contributions are encouraged, expected and extended' (DfEE 1998b, p. 8). This would seem to imply a deeper participation by students with a far higher degree of autonomy than found in the traditional, triadic recitation script of initiation-response-feedback (IRF). However, several studies have reported the dominance of teacher talk, the persistence of IRF as the principal form of discourse, the brevity of student responses and the lack of sustained interaction with individuals (Galton *et al*. 1999; Mroz *et al*. 2000; Hargreaves *et al*. 2003; Myhill 2006; Smith *et al*. 2006).

From the list of characteristics promoted by the National Strategies, teachers seem to have emphasized pace at the expense of discussion and extended responses. The emphasis on pace means that the more questions teachers ask, the less children say (Burns & Myhill 2004). This may indicate a reduction in productive thinking as a result of continued low-level questioning. Even with the inclusion of higher-order questioning, it is debatable whether the continuation of questioning for a high proportion of time is effective in developing learners' higher-order skills, as the principles of 'scaffolding' require the structure provided by the teachers' questions to be withdrawn as the learners develop their own skills.

Table 1. Levels of interactivity in whole-class teaching (based on Tanner *et al*. 2005).

Teaching strategy	Nature of the interactivity	
0. Lecture	Internal mental activity (intra-activity) only	High teacher control
1. Low-level (funnelling) questioning	Rigid scaffolding and surface interactivity	↓
2. Probing questioning	Looser scaffolding and deeper interactivity	
3. Uptake questioning or focusing dialogue	Dynamic scaffolding and deep interactivity	
4. Collective reflection	Reflective scaffolding and full participation	High learner control

It is not surprising, then, that despite the effective imposition of particular teaching strategies, teachers vary in their interpretation of interactive teaching (Moyles *et al*. 2003). Hargreaves *et al*. (2003) derive nine different types of interactive teaching from teachers' descriptions of how they interpret interactive teaching, divided into 'surface' and 'deep' forms. Surface forms had the purposes of engaging students, student practical and active involvement, broad student participation, collaborative activity, and conveying knowledge. Examples included student use of mini-whiteboards to show their answers to questions and inviting children out to the board. The deep forms had the purposes of assessing and extending knowledge, reciprocity and meaning making, attention to thinking and learning skills, attention to students' social and emotional needs and skills. These were less well developed in practice. Furthermore, exploration of interactions concerning task organization revealed a massive shift from questioning to telling students about tasks, which indicates a major reduction in learner participation (Hargreaves *et al*. 2003; Myhill 2006). This is not the development envisaged by Reynolds and Farrell (1996), which is based on a perception of the teaching methods which lead to success in other nations. Although the form of organization can be copied, it seems that the discourse depends on different cultural values (Alexander 1996); perhaps it is less the model of classroom organization and more the quality of teacher–student interaction which is the key feature in promoting learning (Brown *et al*. 1998; Wilson *et al*. 2006).

Indeed, it may be that whole-class interactive teaching has become a meaningless term, with 'interaction' covering the whole range of classroom discourse moves, including teacher-dominated procedures (Myhill 2006). With an extension of the National Strategies to other subjects, the further guidance explains that interactive teaching is achieved through a balance of directing and telling; demonstrating; explaining and illustrating; questioning and discussing; exploring and investigating; consolidating and embedding; reflecting and evaluating; and summarizing (DfES 2002, pp. 39–40). This suggests that interactive teaching should be seen as a whole approach to integrating episodes of teaching into lessons. Consequently, Burns and Myhill (2004) focus on characterizing 'interactive lessons', identifying some important factors and unifying themes present in such lessons:

- Reciprocal opportunities for talk which allow children to develop independent voices in discussion;
- Appropriate guidance and modeling when the teacher orchestrates the language and skills for thinking collectively;
- Environments which are conducive to student participation;
- An increase in the level of student autonomy.

Within the context of whole-class teaching, however, individual student autonomy is constrained by the need to develop collective knowledge and understanding. The studies discussed above suggest that teachers find it difficult to balance the needs for collective and individual learning, and that when analysing the effect of ICT, it will be valuable to focus analysis on the degree of control exerted by different classroom strategies.

