**Practice and subject-specific educational research: the case of mathematics at Oxford**

**Anne Watson**

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**Introduction**

The story I am going to tell is of mathematics education research carried out within the Oxford Partnership (and its predecessor relations with Oxfordshire schools) and the relations of research with practice. The Partnership means that subject education and education researchers are in constant contact with the education systems and practices, so the potential for research to be immediately relevant to and about classroom teaching is always there. In addition research properly carried out and reported publicly has the potential to have longer term effects on practice and the research community more widely. I am going to talk about both conceptual and descriptive contributions to mathematics education research developed here at Oxford, and show how these arise from and within Partnership and in turn influence teachers and teaching in the Partnership and beyond.

**Two-way**

Firstly, research in a Partnership is rarely a one-way enterprise, i.e. rarely is the researcher a separate agent using the school context to give access to individual children or individual teachers for their own agenda. More often research is multi-partite and dialogic: teachers, children and researchers are all likely to be learning and adapting and discussing changes in knowledge, particularly teachers and researchers, and teachers and students, adapting together as the study proceeds. Teachers are therefore key players in research, even if this is not recognised explicitly, since the business of education is for children to learn their subject in normal classroom situations over time and all research conducted in school takes place in that longer term environment. Partnership gives teachers constant access to active researchers, and researchers constant access to teachers and classrooms. Researchers do not always set out to effect change, especially as there are no theorems in education – no sure-fire ways of teaching that guarantee improvements in subject learning.

**What works**

Huge efforts were made in the 70s and 80s to find out what kinds of teaching worked best. Innovation nearly always makes a difference: as has often been said, we WANT the so-called Hawthorn effect in educational research, we WANT what we do to have a positive effect, so enthusiastic teachers and researchers who believe their ideas will make a difference will make sure they achieve that. When researchers *do* set out to affect change, the Partnership ethos ensures that this is undertaken with teachers as knowledgeable professionals and not as impositions – a good thing as one thing we DO know is that imposed change rarely has the effects after roll out that it had in its initial development; we also know that ANY change made by committed teachers can have a positive effect on learning. Hattie points out that the only innovation/intervention studies that have an effect size significantly above that of most is the use of assessment for learning – but this does not tell us the best way to teach any topic, nor is AfL well-defined in use and may only lead to improvement where teachers are not already in the habit of giving learners ongoing feedback. The implications of Hattie’s work are hard to fathom, and one way to read it is to say that an ongoing strong relationship between teaching and research, continual innovation, ensures positive improvement even if the effect size of the particular innovation is below his threshold. Experience in other cultures, where ongoing engagement of universities with teachers engaged in collaborative professional development is the norm, suggests this continual model of PD is worthwhile. Another way to read Hattie is to say that he does not address didactic research – researching ways to teach particular subjects and topics – which is what professional practice in many Asian countries undertakes as the norm.

**Value of teachers’ insights**

Let’s look for example at the question of whole class teaching to see how partnership could enrich knowledge about teaching. There were some in the 70s who claimed that direct whole class teaching is *the* most effective method. This kind of blanket ‘finding’ is of little use to teachers and also hides the fact that direct whole class teaching done badly is often detrimental to children’s learning. Peterson, who had earlier advocated whole class teaching, later had the insight that the subject matter mattered – teachers had been saying to each other things like ‘you cannot teach art, or PE, or ..., by direct whole class teaching’ but if researchers act as if their knowledge is separate from practice the world has to wait for someone like Peterson to wake up to the fact and reanalyse the findings. What he found was that whole class teaching worked better for declarative facts and procedures, but was not the most effective form of teaching for problem-solving, higher order questioning, and so on. “What a surprise!” the teachers said. By contrast, research in partnership takes teachers’ knowledge seriously as a source on which to build, knowing that, while teachers might be biased in a whole range of known ways towards different social groups, particular forms of knowledge and so on, researchers are also biased by their current paradigms, zeitgeist, and their own knowledge and experience, to over emphasise some aspects of practice and be blind to others. Partnership can provide a check to both sides of this, preferably by open dialogue when projects are being developed but also later during analysis.

