

Optimising the use of interactive whiteboards: an application of developmental work research (DWR) in the United Kingdom

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There are concerns that the effective use of interactive whiteboard technology is being inhibited by its use only as a means of presentation. This article looks at the way in which a working group drawn from the university and school areas of mathematics teaching developed materials to enhance the pedagogic use of interactive whiteboard technology. The group worked according to the principles of developmental work research, used mainly in multi-agency social policy planning. The multi-disciplinary, structured and outcome-oriented work was used to support what was considered by the participants to be effective professional development for all participants. Analysis of the approach according to culture, partnership, reflection and conceptual challenge offers evidence that cross-sector experiential learning is mutually beneficial because it enhances both process and outcome.

Background

Although there has been generally laudatory welcome for the interactive whiteboard (IWB) in classrooms in the United Kingdom, concerns have been expressed that the system is only valued for its presentational, and to a lesser extent motivational, aspects and it could well be a passing feature of limited value in improving subject understanding (Glover *et al.*, 2005; Hall & Higgins, 2005; Slay *et al.*, 2008). As a result, much capital investment could prove ineffectual. The emerging view is that the technology needs to be assessed as part of the teaching armoury subject by subject and that there is need for greater attention to the pedagogy associated with interactive whiteboard use (Miller & Glover, 2006; Kennewell *et al.*, 2008). This requires professional development opportunities for teaching staff with an emphasis on both the content and approach to subject teaching and learning given the new classroom

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technologies now available. This article outlines the way in which this has been achieved by a group of teachers and university staff following a particular pattern of development known as developmental work research (DWR). Whilst it is related to work in mathematics, the article offers evidence of a successful approach to professional development that might be more widely used.

The focus for pedagogic change in mathematics has been on the use of IWBs, to underscore pupil understanding through the use of visual, kinaesthetic and, at times, auditory learning. Current evidence at both primary and secondary levels (Glover *et al.*, 2004, 2005; Smith *et al.*, 2006;) points to a reluctance on the part of many teachers to do other than use the IWB as a visual textbook in the same way lesson by lesson. As a result, pupil boredom once again inhibits understanding and achievement and the potential for changed approaches is lost. To overcome this there is an awareness on the part of agencies and professional associations of the need for effective experiential professional development to support enhanced understanding of the IWB as a pedagogic tool, as shown by BECTA (2004) and by Bayliss and Collins (2007). The philosophy behind the continuing professional development programmes developed by the research team at Keele to facilitate IWB use has been based on the work of Harland and Kinder (1997). This concentrated on the need to meet the first-order outcomes of value congruence (so that providers develop an awareness of the potential gains from changed practice) and knowledge and skills (so that participants feel that they can use that changed practice). In practical terms, the continuing professional development experience has also enhanced motivation through positive experiences and led to whole-school changes when pedagogic change has been successfully modelled. Coombs and Denning (2005) have shown that these outcomes can be more successfully achieved where there is an educational research element and inbuilt evaluation. Our aim has been to work with colleagues in the schools to promote IWB training that offered these outcomes for delivery at a local level promoted by local 'expert' teachers (Berliner, 2001)

As part of an initiative by the National Centre for Excellence in Teaching Mathematics, the IWB research group in education at Keele University has been involved in developing materials to support school-based, on-site, professional development for the more effective pedagogic use of IWB technology. The need for this approach was identified from work with seven schools in the initial stages of interactive whiteboard use for mathematics teaching (Miller & Glover, 2006). Arising from meetings with the 38 teachers in the seven mathematics departments involved and additional structured interviews with subject heads, it was clear that there was considerable need for supported professional development—but even though there had been some local authority-wide training, on-site arrangements for provision were considered by the teachers and schools to be more accessible in organisational terms and effective as a training approach. Their comments echoed extensive work in establishing effective professional development as shown by Garet *et al.* (2001) who, in a sample of over 1000 teachers, found that the concerns were with focus on content knowledge, opportunities for active learning and coherence with other learning activities. Later work by Penuel *et al.* (2007) has added a reflection from

400 teachers that the opportunities should also offer time for individualised development and support in a coping with technological developments. Further, Schussler *et al.* (2007) offer a framework within which teaching has to develop if technology is to be successfully integrated. This is ‘hypertextual’ in that it has multiple aspects linking ‘a teacher’s knowledge about students (familiarity) and technology (facility), with a teacher’s teaching practice of integrating technology with content (transparency) and across disciplines and experiences (connectivity), and with a teacher’s sense of support (collegiality)’ (Schussler *et al.*, 2007, p.572) The task of the research group was to develop materials to support professional development for teachers aiming to foster school-based and integrated approaches to classroom practice.