Clearly, some discourse moves afford greater opportunities for student autonomy than others. Tanner *et al*. (2005) have drawn on existing literature to devise a loose framework appropriate for describing whole-class teaching episodes in terms of the locus of control in the classroom (see Table 1). On this scale, higher interactivity reflects more learner control over the trajectory of the lesson and the form which collective knowledge takes.

The positioning of the lecture as the lowest level of interactivity is not intended to imply that learning may not occur in the context of a lecture or even that learners may not engage effectively with the subject matter. A good lecture may result in significant personal cognitive engagement and intra-activity, resulting in personal learning. However, at the lower levels of our scale, learners have little or no influence over the trajectory of the lesson or the form of collective knowledge that is developed.

This brief survey of literature suggests that the idea of interactivity in teaching is very much a British construct. However, a similar approach is adopted by Alexander (2004), who finds from his work in international comparative pedagogy that most teaching is based on a basic repertoire of three types of classroom talk: rote, recitation and instruction/exposition. He suggests these are unlikely to offer the types of cognitive challenge required to extend students' thinking, and he characterizes dialogic teaching as collective, reciprocal, supportive, cumulative and purposeful. Dialogic teaching requires discussion and dialogue, but he acknowledges that these types of talk are less frequently encountered and require greater levels of teachers' skill and subject knowledge. The basic repertoire allows teachers to remain in control of the discourse but the addition of discussion and dialogue gives more freedom to children to explore and challenge the ideas being considered. He concludes that students should be encouraged to ask questions, provide explanations and see answers as leading to further questions. Teacher–student exchanges should provide a model for dialogue which students can adopt for themselves.

Common to most studies of interactive teaching is the recommendation for a shift from high levels of teacher control towards more self-directed learning, greater student autonomy and the co-construction of knowledge. It may be valuable for future research to conceptualize interactivity in teaching on a continuum concerning the nature of the interactivity and the character of the scaffolding provided through the dialogue. We would expect effective teaching to incorporate a variety of levels of interactivity, as appropriate to the learning objectives. It is likely that a lecture approach can be effective in communicating ideas to learners whose conceptual structures are able to support the assimilation of the new material, and that low-level questioning can be valuable when aiming for retention of lower level facts and skills. There is evidence of the value of deeper interactivity and greater learner control in developing concepts and higher-order skills (Adey & Shayer 1994; Muijs & Reynolds 2001), and the scarcity of this level of interactivity suggests that there is scope for improving students' attainment in these aspects of learning.

Can interactive technology influence the interactivity of teaching?

There seems to be widespread expectation that ICT, by the very nature of the medium, provides interactive experiences for learners. The curriculum for initial and in-service teacher training in ICT in the UK specifies a number of particular features of ICT tools and resources which teachers should learn how to exploit (DfEE 1998a):

- speed;
- automaticity;
- capacity;
- range;
- provisionality;
- interactivity.

These features are what make ICT special as an educational aid in comparison with other tools and resources.

The term *interactive* is the one most frequently identified by teachers interviewed concerning the impact of ICT on learning (Kennewell 2004). Despite the apparent synergy of ICT with interactive teaching that this implies, there is a clear distinction between the technical interactivity that students experience when using ICT and the pedagogical interactivity between teacher and learners (Smith *et al*. 2005). It is pedagogical interactivity that is analysed in the studies reviewed above; indeed, none of the studies make any reference to ICT. This perhaps reflects the disjunction between the emphasis on presentation, direct instruction and control prevalent in most models of whole-class teaching and the greater autonomy usually assumed when students engage with activities that exploit the interactive features of ICT (Somekh & Davies 1991; Wegerif & Dawes 2004). However, the recent development of cheaper projection technology has enabled ICT to be incorporated into whole-class teaching strategies. The IWB, particularly, changes the relationship between ICT and pedagogy by combining a display large enough for a whole class to see clearly with a user interface which is integrated into the display. On its own, however, ICT cannot (yet) provide the sustained, contingent, reciprocal and reflective qualities of classroom interaction that we associate with improvements in learning. These qualities are largely dependent on the teacher, and it is not yet clear how IWBs might facilitate the development of the deeper forms of interactivity in teaching. Indeed, a recent study in England indicates that IWB lessons contain more whole-class teaching and less group work, and a faster pace with an increase in the number of IRF moves and reduction in the length of student responses (Smith *et al*. 2006). Although these changes were found to have an initial positive effect on attainment, this improvement was not sustained. This suggests that a deeper analysis of the changes taking place with the introduction of this technology is needed in order to understand how classroom technology can improve learning.