**Effective teachers**

More helpful than global results are descriptions of teaching that show connections between didactics and learning, so that without the problem of defining ‘effectiveness’ we can say that certain didactic approaches are good at developing certain kinds of mathematical activity. This could be about understanding particular mathematical ideas in particular ways, or of mathematical activity that can influence overall mathematical learning over time, up to employment or higher studies. What successive mathematics education researchers have tried to do at Oxford is to work between generic explorations of good teaching and specific didactics for particular mathematical ideas to provide knowledge about teaching and learning mathematics which is sufficiently general to provide shape and structure for teachers’ work, and sufficiently specific to ensure that mathematical concepts and methods are addressed.

**Mathematics education research in Oxford**

I now turn to look at cases of mathematics education research in partnership settings in Oxford as examples of respectful collaboration with teachers, and shall attempt to draw from them some common features.

**John Backhouse**

The earliest published research in mathematics education emanating from here is a set of studies by John Backhouse (about 1980). He obtained public funding for a large project examining the take-up of post-compulsory mathematics using a purposive sample drawn from Oxfordshire schools. This study was undertaken under the auspices of a steering group that included local teachers, headteachers, local authority representatives, academic mathematicians and colleagues from OUDES. It was a multi-layered mixed methods study in which students’ and teachers’ views were garnered as well as other data about choice, teaching, prior attainment, subject content, gender and so on. Although qualitative data was available, Backhouse’s analysis and reporting were quantitative, and nowadays we would question what important variations the data is hiding. Variations in social class and ethnicity can only be guessed at, and variations in how much maths the teacher knew and whether they worked explicitly to enthuse students beyond test preparation were not discussed. By the way, one of John Backhouse’s research assistants was Stephanie Kiryluk who was later a joint author in Richard Doll’s definitive study on smoking and cancer..

**Linda Haggarty**

In the late 80s Linda Haggarty researched what partnership means in the setting up of our current ITE system. She was one of Donald McIntyre’s doctoral students and, after evaluating how the principles had acted out in the context of mathematics ITE at OUDES went on to establish partnership as the model for mathematics ITE at Reading, a fortuitous cyclic approach in teacher education action research which was then published as a book – which ought to be better known as one of the outcomes of the Oxfordshire Partnership since it shows some of the problems with applying principles developed in one place to another. Linda’s research was strongly situated in the partnership, and was about the partnership – it was more generic than mathematics specific except in the fact that the mathematics context in schools was not necessarily of good subject teaching, or of sufficient qualified teachers, and schools were being dragged kicking and screaming (by and large) into new epistemological approaches to the subject and new forms of assessment and activity – this situation is ongoing in mathematics –permanent churn - and I have often questioned some of the pillars of partnership in initial teacher education as a result. Turmoil in school subject communities was not a good way to start the shift to partnership. Interns’ problems, as she reports them, reflect this.

**Teachers as autonomous researchers**

One in particular, when he had become a local HoM, had a disagreement in his school about the implementation of a whole-school policy and set up a research project to show that his point of view was valid, using the substantial changes in maths GCSE results as the outcome measure to compare to changes in other subject GCSE results in the school. The work has been presented nationally, but not yet published as a refereed paper. The aspect, by the way, was the liberal use of praise rather than the use of subject specific comments to value students’ vocal contributions to lessons. His philosophy was that if a student contributed to mathematics discussion, the remark should be treated as one would treat a contribution to discussion in any context and not as an opportunity to smile, say ‘brilliant’ and hand out merits. This is one example of many where whole school implementation of generic policies can pour obfuscatory slime over more subtle subject-based issues. This particular work has contributed to our PGCE course in various ways, not least through influencing interns to think more deeply about how they respond to their students’ comments – this requires a level of upfront mathematical awareness, to ‘listen to students’ rather than to ‘listen for answers’.