The responses of subject heads in seven secondary schools (Miller & Glover, 2006) showed that the content of the materials developed for on-site use would have to accommodate four sets of tensions:

- a. modelling an ideal rather than simply providing resources (identified by two of seven schools),
- b. focusing on the learning versus teaching approach (two of seven schools),
- c. paying attention to technique in use rather than pedagogic rationale (five of seven schools), and
- d. offering collaborative versus individualistic approaches (five of seven schools).

For these to be resolved it was necessary for the subject departments or faculties to be supported at a distance in:

- a. making and understanding resources and their application (identified three of seven schools),
- b. peer coaching of techniques (three of seven schools),
- c. collaborative changing of pedagogy (two of seven schools),
- d. collaborative changing of classroom context (two of seven schools), and
- e. enabling department members to move on a spectrum from the unthinking use of resources to the development of a critical outlook (four of seven schools).

The heads of department in the schools stressed the need to ‘develop materials for those who either stand on the fringe or are downright consider those who are sceptical’, and argued that ‘changing attitudes requires collaborative approaches that are seen to deliver results in a way that has immediate impact’. For this to be a reality they contended that there was a need for one or more ‘champions’ to plan, deliver and evaluate change in each school.

The university research group had been involved in charting IWB use over a 10-year period and were contracted to produce materials and guidance for their use in school-based, colleague-led professional development. Comments from teachers in a previous project (Glover *et al.*, 2005) indicated that they felt university lecturers were detached from classroom practice, in that they ‘were not under the exam pressures’, they ‘didn’t always see the reality of classroom life’ and they ‘were keen to make the interactive whiteboard work—it would be in their interest

to do so'. Jamissen and Phelps (2006) have demonstrated how the need for mentoring and reflection in using new technology is incompatible with external or cascaded interventions.

To avoid any view of 'top-down', imposed guidance from the university sector and to ensure that the classroom context was maintained, the materials were developed, used and evaluated by a group drawn from school and university teachers. As a result there have been two levels of professional development—for the two-sector group concerned in developing the materials, and for those likely to use the materials produced by the group. This paper is concerned only with the professional development of the first group. Development within schools will be assessed after the distribution of the materials produced by the research team during 2008.

Selecting professional development approaches

Several approaches are currently in use in professional development work for IWB users, ranging from one-off didactic lectures used when the technology is introduced to the school by suppliers to longer term experiential problem-solving supported by local authority advisors. Franke *et al.* (2003) centres on the child as student and identifies cognitive development as the focus of collaborative teacher activity, Loucks-Horsley *et al.* (2003) offer 18 strategies for professional development, including 'aligning and implementing, collaborative structures and teaching and learning', and Borko (2004) outlines the 'new terrain' as including teacher as well as student learning. Within professional development for mathematical education there is, however, a research into the way in which new technologies can be understood and implemented. Four elements can be identified:

- a. *Culture*. In establishing a framework, Tearle (2003) considers the particular approaches necessary for effective professional development in all areas of the use of Information and Communications Technology (ICT), and suggests that the most important factors in successful programme implementation are a whole school learning culture and access to technology supported by structured development approaches (Tearle, 2003, p. 457). Glazera and Hannafin extend this to a collaborative apprenticeship model within the community of practice (2006, p. 190)
- b. *Partnership*. The second element involves partnerships between teachers and their external trainers, and Schrum *et al.* (2005, p. 280) detail the CREOLE approach (Creating Optimum Learning Environments) by which school-based professional development projects are supported by a paired university team. Erickson *et al.* (2005, p. 798) stress the importance of an atmosphere of trust for such partnerships.
- c. *Reflection*. In approaching methodology, Butler *et al.* (2004), Clarke *et al.* (2006), Baumfield (2006) and Jamissen and Phelps (2006) argue for a reflective learning community reflecting on practice, following inquiry-based learning, constructing conceptual knowledge and then making important instructional shifts

- d. *Conceptual challenge.* With concern for mathematical learning, Farmer *et al.* provide evidence that most effective mathematics professional development involves some challenging mathematics learning for the teachers concerned (2003, p. 358). Lin (2006) develops this by stressing the importance of conceptualising learning consequent upon such challenges and then incorporating it in subsequent teaching.

