MAXIMISING POTENTIAL: THE DEVELOPMENT OF A PEDAGOGY FOR MATHEMATICS TEACHING IN THE INTERACTIVE WHITEBOARD CLASSROOM

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Over the last seven years interactive whiteboards have been widely introduced into secondary mathematics classrooms in England with research evidence showing how this improves pupil motivation. More recently, as part of a national evaluation project, mathematics lessons in seven secondary schools have been video recorded and analysed. This paper reports on an analysis of four lessons concerned with the equivalence of fractions. In these lessons four aspects of classroom culture are considered, these are: perception of the role of the teacher; the use of the interactive whiteboard; questioning and learning models. The conclusion is that although teachers might be making progress in using interactivity they need to act more in the role of teacher-as-mediator rather than in the role of teacher-as-instructor and re-consider how they plan lessons accordingly.

The recent widespread introduction of interactive whiteboards (IAWs) into mathematics classrooms in England has been funded either by the Government or by schools based in the belief that IAWs can enhance presentation and consequent motivation of pupils (Miller et al., 2005). There is considerable evidence that as teachers gain confidence and competence in working with the new technology they also seek changes to the way in which they teach (Becta, 2003; Becta, 2004; Beeland, 2002). Miller et al. (2005) have developed a typology of teaching approaches which describe the locus of development as teachers gain IAW experience.

METHODOLOGY

In the past four years the IAW team at Keele University have been recording and analysing mathematics lessons. In 2005-6, as part of a government funded research project looking at the impact of IAWs on classroom practice, lessons were recorded on two visits to seven secondary schools: 42 on a first visit and 46 on a second visit (roughly nine months later).

In this paper, which concerns work in progress, we consider the detail of particular lesson episodes in terms of the role of the teacher and the extent to which he/she uses IAW affordances (Gibson, 1979) in the lesson. Each lesson concerns equivalent fractions - the topic was chosen since it was covered in different schools and with pupils of different ages and abilities. Lesson and episode analysis is based on a two dimensional model (see table 1) in which the role of the teacher is set against the extent to which the affordances (Gibson, 1979; Norman, 1988) of the IAW are perceived and utilised. Thus, developing a model suggested by Ernest (1994) we regard the teacher mode as being either an instructor or mediator (Tinzmann, 1990).

The scale of IAW affordances runs from the presentational features to the truly interactive.

	IAW Affordance of Presentation	IAW Affordance of Interaction
Teacher – as-Instructor	Teacher led, with emphasis on the presentation of facts and algorithms, low level questioning with the e-screen only used for illustration.	Teacher transmits definitions and algorithms but uses the e-screen for limited and simplistic exploratory illustration.
Teacher-as-Mediator	Teacher develops concepts with pupils through higher level questioning but relies on e-screen illustrations.	Teacher develops concepts through higher level questioning and the use of manipulatives and other IAW features to foster engagement and understanding.

Table 1: Pedagogy associated with teacher roles and interactive whiteboard use

Identifying the role of the teacher is achieved by observing: relative emphases on content and procedures; assumed models of teaching and learning (Adhami, et al 1998) and the levels and nature of questioning (Bloom, 1956). Each of these elements can be inferred directly from the video recordings; the phasing of the lesson and the extent to which this allows for group and individual work by pupils; and classification of the type of questioning throughout the various episodes.

The appeal to the affordances of the IAW is demonstrated by its use. Simple and obvious presentational use does not make the most of the IAW's features and (generally) could be replicated by less sophisticated technology (usually just a projector and screen). Typically such use is associated with a 'delivery' method of teaching. Features that are complex and not obvious but support interactive use of the IAW make the most of the features of the IAW. Generally, these cannot be efficiently replicated by less sophisticated technology. Typically such use is associated with a style of teaching involving exploration and mediation (Tinzmann, 1990) allowing the IAW to be used for feedback and modelling.