**The need to learn**

While Linda’s reported research is mainly around how interns learn behaviour management and has generic value, the course she constructed had several subject-specific features. The taught content was structured around an influential report by Cockcroft in 1982, in which various recommendations on the teaching of mathematics were put forward which required big changes in the ways in which mathematics is taught and assessed. Interns were therefore introduced here to practices that they were unlikely to see in schools, and forward thinking heads of mathematics and mentors hoped that the presence of interns would help to make these changes in school. Of course, what happened more often was that the new ways of teaching and assessing would be attempted maybe once by interns, but the rest of the time their practice would fit into the school norms. Linda’s work showed that, however carefully two-way programmes were constructed to coordinate reading, observation, experience, discussion, if interns did not recognise a ‘need to learn’ in their own teaching then little was achieved in the longer term.

**Attempts to use ITE as a conduit for school change**

Jumping forward from this, the model of using ITE as a conduit for more general change was used extensively, and not very effectively, by successive governments who more and more defined ITE course content to match with their plans for school-based change. For example, high demands on ICT use on ITE courses was supposed to bring about change in ICT use in schools. Governments saw ITE course content as forcing belief change, rather than as educating future teachers to think about teaching. Those of us who examine other ITE courses saw often the effects of this in the content structure of such courses, - something of the depth of teacher education, and the nature of teacher knowledge, has been continuously eroded by government attempts to control content, but – still not satisfied – the whole role of the university is now seriously challenged – maybe because impositions into ITE did not bring about massive change in schools.

**Shared roles in partnership research**

In terms of research and the partnership, Linda’s research showed that partnership learning might work best when there is a shared role of knowledge-based reflection, questioning beliefs, exploring alternatives, responding to teachers’ ‘need to learn’,.

**Barbara Jaworski**

The shared roles of teacher and researcher were reified in Barbara Jaworski’s work. When Barbara came here she had already become an established expert in understanding mathematics professional development, and also had generated a model of understanding teaching. This model, the teaching triad, had been developed through a grounded theory approach from hours of teacher videos; it can be seen as a nuanced version of the more traditional “teacher, learner, subject matter” triangle, sometimes called the ‘didactic triangle’ (Herbart 18th century Germany), or in French didactics theory situations didactique: student, subject matter, milieu. What Barbara had found was that, in the teachers she studied who were all trying to use these new ways of teaching, at any moment all three of these aspects would be acting together in teachers’ decision-making – therefore this triangle might be a tool for reflective PD.

Management of learning

Mathematical challenge

Sensitivity to students

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During her time here she took several partnership based opportunities to research PD using this triangle. The Best Practice Research Studentships were established and several partnership mathematics teachers took these up, working with us on developing ‘best practice’ in their partnership schools. The relationship between research and practice was quite complex in these situations, because while teachers were researching their practice, Barbara was researching the processes and relationships by which they learnt, and also the research relationship itself. Sometimes my understanding of it felt like a bad-hair day I tried to capture this complexity in yet another triangle

Research into any of these relationships can be done from outside, or inside. The relationships might be between different people, or might also be roles for one person. This became particularly true when the teachers were also students on part-time courses, such as Diploma in Educational Studies or the MSc in Professional Development in Education, both of ran here over a few years. The same would be true now of the MScLT. Barbara was increasingly researching and conceptualising the process.

In Barbara’s work, the principles Linda had identified as important in partnership ITE were also embedded in PD practice, with the university providing not only the access to research knowledge and the accredited collaborative space for sharing views and for challenging perspectives, but also the research tools with which to evaluate learning. Her work took her in the direction of the nature of professional learning communities, and co-learning, rather than in the nature of what is to be learnt. The work has been most successful in Norway, where a large project that structurally embeds shared enquiry at every level of mathematics teacher education, education research and classroom teaching has been set up. The mathematics-specific nature of this structure is characterised by the central role of adaptation and use of mathematical tasks as tools for development in each activity.