The planning group adopted an approach that brought these four elements together in a way that built upon the experiential learning used with a group of teachers from associated schools in connection with a Nuffield funded project considering the transition from traditional to IWB-based learning (Miller & Glover, 2004). In this work teachers were encouraged to become the creative force and not simply to act as evaluators, but there remained a view that the university staff were acting as course directors, setting the agenda to conform to their research brief and previous research findings. A different approach was needed to ensure equality in establishing the direction of the work and the contribution of participants. The potential for greater creativity was felt to be through DWR.

This stemmed from an activity theory approach developed by Engestrom (1987, 1997, 2001) based upon Vygotsky's views of human interaction with cultural artefacts. This seemed appropriate for the task because it is marked by a problem-solving approach based upon reflective practice, evolved between professionals from differing sectors and focused on discernible outcomes that would affect the experience of client groups. This approach has already been used to foster professional development where participants have been drawn from a number of agencies brought together to implement the legislation and initiatives consequent upon the Every Child Matters (2003) policy in England. The main difficulty at that time was that professionals drawn from education, health, social services and other agencies had differing cultures, practices and philosophies. DWR was an attempt to secure enhanced understanding and a changed focus for participants so that they could deliver a more coherent service. Warmington *et al.*, in justifying a DWR approach for 'at risk' young people, comment that inter-agency working 'is informed by three particular concerns: the identification of new professional practices ... the creation of knowledge that is rooted in reflective, systematic analysis ... the location of emergent multi-agency practice' (2005, p. 1).

Whilst it could be argued that education is a single agency, there is evidence of differing approaches to pedagogic practice between the sectors, and especially between the secondary and higher education sectors in considering subject-based learning as outlined by Knight (2002), who questions the value of courses and workshops led by higher education teachers and sees subject departments within schools as the locus of professional learning—doing rather than done to. Effective change will only occur where there is mutual understanding of the aims and objectives of subject content, of the pedagogic practices appropriate to age and ability, and of the constraints of the teaching and learning environment. This provided an opportunity to develop a stronger partnership concerned with both process in looking at the

pedagogic background to new materials and outcomes in the production of those materials as a basis for professional development within schools.

Research methodology

In applying the DWR model as means of cooperative learning activity, Leadbetter *et al.* (2007) suggest a six-stage process of investigation, evaluation and reflection.

1. Drawing on evidence to question existing practices
2. Analysing the historical origins of existing practices
3. Modelling new practices
4. Interrogating the model
5. Implementing and monitoring the model
6. Reflecting on the processes and outcomes (Leadbetter *et al.*, 2007, p. 91)

This approach was considered appropriate because of its suitability for analysis, planning and implementation of both procedural and pedagogic change and was integrated into the individual sessions and the overall approach.

Whilst DWR has been developed as a means of multi-agency involvement in agreed and changed practice, it also has product outcomes in policy and guidance documents. For this reason it was applicable to our task of bringing a group of people (the planning team) together to produce materials to be used by others. Meetings were planned to take place over a two-year period and, although structured to follow the six-stage approach, there was no prescriptive format and each meeting had elements of reflection on observed materials and practice, discussion of pedagogic strategies and materials, and consideration of developed materials against the criteria for enhanced IWB use.

The membership of the group was as follows:

- Two post-probationary secondary teachers.
- Two heads of mathematics department.
- Three advanced skills teachers (one of whom was an OfSTED inspector).
- Two university mathematics education lecturers.
- One university research associate and former head of a secondary school.

The teacher members of the group were selected by invitation as known 'effective practitioners' at national and local level.

The task of the group was agreed in the research brief to ascertain:

- why IWB technology is not always used to advantage,
- what pedagogic changes would be necessary for effective IWB use, and, after defining these,
- to provide agreed exemplars of good practice as the basis of on-site professional development.

After the first meeting it was agreed that each mathematician in the group would, after each meeting, produce an example of good practice set within its pedagogic

context and submitted with the appropriate IWB materials. It was also agreed that participants would video-record themselves teaching the submitted good practice. The intention was that this would show 'practice in action' and would offer opportunities for evaluation of materials in use by the other group members. The materials were changed following comment at a reflective session each meeting, and will be prepared for distribution to schools in late 2008. This second stage of professional development at school level will be analysed in subsequent work.