Approaches to analysing technology's influence on teaching

In order to explore the potential of new technologies for improving learning through interactive teaching, a suitable framework for analysis of relationships between teacher, learners and resources is needed. Such a framework needs to be able to capture a fine level of detail concerning the nature of the ICT, the cognitive processes which may be supported and the key role of the teacher in managing the process (Passey 2006). We would expect quite different effects from a teacher showing a PowerPoint presentation, from a student using commercial game or quiz software, and from a group of students collaboratively developing a concept map. Consequently, we have sought a model for learning which complements Passey's (2006) focus on individual student cognition by recognizing the influence of the whole learning environment, which includes human, physical and cultural features.

Affordances and constraints

In order to account for the influence of environmental features on learning activity, many recent papers concerning the impact of ICT on teaching and learning to refer to the *affordances* of ICT. This idea was developed by Gibson (1979) to help analyse visual perception and adapted by Norman (1998) to characterize features of machines. The common ground in the most explicit views (Laurillard *et al*. 2000; John & Sutherland 2005; Webb 2005) concerns the opportunities or *potential for action* provided by features of the setting, usually in the form of tools which convey some indication of how they might be used, or models and examples which may be copied. The use of the related idea of *constraint* (see, for instance, Greeno *et al*. 1998), in conjunction with affordance, provides a more comprehensive characterization of the relationships between the environment and the people acting in and on that environment. In this interpretation, the term constraint carries no negative connotations. It refers to a boundary, guide or *structure for action*, and may take the form of a prompt or question, rather than a physical property. In general, perception of potential and structure for action will depend on the knowledge, skills and dispositions of the person(s) acting, and will be relative to the setting and the goal. In some circumstances, therefore, a constraint may be perceived as a barrier or obstacle to action.

The classroom setting and the teacher's role

The idea of affordances and constraints can be used to analyse activity in any setting in relation to the goals of the activity. The particular features of the classroom include the teacher (if present), other students, tools and resources, classroom ethos, subject culture and educational policy. The students will bring knowledge, skills and dispositions relating to the subject matter being taught, together with generic skills such as literacy and working with others. The combination of the affordances of the setting and students' knowledge may provide potential for action towards students' goals. At the same time, the setting's constraints may provide structure for their actions in a positive form (guidance) or a negative form (obstacle to be overcome). The same feature can contribute both potential and structure.

The classroom is non-typical as an activity setting, in that it is characterized by an intention that learning takes place. Although the students' goals may be primarily those of task completion, the tasks are designed in order to achieve learning outcomes rather than merely creating physical products or providing services. Furthermore, a teacher is not merely a manager of the activity which takes place. Their role can be seen as orchestrating the features so as to ensure that the activity proceeds fruitfully towards achievement of the planned learning objectives as well as completion of the task itself (Kennewell 2001; John & Sutherland 2005).

From socio-constructivist theories concerning 'scaffolding' (Wood 1998, p. 99), we expect that the most effective learning should occur when the production goal is comprehensible (and ideally motivating) to the students but not be easily achievable without support. In order to complete the task, some cognitive effort on the part of the students will be required if learning is to occur. If students have difficulty with their task, the teacher acts to increase the potential and/or structure for action in a minimal way so that the learner has opportunity to achieve as much as possible for themselves. It is expected that the learner will be able to achieve the goal with less help in future as the assistance is 'faded' (Wood 1998, p. 100). In this view, the role of the teacher is one of setting tasks which present some challenge to the learners and then 'orchestrating' (Wood 1998, p. 98; Kennewell 2001, p. 106) the activity by continuously manipulating features of the classroom in response to students' actions, so as to ensure successful task completion with the minimum of support. The teacher uses knowledge of the learners' attributes to set a level of cognitive effort that will stimulate the desired learning.