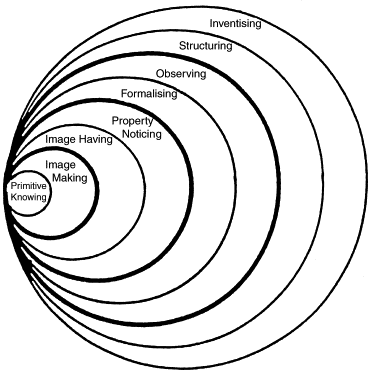
**Susan Pirie**

My predecessor Susan Pirie’s research was a different model of research partnership. She was trying to find out about school students’ learning over time in classroom contexts – she was after a generic model for mathematics learning that captured students’ construction of meaning, whatever the individual topic, whatever the task-type. In this respect she was focusing on the nature of school mathematics learning. This approach is closer to my own concerns.

Her research took place in partnership classrooms where practice ensured discussion amongst students as they carried out extended mathematical tasks. She wanted to map what happens as students encounter new ideas over time. Her focus was not on the groupwork, discussion, dialogue *per se* but to use these as giving access through language and gesture to the growth of ideas. The underlying assumption was that what happened during these episodes somehow replicated what might happen for learners in other kinds of teaching/learning situations over time as their experience of a new mathematical idea took different forms. I find that it has some illuminative power in my own mathematical work and to that extent it could be said to fit with the illuminative research tradition. For this she needed classrooms in which working together on extended explorations over time was the norm, so that she could record particular groups of students over several lessons as they grappled with a sequence of related tasks in their normal lessons. She found schools and teachers for whom this was normal practice, and used the investigative work they were doing at the time as her mathematical context. Others at the time and since were researching such classrooms as cultures or discursive communities in their own right, but for her they were the windows to mathematical understanding.

She managed to get a massive (for then) grant to carry out this work, half a million pounds from Leverhulme, from which some was used to develop the basement of number 28 as a mathematics education research centre, with pods for her doctoral students (one of whom is now a professor in mathematics education in Canada) and semi-hexagonal tables, ideal for mathematics PGCE teaching, ... now where did they go? Her research took place in partnership schools, and often her relationship with the schools would be multi-layered, with her as researcher, PGCE tutor and general tutor in the partnership, an approach which not only saves time and travel and makes life liveable for us, but also ensures that interpretation of data takes into account the context and other variables not observable in the videos themselves. Also, it establishes researchers as people who do know about schools, students, and teachers’ lived experience, and not as outsiders whose judgements may be partial.

The model of understanding that she developed did not become instantly popular - at the time the zeitgeist was to focus on ‘becoming mathematical’ or ‘mathematising’ in a general sense, that is developing habits of mind and ways of being, rather than ‘learning mathematical ideas’. The final version, which went through several transformations before publication – many of which I found in filing cabinets and rubbish bins when I took over her room, was nicknamed ‘the onion model’ and is now more widely known and used as the mathematics education research field veers from sociology of the classroom (sometimes quite extreme, in my view, such as describing mathematics itself as embodying masculinity) back towards mathematics cognition (possibly due to increased engagement of researchers from CHC). It can now be regarded as a major contribution to understanding mathematics learning over time, a particular feature being the affordance to track ‘folding back’ as learners return to earlier images and knowing when they tackle more complex conceptual challenges.



**Learning from teachers**

Whereas most of Pirie’s work was using partnership to provide a context, she came across some particularly innovative teachers during her work and published a research paper about methods for solving linear equations as a result – off her beaten path. This leads me to partnership as enabling researchers to learn from teachers. I use four examples, all from research students. In all cases the partnership traditions of trust and multi-layered relationship enabled the projects to be set up – but there is more.

**Brooke Maxfield**

Brooke went in with a clear idea that she wanted to research the effectiveness of her own favourite method of teaching ‘collecting like terms’ when used by other teachers, an aim many ex-teachers and ex-tutors have when thinking about research. Pre- and post-test with comparison group to ‘control’ is expected to give them the results for which they yearn. Asking schools for volunteer teachers has pitfalls, as one school put her with a particular teacher who, once the study was running, did not do what Brooke asked her to do at all. The project could have collapsed but two things happened to save it – firstly our close links with schools allowed us to find a partnership school at short notice where the project could be repeated; secondly, and more importantly for this talk, because many of our p/ship teachers are aware of the nature of research one of them engaged with Brooke to show her his favourite method of ‘collecting like terms’. This enabled her to see that her method was one of a class of methods that aimed to draw visual attention to similarities – because of this she was able to conjecture that (ii) it was the visual attention that mattered and (i) her method might be more effective than methods that did not use visual emphasis. In the time constraints of a masters’ thesis she could do little to explore this but the important thing is that she recognised an issue beyond her own concerns – the importance of perceptual responses to algebra was what she was really learning about.