All meetings were recorded verbatim and this paper is based on the research records. As such, this is a largely qualitative study but it does offer pointers to enhanced professional development opportunities at a sector interface. The day-long meetings followed a regular pattern of reflection on experience since the previous meeting and a sharing of recent 'interactive whiteboard news'. This was then set into its pedagogic context before a coffee break. The second session each day was concerned with the detailed application of IWB techniques to specific teaching objectives, including the use of materials developed since the previous meeting. After a lunch break the group then worked to develop resources, putting discussion into practice. By agreement the sessions were facilitated by one of the university lecturers in a fully equipped classroom so that the IWB pedagogic potential could be fully realised.

Findings

These are presented according to the concepts we earlier suggested underpin current work in professional development for teacher using new technologies.

Culture

This element underpinned all working relationships. At the initial meeting there was evidence that the group were following the Tuckman (1965) pattern of behaviour. Recent work by Hingst (2006) confirmed that this pattern of group development still has validity. At the forming stage, introductions were followed by a degree of uncertainty and anxiety—especially when the two post-probationary teachers felt intimidated by the superiority of one of the expert teachers and so said very little. After the second session, however, the group were much more cohesive and a significant start to the experiential afternoon work was that participants were offering their own ideas and resources to others from both sectors as a 'norming' stage. Significantly they were establishing a way of working that allowed criticism without conflict, and were moving to the creative development of materials and their use in intended lessons. The group could be said to be 'performing' at the end of the first day of working.

The pattern for subsequent meetings was very similar but all discussion operated at the 'norming' level during the first reflective session of the day and then quickly moved to 'performing'. The final meeting had the task of defining the content and pedagogic elements of the materials, and this pressure led straight into a performing mode. Mention should be made of the role of the leader. He saw himself as facilitator

because he brought the group together and was responsible for funding, accountability and domestic arrangements. Initial 'respect' gave way to collaborative relationships and a culture of togetherness, sharing and good natured criticism marked subsequent meetings. During the final meeting it was observed that the group were working as a team—setting out the objectives and moving together to secure their achievement. The comment 'we really seem to have got going now and need more time together' was indicative of the working culture.

In developmental terms the meeting routine followed the six-stage approach suggested by Leadbetter *et al.* (2007) This was underpinned by the daily routine pointing participants to question practice, to model responses and to evaluate outcomes. Much of this had to be undertaken 'off-site' when participants returned to their schools, or to the group of teachers in training. To facilitate this, considerable use was made of shared and copied materials, facilitated but not directed by the group leader. One gain from this was that a culture of experimentation grew between meetings and so the initial stage of subsequent meetings was based upon a questioning of practice from both classroom and academic viewpoints. This was important in the final two sessions when decisions were being taken about materials to be included on the CD-ROM being developed for school use. The gains were that the university lecturers stressed the cognitive development whilst practitioners were more ready to question conceptual development.

An example of developing culture from the first meeting was seen in discussion of the role participants fulfilled in their working situation and of their reaction to data from the work in the seven schools that prompted this work. After discussion of the tensions identified by practitioners and outlined above, the progress towards interactive teaching was agreed as involving the following:

- The teacher's understanding of the challenge (e.g. when a child is at the IWB, he or she should say what they are doing, and why, to enhance their and others' learning).
- The teacher's point on the IWB learning curve, however this is defined.
- The teacher's understanding of, and access to, produced materials.
- Recognition that the IWB does not always solve problems of teaching and learning.
- Recognition of the need for planning, preparation, assessment and enhancement at macro and lesson levels.
- Recognition of the rationale for IWB use in the 'board, desk, brain' interrelationship.

The outcome of this agreement was that all subsequent discussions began from an agreed set of assumptions about interactivity and that individual work in developing materials was based upon this set of beliefs. The value was shown in the final meeting when the rationale for inclusion of pedagogic and practical materials was being explored. There was a ready reminder from one of the post-qualification teachers that 'it has to be material that can make teachers feel that it is worth while trying to make a difference', from one of the advanced skills teachers that 'we have to offer something

that challenges teachers in the way that they do things’, and from a university lecturer that ‘we shouldn’t lose sight of the changes to the curriculum framework in deciding what we can offer so that teachers understand why it is worth changing their approaches’.

Partnership

In order to prepare materials for use in professional development in schools it was essential for there to be a successful partnership between the research group and teachers in the classroom. The planning team functioned at three levels:

- as a production group;
- as teachers with their own classes; and
- as teachers able to influence others at work.