FINDINGS

Although three of these lessons were at the highest level of the analytic typology (Miller et al, 2005) it was clear that teachers could be working towards a much higher conceptual and cognitive level to bring about far-reaching changes to mathematics pedagogy. Miller et al., 2005 have shown that there is a difference in approach to mathematical thinking when the technology becomes the focus of presentation in teaching and there is a pedagogic shift from didactic to experiential and interactive learning. Here we consider four aspects of classroom culture as manifestations of

teacher-learner relationships: perception of the role of the teacher; the use of the IAW; questioning and learning models.

Perception of the role of the teacher

Ernest (1994) suggests an elementary typology to describe the role of the teacher. The teacher as 'instructor' is concerned with the presentation of concepts as rules followed by practice; the teacher as 'facilitator' is concerned with approaches that enhance understanding and the teacher as 'mediator' where, following Tinzmann et al. (1990) there is a bridging between pupil understanding and mathematical development.

The teacher-as-instructor typically sees mathematics as an accumulation of facts, rules and skills to be used for some external end. The style of teaching is likely to focus on the mastery of certain skills and achieving the correct answer – the IAW is a vehicle for presentation. A teacher-as-instructor example episode (Lesson 139) is:

> The e-screen is adjusted from the computer. It shows six questions and twelve potential answers. Pupils are told to write into their books "Fractions of Amounts". The teacher writes the same heading in an additional panel on the e-screen . The panel is hidden and the questions addressed. Using the IAW the teacher develops the routine "To find one half, we divide by two; to find one third, we divide by three …". He then engages in low-level question-answer routines for the first three questions. He repeats some elementary algorithms. Pupils then have to complete the final three problems themselves.

However the teacher-as-mediator is likely to regard mathematics as a cultural product that is dynamic and is continually expanding as a result of human creativity and invention. Thus, the teaching style is likely to be associated with questioning and problem solving – the IAW is a vehicle for interaction with pupils. A teacher-as-mediator example episode (Lesson 142) is:

> The teacher establishes terms for the numerator and the denominator of a vulgar fraction. With very heavily flagged questions and gestures she establishes that the denominator represents the number of parts the shape is divided into and the numerator represents the number in the required part of the whole. This is written on an associated non-IAW.

During this phase, one can see indicators of the teacher acting as mediator in a limited fashion, since she is trying to make sense of the mathematics that has appeared on the e-screen by asking questions about what the numbers might represent. At this stage, however, there is no annotation or highlighting of the presentation that would be apparent in a skilled teacher-as-mediator.

The use of the IAW

In both these episodes the affordances of the IAW enhance the role of the teacher. The teacher-as-instructor will often be working with a presentation in a logical sequence as the basis of the teaching. The focus is focussed on statements of facts and definitions, etc. but there will also be examples to be copied and exercises – the

practice and skills of algorithms - to be completed. Such material is usually organised, clear and monotone. On the other hand, the teacher-as-mediator will be concerned with how the IAW can support the features of mediation such as modelling and coaching in relation to the topic.

Modelling serves to share with pupils not only what one is thinking about the content to be learned, but also the process of communication and collaborative learning. There may be thinking aloud (sharing thoughts about something) or demonstrating (showing something in a step-by-step fashion). Whereas coaching involves giving hints or cues, providing feedback, redirecting efforts of pupils, and helping them use a strategy so that pupils retain as much responsibility as possible for their own learning (Tinzmann et al. 1990). These are both evident in this episode of lesson 142:

> The teacher asks pupils to record answers on mini-whiteboards. She works through an animation and asks pupils to suggest what might come next, affirms their answers and writes some of their (correct) answers on a non-IAW. From time to time she asks pupils for further explanation in their responses.

In lesson 109 the teacher-as-instructor uses the IAW for mediation in this episode:

> The teacher uses a virtual manipulative (a fraction wall) to demonstrate equivalence of fractions and allows pupils to use the IAW also. Here the IAW is being used for modelling purposes – a tool for mediation. So whilst his role might be seen as instructor, the IAW is being used for mediation.