**Thabit Al-Murani**

Thabit used mixed methods to set up a comparative study using local partnership networks to explore the effects of deliberate use of variation in the teaching of algebra. He introduced teachers to his understanding of variation and found some who recognised its potential importance. He found some small positive effects for teachers who were using variation with some awareness, but not a dramatic effect. In fact one of the ‘untrained’ teachers was using variation more clearly than some of the ‘trained’ ones – possibly because variation is embedded in mathematics anyway as a feature of tasks and teaching. Approaching teachers as someone willing to learn *from* them he looked for other aspects of their work that might contribute to differences in students’ learning and found a clear difference in patterns of classroom discussion that might account for differences in learning: it was not the use of variation *per se*, but the different ways in which teachers exchanged ideas about variation with students in classroom discourse. From this he constructed the concept of ‘exchange systematicity’ meaning that some teachers appeared to have systems of exchanging variation with students that kept variation ideas ‘on the boil’ in classroom discourse, whereas other patterns of discussion seemed to leave students’ ideas hanging or lost.

**Emily Macmillan**

Emily Macmillan set out to find out if teaching proof to students developed their deductive reasoning capabilities more widely, as is assumed in the arguments for teaching proof to everyone and its inclusion in the curriculum. She devised measures to see if students’ reasoning behaviour changed due to having had some lessons on proof. As with the other two students, she was also open to learning from teachers and consequently the most interesting part of her thesis was that in which she identified two different kinds of emphasis her teachers gave to aspects of proof, meaning that students would have different concepts of proof from their lessons. In one case the teacher used empirical testing of cases to ‘back up’ the logical argument – so empiricism trumps logic – while in another the reverse was the case. You could say that the first teacher was educating engineers and the second educating mathematicians.

Both Thabit and Emily were full partnership products, having been educated in partnership schools, having Oxford PGCEs, having taught locally, and then getting ESRC grants to research in schools.

**Nichola Clarke**

Willingness of partnership teachers to ‘expose’ their teaching of year 11 bottom sets to critical gaze over time – her analysis of how teachers varied in their willingness to provide opportunities to reason, and to develop reasoning....

**Learning from teachers**

In all three cases, the researchers set up classic kinds of research with teachers and teaching as the focus, but went beyond that to learn about differences in teaching within superficially similar situations. This is the kind of didactic contribution we have made from Oxford through our regular, non-threatening, relations with teachers and schools – the detail of the shaping of mathematical knowledge in lessons. In Brooke’s case this was particularly noticeable as an unexpected contribution to Brooke’s thinking by a teacher who understood research.

Conceptual contributions that have emanated from here due to these relationships include those I have just indicated, how to exploit visual attention; patterns of discussion; and how the nature of mathematics is shaped; plus further ideas from my own work and that of colleagues about how awareness of example spaces, variation, task design, questioning, reasoning, sequencing, can influence learners’ mathematical activity. This is in addition to any deliberate input we might provide through research or CPD, such as Andreas Stylianides’ ESRC-funded project on proof with a partnership teacher, Karen Russell, who co-presented work undertaken in her classroom on students’ understanding of proof at a national conference in 2010, and Gabriel’s and my deliberate inclusion of ideas from our research in our teaching, such as Gabriel’s work on cognitive conflict, and planning lessons around a pivotal idea.

**Anne Watson**

My own reasoning about research in mathematics education is that teachers are the experts in the complex tasks of teaching, so it is from teachers I can learn. Most of my research has started by observing teachers or discussing issues with teachers. However, I have aimed not at the construction of general models but more at describing the variety of possibilities in particular situations. I am going to illustrate the approach with three kinds of relationship between research and practice within the partnership.