This was true of the university lecturers as well as of the school teachers because they also worked with students in training and in conventional school-based professional development work.

Partnership in the group was sustained through the culture of belonging, the sharing of materials and the need to respond to evaluative discussion. It was extended into the schools through the ability of participants to work with others, either as advanced skills teachers in several schools or with faculty teams. There was common agreement that the task of the planning group was to influence pedagogic practice by showing how the IWB could be more effectively used. To this end, the first session of each day meeting was concerned with reporting back on how materials, practices and concepts identified in the previous meeting had actually been applied. This enabled the group to work towards a ‘production’ pattern of considering the concepts to be followed in looking at a mathematical topic. This was achieved by sharing approaches currently in use, developing a rationale for any changed approaches, considering the IWB techniques available for new materials and then applying these in a lesson situation. True partnership was needed in this because of the need to trial materials with pupils of differing ages and abilities, and with other teachers who had not had the benefit of the pre-production discussions.

Agreed assumptions about group culture underpinned attitudes in developing materials as shown in the report on part of the second meeting.

We considered how we had changed since the start of this project. Examples of changes included:

- use of Activvote to help pupils improve their own performance (using KS3 paper), recognising that this might be useful just for some questions, not all questions;
- printing off flipchart pages to help with work on the desk, but also to help focus the work on e.g. graphing the data rather than drawing the axes, but also making it so that it matched the on board template;
- similar to above, but only providing some pupils with this support;
- improvements made in sizing work and using snap to grid;

- using ActivStudio as the means to organise all electronic resources (embedding files and placing all links in it);
- recognising need for whole school (mathematics) consideration of indexing and sharing files;
- using the ‘Starter of the day’—and using some of these at the end of the lesson as well;
- using a greater variety of questions;
- one, two pupils at the board solving a problem that has been posed while the rest of the class might be completing similar (simpler or harder) examples;
- using very short timer to answer e.g. 4 non-straight-forward questions (pupils get better as they learn what is needed);
- recognising that it takes time to do these things and that it helps to have specific time for departments to share ideas as well as resources; and
- use of show and tell.

In this discussion there was no sign of hierarchies of opinion or deference to either the advanced skills teachers or the university lecturers. Genuine characteristics of partnership were seen in the easy way in which criticism was given and taken, in the many offers of help and sharing materials and in the way in which working groups varied in composition.

Reflection

This became an important part of the process because every set of materials had to be developed within its pedagogic context. To facilitate this, three framework questions were agreed as a basis of planning.

- What is to be gained from developing a set of materials for this topic?
- How does past, and shared, experience of teaching the topic affect possible approaches to changed materials?
- How does interactive whiteboard technology offer potential for new approaches?

The pattern of meeting organisation did much to prompt reflective activity, as did the practice of having laptop facilities at each meeting so that the sharing of materials became the norm. Indeed, frequent exchanges between participants during breaks ended with ‘I will send it on to you’.

There was, however, a need for a conceptual structure so that the process of reflection was guided and purposeful. To this end each topic was examined in a round-table way, asking for details of present practice. The group then worked as pairs to ascertain possible changes to practice, and the link to mathematical concept development before a plenary session allowed consideration of cognitive aspects of the work and a return to the practical implications of reflection for the task in hand. This was shown in the discussion of the framework for the production of materials according to the requirements of the New Maths Curriculum:

My maths and boardworks are easy to use, require limited preparation and offer homework opportunities but considered as no better than textbook pages and as such will not stimulate interactivity. (Speaker 1, advanced skills teacher)

Requirements of materials therefore to be something offering the ability to learn to discern so that teachers can reflect, evaluate, stimulate interactivity and share ideas. (Speaker 2, lecturer)

But we want that to be in real terms as giving immediacy of feedback, coverage of as many curriculum topics as possible, time-saving help for preparation and homework ... (Speaker 3, teacher)

Yes ... and somehow sparking interest based upon coping with the New Maths Curriculum and especially with the bits they call the process elements ... (Speaker 4, head of department)

... but we have also got to offer some opportunity for things like voting systems and the development of texted answers for immediate assessment. (Speaker 1)

Doing that sort of thing means that the missioners are the key to sharing experience ... and so we need to do things so that we attract enthusiasts for existing approaches, enthusiasts for new approaches, and enthusiasts for IWB use as technology ... (Speaker 2)

... and still be interactive! (Speaker 3)

This then led to consideration of the role of consultants, peer specialists and collaborative learning within schools. Pairs work identified practical desiderata for effective learning with the materials being developed by the team. This reflection led to the following conclusions.