The idea of orchestration of features was developed in order to help evaluate resources, to help plan and evaluate teaching and learning activity which is organized and supported by the teacher, and to compare teaching approaches. It represents teachers' planning of lesson structure, student tasks, instruction and resources appropriate to their students' characteristics, and also represents the continual process of response and intervention that teachers pursue during the lesson that is contingent on students' progress with the task. It incorporates the arrangement of contrasts to help learners notice new features and learn which features are relevant to a new concept (Sutherland *et al*. 2004). It is not only teachers who orchestrate features in the classroom, however; learners also may actively seek and evaluate resources to help them achieve their goals, decide on who to approach for advice, and impose structure on their activity. One of the challenges for the teacher is to orchestrate the features of the setting with a sufficiently light touch to allow the student to maintain a degree of autonomy over the learning.

During effective whole-class teaching, it is expected that students are continuously engaged in relation to the subject matter to be grasped. Even when their activities are purely mental (intra-active), the features of the setting (including ICT) can still provide potential and structure for actions of assimilating information, accommodating to experiences which conflict with existing ideas, memorizing material and reflecting on activity. Furthermore, teachers stimulate the cognitive engagement of students by posing questions and requesting contributions in order to minimize the duration of periods where students are behaving passively. They also set mental tasks which engage and challenge learners in a cognitively active way. These acts are also characterized as orchestration of features of the setting. Higher levels of interaction are achieved when teachers encourage students to act with greater autonomy, imposing their own structure on learning situations. Students' ideas may then be incorporated into the discourse as the teacher orchestrates the development of shared understandings and collective or 'common' knowledge (Edwards & Mercer 1987; Sutherland *et al*. 2004).

Analysing teaching and learning in activity settings (ATLAS)

In order to identify and analyse salient features of classroom settings, we have adapted Kennewell's (2001) general framework for representing learning from activity in the light of pilot studies of predominantly whole-class teaching. The resulting model for ATLAS is designed to cover all learning situations involving a task or goal-directed activity, whether there is a teacher present or not (see Fig 1). It enables the key ideas of pedagogical knowledge, activity theory and affordance to be applied in a single analytical tool.

Central to the model is the assumption that each participant's activity will comprise multiple actions directed towards some goals. In a classroom setting, the goal may just be to acquire information, to comprehend ideas, or to develop skills. Alternatively, and more usually (Somekh 2001), it will be to produce a public product, either constructed to a specified brief or created with a degree of freedom concerning the outcome. A product may be a physical (or electronic) artefact, or it may involve performance, such as responding to questions, reporting on behalf of a group discussion, or playing a role. The teacher's intention is that the students will learn from such a production task, but if the learner's only goal is one of production, it is likely that learning will be limited. Intentional learning (Bereiter

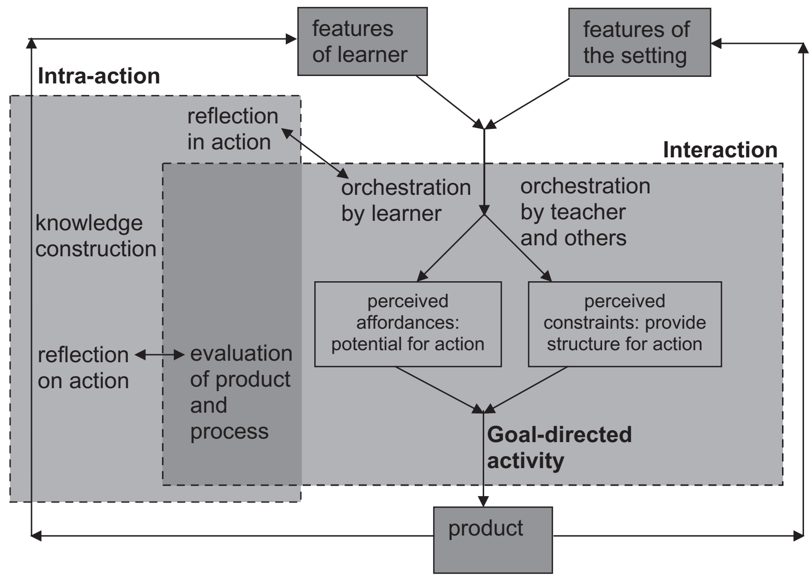

Fig 1 analysing teaching and learning in activity settings framework.