The teacher-as-mediator might be aware of the way in which the affordances of the IAW can be used in a non-linear fashion, is flexible in responding to the needs of the pupils and thereby allowing access to topics in different ways. This accords with the findings of Jones and Tanner (2002) that despite the tendency of teachers to use the IAW as the focus of the lesson, and for subsequent research to show that this may be happening (Miller et al, 2005), successful mathematics teaching requires a balanced use with a changing focus to maintain pace and interest.

Miller et al. (2005) have suggested that as competence improves, mathematics teachers, in particular, become more ready to develop and use manipulations (drag and drop; hide and reveal; the use of colour, highlighting and shading etc.) as the basis of interaction to support the teacher-as-mediator. Some manipulations might lend themselves more easily to mathematical activities as defined by Watson and Mason (2002). The lessons analysed here showed a low level of manipulation use. So although ‘hide and reveal’ is used in episodes in all four lessons it is used simply to affirm an acknowledged correct answer. There is little attempt to use the manipulation to give formative feedback, as necessary for mediation mode.

Questioning

Experienced and effective teachers use questioning intuitively. Inexperienced and poor teachers appear not to have such skills. Mason (2000), in his commentary demonstrates the complexities of the process and relates questioning to both

conceptual and cognitive development. Analysis of the video recorded lessons suggests that open and closed questions and those focussing on product or process are frequently used but are only partially helpful in developing higher order learning.

Watson and Mason (2002) suggest a typology of questioning based on the work of Dyrszlag (1978). They compile two lists: one of structures in mathematics that one might find being discussed in the classroom and in the second the various kinds of mental activity which typify mathematical thinking. By grouping elements in each list together and constructing a simple matrix, they link typical structures in mathematics with corresponding thinking activities.

Bloom's (1956) taxonomy, a classification of levels of intellectual behaviour within the cognitive domain, provides a useful way of categorising questions. He found that over 95% of the test questions pupils encounter require them to think only at the lowest possible level - the recall of information. He defined the levels as knowledge, comprehension, application, analysis, synthesis, and, at the highest level, evaluation.

Low-level questions (in Bloom's levels - knowledge, comprehension, application) are likely to be closed and lead to little mathematical activity beyond a response to the words of the question. Higher-level questions (in Bloom's levels - analysis, synthesis, evaluation) are unlikely to be bounded by the words of the question and are more likely to lead towards mathematical development.

Such an analysis acts as a guide to the teacher both as she interacts with pupils since it suggests how proceeding questions might be phrased in order to raise the level of mathematical thinking and and by indicating the nature of higher level activity for the pupil. Evidence from these four lessons shows that there was little questioning beyond low level activity e.g in lesson 142 the approach was generally interactive but questioning was always at a low level as seen in this episode:

> Pupils are completing an exercise comprised of questions of the type "What is $^1/_n$ of … ?". Each question is in a box and there is a box for the answer. In addition, answers to all questions are shown in the bottom right-hand corner of the e-screen. The teacher points these out as clues. For the first part of the episode, before pupils are allowed to begin the exercise, the teacher seeks clarity of understanding by completing the first question as a class. "What is one half of fourteen?", "Yes, the answer is seven, we divide by two." She then states that if a quarter of an amount is required, we divide by four and if a fifth is required, we divide by five. The second part of the episode is a period of pupils working on their sheets, to fill in the boxes with the correct answer. At this stage there is no recourse to the e-screen. The third part of the episode is that in which the teacher and pupils work through the solutions.

Another episode from lesson 109 makes no reference to the IAW and is followed by a sequence of similar closed, low level questions. The focus is on the algorithm for simplification and there is no use of the IAW for mediation or further analysis.

> The teacher asks "Who can cancel $^{5}/_{15}$ into a simplest form? How do you get $^{1}/_{3}$?" in response to the correct answer and "What did you do to get to it?" Each of these questions requiring only one statement answer with no need for elaboration.