**Case 1: Structuring teacher knowledge: What to observe in mathematics lessons**

Relationships within the partnership in mathematics education are so strong that I often hear stories about concerns teachers have – some see us as outside informed ‘ears’ with whom they can talk about things that bother them to do with curriculum, or pedagogy, or assessment etc. A few years ago I was told, in the space of a few days, several stories about mathematics teachers whose lessons had been judged as unsatisfactory by senior managers who were not themselves mathematics teachers. Clearly, from the stories I was told, some teachers were judged according to a standard model of a ‘good lesson’ that had little bearing on what was being taught. Somehow the world had flipped back to the pre-Peterson belief that a lesson could be judged as ‘good’ or not independent of the subject matter. It seemed that a good lesson was becoming one that conformed to school imposed norms (when the register is taken; how long the first task is; what proportion of time is spent on discussion etc.) rather than creating a fruitful environment for learning.

Because of the strong relationships in the partnership we were able to collect a group of experienced teachers together at short notice to discuss different kinds of mathematics lesson and how these might be appropriate for different aspects of mathematical knowledge. In doing so, I was relying on the fact that many local teachers have, either on our course or on similar ones, been encouraged from the start to have a questioning reflective mindset to professional development and also to be willing to be informed by literature and research findings. As a result of this process, and my ongoing work on identifying the didactic detail of lessons, we produced a resource for observers that showed how lesson structure had to match the aims of the lesson. I do not know how widely it has been used in Oxfordshire, but it has been used by some other local authorities and academy chains, by Ofsted, and also appears on the website of the National Centre of Excellence in Teaching Mathematics.

The types of learning objective were a compilation of what the teachers said, organised according to the ‘strands of proficiency’ that have been identified in a literature review by Jeremy Kilpatrick and his colleagues. The opening sentence matches the findings from TIMSS 2003 analysis of lessons from six high-achieving countries, but it came from our teachers. I could say similar things about all the content of the table – it came from our partnership teachers but – hey presto – it matches the research about effective mathematics teaching. You can understand why I often read research papers and wonder whether the authors bothered to talk to teachers first!

**What to look for in mathematics lessons**

In a good maths lesson there should be coherent development of ideas, clear rationale behind tasks and choices, and a storyline to the ideas in it.

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| **Learning objectives** | **Key processes** | **Features of teaching** | **Questions to ask** |
| ***Conceptual understanding*** | Relate concepts  Reflect on activity  Identifying and naming  Recognising  Reasoning about | ‘Hard’ questions that might not be answered in one lesson  Introduction of ideas that might initially confuse  Dialogue  Students might be puzzled, might resist changing their minds – time to think  New ideas should build on or challenge prior knowledge  A range of representations might be used  Lesson is likely to be stop/start rather than flow quickly  What if…? | How does this relate to their prior knowledge?  What else do they need to experience before they fully grasp this idea?  How does this lesson fit into a sequence of lessons?  What was evidence of learning?  *n.b. there may not be much written work; students may appear to be ‘off task’ at times, look for verbal evidence of thinking* |
| ***Procedures*** | Understand representations  Explain steps  Incorporate prior knowledge  Accuracy  Layout | Worked example(s)  Explanation  Helpful layout  Inclusion of students’ ideas  Possible use of students’ own methods  Opportunity to practice  Written work | Why this number of examples?  Why this choice of example(s)?  How many experiences will they need before they will be fluent? Accurate? Remember procedure?  How does this relate to conceptual understanding?  *n.b. lessons that combine procedures with understanding the concepts behind the procedure are likely to be more like ‘conceptual’ lessons than ‘procedure’ lessons* |
| ***Development of mathematical repertoire*** | Remembering  Recognising in familiar and unfamiliar contexts  Choice  Attaching meaning to representations | Short questions – emphasis on recall  Complex problems that need to be analysed  Memory aids  What does this remind you of?  Students’ reactions used  Several examples offered  Reference to procedures and concepts  Examples made up ‘on the fly’ to respond to students | How does this fit within the scheme of work?  Why is this topic important to remember?  How does this relate to their conceptual and procedural knowledge? |
| ***Development of mathematical strategies*** | Representation  Choice of method  Problem-solving strategies  Interpreting situations  Recognising mathematical structures  Comparing and evaluating strategies | Complex and/or real-life problems that might not be solved in one lesson  Slow entry – time to think; possible confusion and uncertainty  Whole class discussion or groups  Incorporation of students’ ideas  Not much visible progress in a lesson; might be no direct instruction  What if …? | What they are used to?  How does it fit in sequence?  Did you have some idea of a ‘best’ method?  What was evidence of learning?  *n.b. written work may be shared and/or rough; students may appear to be ‘off task’ at times, look for verbal evidence of thinking* |
| ***Development of mathematical reasoning*** | Making connections with other ideas  Looking for, or constructing, patterns  Generalization  Conjecturing and justifying  Communicating reasoning | Whole class discussion or small groups  Slow progress – time to think  Why? Why not?  Individual efforts to express reasoning  Emphasis on particular language formats  Initial muddle as students try to get to grips with good arguments | How does this lesson fit in a sequence?  When is the next opportunity for this kind of reasoning?  What was evidence of learning?  *n.b. written work may be shared and/or rough; students may appear to be ‘off task’ at times, look for verbal evidence of thinking* |