& Scardamalia 1989), in which the students appropriate the intended learning objectives, is likely to be more successful. The features or attributes required of the learner in order to achieve their goals will be some combination of knowledge (factual and conceptual), skills, values, beliefs and dispositions in the target subject matter (Cox & Webb 2004) together with generic skills (such as literacy and ICT capability) and in other subject matter.

The features of the setting include the teacher, other learners, cultural factors, tools and other resources. The features provided by the teacher can be classified as knowledge, beliefs, values and behaviours, and learners demonstrate these features, too (Cox & Webb 2004). Cultural factors include school ethos, policies, subject culture, classroom rules and the home background of students. The tools may be those based on language, such as discussion, or physical tools such as coloured pens and paper. ICT is a particularly versatile tool, and is not easy to classify in nature or function. ICT can be compared with other educational resources, such as books, posters on the wall, information sheets, worksheets, video and audio recordings which help stimulate, structure and support activity in the classroom. ICT does not necessarily replace these more familiar tools and resources; in some situations, the traditional medium may be more appropriate, or it may be used effectively in combination with ICT.

Figure 1 shows how the process of orchestration combines the features of the setting and the attributes of the students. This process is ideally dynamic, in that the teacher's and learners' use of affordances and constraints to support activity are continuously adapted in response to their perceived progress towards completion of the task and achievement of learning objectives, and interactive, in that students gain frequent feedback on their progress towards the goals.

This social process extends the idea of scaffolding and we characterize it as the *interaction zone*.

The learning which results from the activity will manifest itself as a change in the students' knowledge, skills, understanding and dispositions. A process of reflection concerning the activity carried out is likely to enhance the learning, particularly at the conceptual level (Watson 1996). Schön (1983) characterizes two different forms of reflection associated with goal-directed activity:

- *Reflection-in-action* operates on the process of orchestrating features to provide potential and structure for action.
- *Reflection-on-action* operates on the interactive evaluation of the product and the process of producing it.

Reflection-in-action is characteristic of relatively autonomous learners and may not occur naturally during classroom learning situations in which the dominant discourse moves tend to restrict learner autonomy. However, reflection in action may be stimulated when teachers orchestrate more dialogically based discourse moves that stimulate greater degrees of student autonomy, such as uptake questioning or focusing dialogue.

Reflection-on-action may occur during plenary sessions when teachers orchestrate collective reflection through providing potential and structure for students to consider together what they have achieved, how they have achieved it and what they have learned from the activity. Students may learn to carry it out independently if an evaluation phase is part of their normal task activity.

The model is not deterministic; the number and nature of the variables involved are such that we may never be able to predict exactly what will be learned by particular students in particular settings. In whole-class and group activity, some learning may be common to all participants, while other changes will occur only in certain individuals depending on their prior knowledge, skills and dispositions. The framework's sensitivity to the detail of activity enables us to gain fresh insight into the ways in which individual learning is influenced by the many variables to be found in classrooms, particular the way that ICT is used.

Comparing activity settings using ATLAS: a case study

Having been piloted and refined during studies in ICT-rich schools (Kennewell 2004), the ATLAS framework is being used as one of the main instruments in the Interactive Teaching and ICT project within the ESRC's Teaching and Learning Research Programme. The first phase of this project (September 2005–June 2006) aimed to explore differences between ICT-based and non-ICT-based teaching in terms of interactivity of teaching and measured attainment of learners aged 5–14 years. The second phase (September 2006–June 2007) continued work with the same teachers, but with all teachers using ICT where they consider this to be the most effective approach. The main criterion for selection of teachers was the effectiveness of their practice, rather than expertise or innovation with ICT.

Central to the design is the observation and recording of typical lessons taught by the participating teachers, followed by video-stimulated reflective dialogue between the teacher and their partner researcher. The lessons to be observed were selected by the teacher to exemplify their use of interactive approaches. The teachers watched the recording of the lesson on DVD and selected some episodes for discussion during the reflective interview which was normally held a few days later. Students were also interviewed concerning the lessons where feasible. The lesson notes and reflective dialogues were analysed in terms of the goals, the activities, the perceived learning, and the orchestration of the affordances and constraints of the setting in order to achieve the goals of the participants. A systematic approach, using the relationships set out in the ATLAS framework, enables qualitative comparisons to be made across the factors and relationships in the teaching model. The framework will also be used to make comparisons across each teacher's practice in the two phases, to refine the characterization of development in pedagogical expertise with ICT.