- Need to create a 'manual' for teachers, which should be simple and should link clearly with resources that may/may not be specially created.
- Focus should be on mathematical learning as much as on technical skills for IWB use in order for it to be accepted by teachers.
- New training and development resources should be user-friendly and help improve use of planning, preparation and assessment (PPA) time.
- Materials should be accessible in terminology to need to allow for use by the more sceptical, and by non-mathematicians.
- Materials should help teachers adapt current resources easily (e.g. PowerPoint files).

Conceptual challenge

Arising from the reflective activity was the agreed view that:

There is still a great danger of participants assuming that they would be developing materials to utilise the presentational potential of the interactive whiteboard ... going back to the 'wow' factor. This would have been mechanical and offering responses to teachers who ask 'How can we show this differently. (Advanced skills teacher)

We have got to move beyond alternative presentational devices ... most of these are applicable mainly to year 7 and 8 mathematical topics, to looking at the way in which interactive whiteboards could be used to support enhanced understanding of more complex mathematical concepts. (Lecturer)

The questions used in reflection activities were then revisited but within the mathematical curriculum context. As a result, participants were encouraged to consider the

steps that make for effective learning of a concept, expressed by one post-probationary teacher as ‘selecting the bricks for the wall’. This led them to a way of working that integrated mathematical understanding, pedagogic approaches and the use of IWB technology. This was driven by the need not only to produce materials but also to explain to others rationale for the inclusion and use of materials for distribution to schools together with guidance to colleagues for their use. In terms of DWR thinking, this was the aim of the activity. Expressing personal views of accepted practice in a way that could be justified in pedagogic terms and shared with others was not always easy and so became a challenge often helped out by interaction between the sub-groups.

Conceptual challenge sprang from discussion of the role of interactive whiteboards as an affordance in mathematics teaching. Earlier work revealed comments from teachers who had been unable to see how the IWB could be other than a presentational device (Miller *et al.*, 2005), and, to overcome this, the group worked at applying a threefold approach so that the affordance was integrated into lesson planning. One of the teacher members argued that the greatest problem ‘is that many teachers are opposed to what they see as a way of teaching that takes away their control of what is happening’. Subsequent discussion led to focus on the need to persuade many teachers to move from didactic ‘problem, method, example, practice’ approaches. As an advanced skills teacher commented: ‘we shall only have been successful if we have convinced our colleagues that they can work in a different way’. One university lecturer posed the question ‘what actually happens in a successful lesson?’, and after further debate it was agreed that the guidance on the use of the materials should focus on what was happening:

- at the board—mediation between concepts, materials and activities;
- on the pupils’ desk—activities for exploration and consolidation; and
- in the pupil’s head—the lesson outcomes.

At a subsequent meeting this was illustrated by a set of materials produced by a teacher participant on developing the relationship between the number of sides of a polygon and the contained angles.

Conclusion

The use of the DWR approach has proved to be of great help in this work because its task—the preparation of materials for use by others—has been fostered by the interaction of people from differing educational contexts and career patterns. The preparation of a set of materials provided the catalyst for working together and the use of a sequence of investigating existing practice, developing new approaches and then implementing these with subsequent evaluation has strengthened the capacity of the group to work effectively in securing intended outcomes. This is shown in their conclusion that in developing the materials and guidance on their use:

...we will work around the idea of episodes associated with ‘at the board, on the desk, in your head’, questioning informed by Bloom’s taxonomy, and then looking to target questioning at the ‘analysis’ level. (Head of department)

Many would argue that DWR is not a new way of working and that there is not a significant initial difference in outlook between participants in this activity and those involved in school-based workshops, but we feel that much has been gained from an approach that offers equality of participation, team effectiveness, systematic reflection and challenge. The aim to explore the potential for enhancing technological affordance for pupil's mathematical understanding appears to have been met in the production of the CD-ROM of materials for schools. Our task is now to see whether these do prompt pedagogic change in the schools we will be working with once the materials have been circulated. Whilst DWR is intended as an inter-agency approach, our evidence is that it can work wherever there are assumptions of status and power that have to be overcome if there is to be true cooperation. This situation could occur within schools where 'expert–novice' relationships could be exploited to secure learning outcomes.

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