This kind of work justifies using local teachers as a source of knowledge – and what do I as researcher add to this? My role in situations like this is as a synthesiser, which I can do because of my outsider and overview stance, and because I have knowledge of a wide range of frameworks and language forms in which to express what, for teachers ‘in flow’, might be tacit. My ways of seeing are about patterns and elaborations of generalities of practice, where an individual teacher will have the specifics of her practice. So I can look for similarities and connections between the statements of individual teachers, and also spot omissions and think about how to prompt them to talk about missing aspects.

**Case 2: conceptualising teachers’ activity: IAMP and CMTP**

These projects involved constructing descriptive reports of teachers’ practices and processes: in these cases teachers who made a difference beyond the norm for students who enter secondary school with below national levels of attainment. I found these teachers within the partnership by asking for *evidence* of their success, not by reputation as is often used to find ‘good teachers’. The fact that we have a trusted relationship makes this easy to do. The full story is too complicated to tell here. We identified a set of principles that underlined the practice of individual teachers, when their observable practices looked very different. Publication of these inspired several groups of people and were widely distributed and influential beyond the dissemination we did ourselves. Two partnership schools picked up the ideas and got in touch with me to tell me they were going to use them to guide the work of the whole mathematics department and we then did the same kind of study for the departments (plus one other which I found through opportunistic national contacts). In these cases we did not influence practice by intervention of any kind – instead we made available for others the work of a few. What was the research role? Our work in this context was pure Stenhouse: systematic inquiry made public. The inquiry was our own, but also the teachers’ as they went about their work and evaluated their progress. We ‘made it public’ but part of this was organising what we saw and in this endeavour we were influenced by two theoretical approaches – firstly some moves that are technically associated with grounded theory, of refining our instruments and foci according to what we were learning along the way, and later by organising our data according to the structural approach of activity theory – as interacting systems each with their particular intended outcomes and tools and community structures. We had not set out to see their work as if it fitted an activity theory lens, rather we set out to collect rich data about their activity and organise it so a story could be told. The story we told had, in the end, to explain changes and disruptions along the way and we used the most appropriate intellectual tools for that task. In many ways our findings match what is known more generally about school improvement, but is clothed in subject specifics, including considerations of how teachers’ personal subject knowledge was most effectively tackled, and the classroom use of statements about expertise in mathematics to help shape activity.

**Case 3: Helping learners in school learn mathematics: post Nuffield**

Neither of the above kinds of research really get at how to help children *learn* mathematics in school, however. The third type arises from consideration over time of the practices of all the teachers I have ever observed. This is the responsibility we have as researchers to describe what cannot be described by others, because of our privileged position of being able to have a critical overview and to juxtapose what we see in one situation with what we see in another. It is the way I became articulate enough to turn statements from teachers into questions for observers in the ‘observation’ resource.