The following analysis of a typical lesson observed at an early stage of the project shows how the framework can be used to compare whole-class, group and individual activity involving the IWB and other ICT resources, and to draw conclusions concerning the relationship between technical and pedagogical interactivity.

The setting

The lesson observed was in mathematics with a class of 29 boys and girls aged between 9 and 11 years, a teacher and two Learning Support Assistants. It took place in a large, modern classroom with an IWB at the front and three networked desktop computers at the back of the room. The class had an ethos of collaboration and mutual support, with pupils seated in groups of about six children who are accustomed to working together. The learning objectives concerned understanding and skill in addition and subtraction of whole numbers involving negative values, and specifically for the children to adopt a purely mental strategy for calculating with directed numbers, using familiar number bonds rather than counting physical moves on a number line. The lesson comprised four phases; this is the standard pattern in the school and many others in Wales and England. The initial phase was a whole-class activity concerning the familiar idea of placing directed numbers in order on the IWB, the main teaching phase was another whole-class activity which extended the learning to calculations of differences between directed numbers, the third phase involved group/individual work on activities similar to those in the second phase, and the final phase was a plenary session in which the teacher helped the students to reflect on and formalize the ideas that they had been developing during the previous phase. The middle two phases of the lesson are described and analysed here in terms of the orchestration of features, the potential and structure for action perceived by students, and their influence on activity and learning.

Main teaching phase

A piece of commercial software was displayed on the board. The teacher chose a particular option and the board showed a diagram of a thermometer with a temperature scale. One position (–2) was marked 'Yesterday's temperature', another (+6) was marked 'Today's temperature', and the question was posed: 'How much has the temperature risen or fallen?' The goal of the activity was to answer correctly (in this case, 'a rise of 8 degrees'). The teacher asked the children to discuss this in their groups for 2 min and then to nominate one student from each group as a respondent. This was repeated for three more similar tasks generated by the software with random values. After each group discussion, the teacher took answers from the nominated children, prompting some to give extended responses and/or demonstrations at the board to explain how they have obtained the answer. Sometimes the teacher intervened in a group discussion in order to resolve confusion or misconceptions for individual students, and then invited the student who had learned from this intervention up to the IWB in order to explain to their peers how to do the task. When a student explained a mental method for dealing with a change in temperature which crosses zero (such as −3 to +10), this was taken up by the teacher who used focused questions to emphasize the key features of the procedure that she expected them to use.

Analysis of main teaching phase

The large, clear visual display provided potential for the action of identifying the direction of change and counting the number of degrees between the start and end values. The potential increased if the child came up to the board and moved a finger along the number line while counting. There was no structure provided by the software that would constrain the student to use a specific method; in order to stimulate the intended learning of a mental strategy, the teacher identified a student who was using an appropriate mental method, and asked them to explain what they had performed. She then took up this explanation in order to make explicit the mental process, validate it and emphasize why a mental method was preferred over counting. The teacher was skilfully orchestrating the known abilities of the students, together with the dynamic visual and tactile features of the IWB display in a manner which was contingent on both the problem selected randomly by the software and the students' responses. This is characteristic of level 3 of the whole-class interactivity scale (Table 1). The IWB acted as a shared resource for the class and, in fact, only the students interacted with it directly after the initial loading of the software by the teacher.

Group activity

During the next phase of the lesson, one group of six children was designated to work together on a task at the IWB. The group task was similar to the one in the whole-class activity, except that the starting temperature was indicated by a bar on the temperature scale and the value by which the temperature will rise or fall was given (see Fig 2). The student was expected to use the IWB pen to indicate the resulting temperature on the scale, and feedback was given (a pop-up message on screen together with an audible 'hoorah' if correct or 'uh-uh' if incorrect). In either case, the software immediately provided another question with randomly chosen values constrained to give answers within the range −10 to 10. The goal was to maximize the number of correct answers in 2 min, and a score was shown continuously, together with the time remaining (see Fig 2).