Learning Models

This element in developing interactivity stems from the learning model espoused by the teacher. Here we consider two, and we assume that they can be used co-jointly in order to explain best practice in the classroom. Cobb (1999) refers to these "Two major trends … identified in mathematics education research during the past decade." - the constructivist and sociocultural perspectives - form the basis of the theory behind Thinking Maths (Adhami and Shayer, 2006), which in turn develops an approach to teaching and learning using the constructivist and social-constructivist views of learning as defined by Piaget and Inhelder (1974) and Vygotsky (1978) respectively.

The constructivist Piagetian model required here is that children construct concepts and meaning, as a solo activity, based on their own experience. This is associated with the notion of 'cognitive conflict' (Swan, 2001) whereby pupils are exposed to something that is different from (conflicts with) their currently perceived models. From Vygotsky, we focus on the social-constructivist view of 'language' linked with the formation of knowledge. Furthermore, we take his view that all knowledge is a social construction and based on shared views and images.

These two models of learning lead to a view of a lesson as a series of episodes (Adhami and Shayer ,2006). The first, preparation, is where views and terms are clarified and areas of activity are defined; the second is when individuals or small groups reflect on the matter in hand; and the third is when these views are shared by the whole class. In IAW terms there is a link here between the nature of the episodes and Miller and Glover's (2006) 'at the board', 'on the desk', in the 'pupil's head'. They recommended that topics are planned together to help pupils 'triangulate' learning. They comment:

> To do this involves linking practical, concrete or active work on the pupil's desk directly to the work on the IAW (in look, ideas and movement) in order to help pupils develop understanding of the mathematics. Typically this may involve pupils looking at e.g. areas of shapes made on, for example, pinboards using elastic bands, copying the shapes onto dotty paper and then discussing the findings as a class with the teacher who uses a virtual manipulative of a pinboard on the IAW (it is important that pinboards are used as drawing shapes straight onto dotty paper may not provide the same level of understanding).

It is important to point out that there are other episodes in the lesson when pupils might be engaged in other activities associated with the IAW. They might for example be completing exercises and/or copying diagrams and notes. Although a legitimate activity this in itself can be a low-level activity and, as with low level

questioning, should be used sparingly. Examples from the lessons analysed suggest that whilst there is an element of constructivism in the structure of the learning process, teachers are wary of using social-constructivist approaches because these may inhibit control. This is shown in adherence to 'rules' in the following episode from lesson 142:

> The teacher states that ½ is equivalent to $^4/_8$ and ¾ is equivalent to $^6/_8$. Each of these equivalences is written on a non-IAW. A pupil is invited to the IAW to indicate a fraction of a circle. She marks with a pen one of the eighths, the teacher then annotates the presentation to clarify the other four eighths that constitute one half and states the equivalence algorithm "To make an equivalent fraction you must multiply the numerator and the denominator by two." This is demonstrated by the teacher, to transform ¾ to $^6/_8$.

Similar episodes are found in the other three lessons.

SYNTHESIS

A common IAW episode is one in which the e-screen presents a starter whilst pupils are entering the room. Generally this is a set of questions to be completed, a problem to be solved or a heading and some notes to be copied into books. Such an episode begins with the teacher giving instructions to the pupils to complete the examples or write down the words. The episode is completed when pupils have finished the set tasks and the teacher has either worked through the set exercise or read out the written words. Sometimes this might include low level question and answers.

In only one lesson (139) the teacher allowed pupils to work at the IAW as part of group work. Two groups of two pupils worked at the IAW whilst others worked at their desks. They used 'drag and drop' to explore and match equivalent fractions. At times the teacher worked with the pairs at the IAW and it was clear that he had shifted from instructor to mediator mode and the IAW use had changed accordingly.

In all lessons pupils would work, with varying degrees of silence, on the set tasks as required but this may be a reflection of known classroom culture rather than response to IAW use. The level of questioning in all lessons was generally low level focussing on knowledge of and application of algorithms associated with simplifying and finding equivalents for fractions. Thus questions were generally closed, focussing on product "What is an equivalent fraction?" and process "How do you apply the algorithm in this situation?." There was considerable evidence of "funnelling" (Mason and Johnston-Wilder, 2004) where pupils 'extract' answers or methods from the teacher by appearing not to know the answer or giving only partial answers .