The research perspective I bring to it is: what experiences does a learner need in order to understand a particular concept, and how does teaching shape these experiences? This means publication in research contexts is not the main output; the main output is teacher workshops in which teachers might be able to take a new look at familiar ideas, and I develop and refine ways of thinking and talking about the associated didactics.

A recent example: multiplicative reasoning is a key mathematical idea that currently not all students manage to understand enough to make progress in secondary mathematics. To do so requires some perceptions of quantities and number relations whose roots are not in counting but in comparative measurement or enumeration. Furthermore, it requires vigilance by teachers to ensure that students who use additive reasoning to solve *ad hoc* problems are helped to develop multiplicative strategies alongside – for example by providing tasks that cannot be solved using additive strategies, and by providing images, diagrams, contexts and language forms to shape multiplicative understanding. Typically this learning – in school - takes place over several years. The work Terezinha did in our Nuffield project Key Understandings in Learning Mathematics introduced me to some of the literature relating to this in young children.

I began to work with some resources that afford representations of quantity that, while being about number, were not themselves numbers. Some of you will know these as Cuisenaire Rods. John Mason and I have juxtaposed these with the use of elastic to represent scaling – an idea I came across in some Swedish research and then again in some New Zealand research. Over a series of workshops with primary and secondary teachers all over UK and elsewhere I have developed a sequence of tasks that draw teachers into some possibly new insights into the relations between multiplication, scaling, division, ratio and measurement. Having refined this over several years in several contexts and used the feedback and enthusiasm of teachers I felt able, in the current curriculum draft, to present the related concepts in a new order and with new connections that I knew, from teachers, were teachable. Of course there has not been time to trial the curriculum but that is not my fault! What I have instead is the knowledge that, with appropriate time to think about the ideas and design schemes of work and teaching, the sequence is teachable. Teachers have confirmed this, and being embedded in partnership has helped me do this work, helped me communicate.

I then extended these ideas for secondary mathematics for a Nuffield funded new book, Key Ideas in Teaching Mathematics, written with two colleagues. The transformation of knowledge from personal mathematical knowledge, plus research knowledge about learning, into knowledge about teaching is not trivial. Recently I have seen this as at the heart of the teacher education project – the responsibility to work personally on such transformations particularly in key areas, such as the shift from additive to multiplicative reasoning I have just described. The researcher and teacher educator, whether the same person or different people, have to find language and representations for and of key mathematical ideas; transform this into language for and of teacher education; and help teachers transform it into language for and of classroom learning. If you knock out the research component – as will happen as teacher education leaves universities – you knock out one of the nodes of this structure.

**Practice and research**

I will conclude by summarising not the forms of research relationship, because they are well-known, but the factors that enabled them to be successful:

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| **Opportunities** | **Tensions** |
| **Questions**  How does research respond to, adapt to, ignore, the pace of imposed change in school?  Different kinds of research question and insight can arise from HE, schools and teachers working together | Research can be disrupted by policy change  Teachers may be more concerned with policy change than with longer term issues  Teacher and researcher perspectives and knowledge interact, interrogate and augment each other |
| **Opportunities** | Tensions |
| **People**  **Teacher knowledge and practice adds depth and relevance to research**  **Much depends on individual research interests in HE and in school** | Some school-based opportunities and initiatives may not be taken up by researchers and vice versa  Researchers’ interests may not match those of teachers  Role of teacher in publication: co-author or pseudonym? |
| **Opportunities** | Tensions |
| **Funds and resources**  **University-initiated research has to support teacher time; teacher-initiated research has to support academic time; teachers need access to research resources** | Research funding needs to include full teacher participation costs  Costs of HE engagement are high for schools  Even research-aware schools can depend on reports, summaries, websites, newspapers  Studies of imposed local change v. international publication |
| **Opportunities** | Tensions |
| **Work**  **I see the dyadic work of teacher education and research as continual recontextualisation and transformation of subject matter and the provision of experiences to enable others to do the same** | Transformation into practice requires particular kinds of knowledge and process  Removal of teacher education from universities?  Working practices and attitudes in universities and schools, such as separation of research and education |