The group was briefed to discuss the answer to each question before entering a response. This strategy proved effective in gaining correct answers and the feedback sound for an incorrect answer was never heard.

Analysis of group activity

The display on the board could be seen and touched easily by the group; this provided potential for the action of counting an appropriate number of steps. However, the structure imposed by the teacher of discussing and agreeing the answer as a group meant

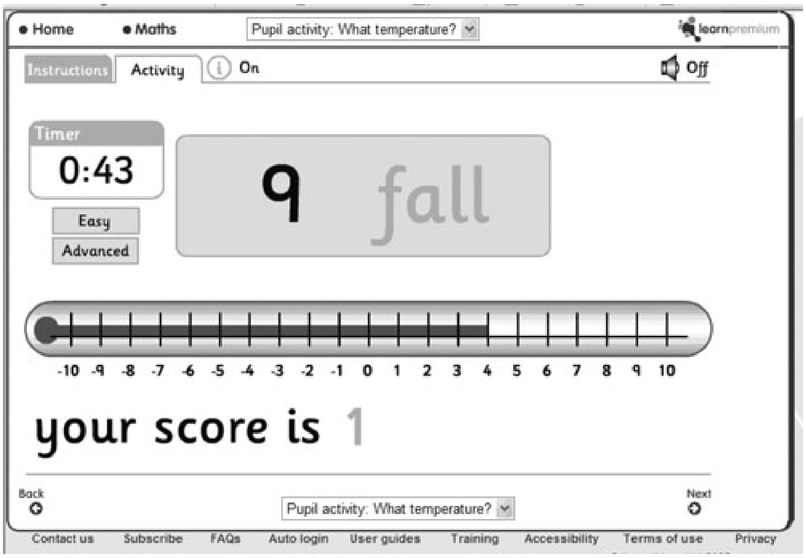

Fig 2 Screenshot from software used for individual activity (© 2006 Learn, 119 Farringdon Rd, London EC1R 3ER, UK; http://www.learnpremium.co.uk/).

that usually the answer was obtained by mental calculation. In addition, the students did not want the feedback sound for a wrong answer to be heard by the class; it seemed to be perceived as a constraint which ensured that they consulted with each other in order to be confident of a correct answer. It was not clear whether all the students were able to work purely mentally, however, and the successful students did not explain their method unless the teacher intervened. The board also provided a social function in that it had to be shared; although the student who held the pen could act unilaterally, peer pressure ensure a structure of turn-taking. The pen holder orchestrated the knowledge of peers together with their own ideas in formulating a response. This orchestration was mostly at the superficial level of identifying the answer, however, with little strategic discussion about the process of calculation.

Individual activity

A group of six children were briefed by the teacher concerning the software they were to work with (the same software as the IWB group used) and were allocated to the three computers in pairs. The pairs operated largely as turn-taking individuals, although there was some discussion within pairs and between neighbours, mainly concerning basic operation of the software and comparing scores rather than calculating strategy. Pupils could be categorized into three broad groups concerning their strategies for the activity:

1. Using the mouse to count forward or back with the pointer on the number line each time. This strategy led to a score of around 9–13 correct answers in the 2 min available.
2. Calculating mentally. This led to a score between 26 and 32.
3. A mixed strategy – visual counting or calculating for small changes and/or those which did not cross zero, counting with the pointer for questions that they found more difficult. Children using this approach scored around 16–20.

The students using the computers remained continuously focused on their goal of maximizing the number of correct answers, and it was very rare for an incorrect answer to be given. There was no discussion observed concerning the relationship between strategy and score in the pairs/neighbours. The teacher checked on the group from time to time and intervened to provide structure in two ways: checking that students were taking turns and prompting them concerning the desired calculating strategy.