In these lessons all four teachers acted predominantly in instructor mode. This was evidenced by the number of statements and instructions relating directly to the screen "Today we are looking at this, put the heading in your books, put the objective and the date", "So what we have here are equivalent fractions."

In only one lesson (139) is there an episode with a teacher encouraging pupils to work at a high level. “From these fractions (on the e-screen), can you match equivalent pairs?” This episode showed one of the few uses of ‘drag and drop’ in a flexible manner – allowing ‘wrong’ solutions and adjusting them afterwards.

The considerable potential of virtual manipulatives (here a fraction wall) was minimised by ineffective use. In one case, the teacher simply worked through a commercially produced package, reading the questions as they arose on the e-screen and manipulating the fraction wall accordingly. Whilst at a later stage, pupils were invited to the e-screen to manipulate the fraction wall; they were told what to do by the teacher. In another instance, the teacher worked through an interactive presentation at the e-screen. In doing so she asked questions requiring one-word knowledge and comprehension type responses.

The manipulation ‘hide and reveal’ was used extensively to affirm answers to given questions. In one case this involved sliding a screen-element to reveal the answer underneath. Pupils were invited to the e-screen to undertake the manipulation once a correct answer had been derived elsewhere. In other cases, the answer would be revealed as the animation from the software was completed by a tap of the e-screen. Usually, ‘hide and reveal’ would be linked with comprehension and application type questions. In some cases this process could be protracted.

CONCLUSIONS

The huge potential of the IAW is being lost in the mathematics classroom when a teacher operates in a teacher-as-instructor mode. In this case the IAW is an e-screen containing information that is to be repeated, replicated and remembered. To realise the potential of the IAW, teachers need to operate in a way more closely aligned to the teacher-as-mediator model in which the affordances of the IAW are utilised to enhance the teacher’s role through effective modelling and the management of levels of feedback.

With reference to table 1, nearly all of the episodes analysed were either Instructor-Presentation or Instructor-Interaction in nature. It seems that there is a sequence of teacher understanding that begins with the use of the IAW as an enhancement of instructional teaching and learning. Teachers then understand more of the pedagogy and achieve greater competence in the use of IAW technology, and we have seen in some of the more interactive lessons an attempt to secure enhancement to the point that the IAW is used for mediation of materials or processes. However at present there is little evidence that teachers are maximising the potential of new presentational technologies to create total mediation.

Not only do teachers need to be more aware of (i) their role as a mediator of learning, rather than as an instructor; (ii) the level of questioning used and the part played by learning models in fostering conceptual and cognitive learning but they also (iii) need to have a greater understanding of the potential of the IAW. Currently manipulations

are being used for limited effect. For example the use of 'hide and reveal' for affirming answers is lessened if it not preceded by some detailed activity by pupils at the desk, some reasoned conjectures from all and alternative answers that have been evaluated by other members of the class. It is not just a question of giving the right answer. 'Drag and drop' enables a flexible, responsive approach to sorting and classifying as in matching equivalent fractions. However, alternative and even incorrect solutions should be allowed in order to promote further discussion (i.e. through cognitive conflict). The use of virtual manipulatives need thought and consideration rather than being used as a simple prompt for the teacher.

There is also need to develop creative links between the manipulations of the IAW, a typology of mathematical content and processes and a level of questioning. Furthermore teachers should be encouraged to recognise how classroom practice with regard to the IAW is more effective if it is associated with other classroom processes such as those defined by Thinking Maths and by Miller and Glover (2006).

Whilst it is relatively easy to draw the attention of teachers to the enhanced use of manipulations, to more developmental questioning, to the location of virtual manipulatives and to encouraging interactivity the fundamental need is for revised lesson planning. "This will involve new ways of thinking about lesson development – how would I teach this making use of the facilities of the IAW, what questioning will I use to help the pupils move forward and what activities should the pupils do on their desks to help embed the learning. It helps if there is interaction between the IAW, the pupils and the mathematics." (Miller and Glover, 2006)

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