Analysis of individual activity

The publicly audible indicator of an incorrect answer again seemed to motivate students to respond correctly but did not constrain them to a particular method. Consequently, the students used the affordance for physically counting the steps and tended to adopt this as the strategy which gave them most confidence in gaining correct answers. The software's perceived potential for physical counting was not counteracted by perception of the structure provided by the teacher, nor did students seem to be aware of the constraint provided by the on-screen clock. Although one student seemed to be tentatively shifting from use of the mouse to mental counting in order to speed up the process, it was not clear that any student made the transition from counting to calculating during this activity. When the teacher intervened to emphasize the constraint on strategy, the student's goal did seem to change from that of gaining a correct answer to that of using the teacher's strategy. However, when this resulted in an incorrect answer on one occasion, the student lost confidence in the calculating method and reverted to counting for some problems. As with the group activity, the students' orchestration of ICT features and peer knowledge was generally at a superficial rather than strategic level. Although some students may have made the link between a mental strategy and speed of calculation, no interaction between students or with the teacher about this point was observed.

Summary and discussion

In our case study, the teacher was well aware of the importance of developing a calculating strategy in the task, and took every opportunity to discuss this point with students, using high pedagogical interactivity (level 3 in the scale of Table 1). The pupils using the board in front of the whole class did not mind making mistakes; indeed, they were encouraged by the teacher to do so and then discuss them as a means of learning (as confirmed by the students in their initial interviews). This was afforded by the culture of the whole-class work observed. However, when working as groups and independently, the students' main goal was to achieve correct answers. Although the students were interactive technically, there was no constraint on their method, and they orchestrated the features of ICT in pursuit of their goal rather than the learning objectives. With little perception of the time constraint, their reflection-in-action was not leading to changes in strategy. Recognizing many students' reluctance to change strategy despite teacher intervention during the individual work, the teacher elicited contributions from students during the final phase of the lesson which generated collective reflection on their calculating strategies, characteristic of level 4 on the scale of Table 1. During a subsequent interview, however, the teacher indicated that the students' learning was still tentative by the end of the lesson and felt that most of the students were not secure in the learning objectives until the following lesson.

Although the level of interactivity in the lesson was largely controlled by the teacher, the influence of the ICT resources is important. The software used in this lesson, although apparently highly interactive, did not provide the sort of constraints which would structure students' actions and reflection-in-action in a way that would achieve the learning objectives. When interacting directly with the students, the teacher was able to orchestrate features of the setting, including the students' existing knowledge, so that they used the required mental calculation strategy. However, when the teacher was not present, the students did not appropriate the learning goal and orchestrated features purely in pursuit of the production goal. This suggests that technical interactivity is not in itself effective in securing learning, and that students also need the intention of learning and the skills required to marshal resources – including the features of ICT, their own cognitive faculties and those of their peers – towards learning goals. It is an increase in pedagogical interactivity that is more valuable; this is located in the orchestration of features rather than in the features themselves, with the higher levels of interactivity involving students developing the ability to orchestrate features in pursuit of learning and being given the opportunity to do so.

Conclusion

It is clear that the transformation of pedagogy towards more pupil autonomy and personalization of the learning experience, which the early adopters of ICT envisaged, has not yet been widespread in the UK. Indeed, the advent of the IWB may be seen as a backward step, in that it gives a new impetus to traditional, teacher-centred approaches. The picture we have developed from the analysis of observations is much more complex than this, however, and the ATLAS framework has provided a valuable perspective from which to characterize the activities taking place and analyse their effectiveness. Our preliminary work suggests that it would be fruitful to focus on:

- the relationship between product goals and learning goals during activity designed for learning;
- the role of the teacher, software designers and students in providing and orchestrating the features of the setting to provide potential and structure for action;
- a shift in responsibility for orchestrating features in the classroom from the teacher to students (individually and collaboratively);
- the role of reflection-in-action during activity as well as reflection-on-action at the end of a lesson;
- developing interactivity scales for group work and individual computer use in order to analyse and compare the effects on learning of different ways of orchestrating features of these settings.

Our close observation and analysis shows that learning can be very sensitive to the goals of the activity and the features of the setting. While technical interactivity is a valuable feature of ICT resources, and can motivate the repetitive practice of skills when the teacher is not present, it is the characteristics of pedagogical interactivity that are more important in stimulating the reflection and intentionality of higher-order learning. If these characteristics can be appropriated by learners when using ICT, we should start to see the benefits of the greater learner autonomy which ICT provides.

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