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Theories of Mathematics Learning and Teaching for Beginning Teachers

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What should beginning teachers know about theories of mathematics learning and teaching? How should they come to know? If reflective practitioners are to be empowered beyond the walls of their classrooms, they need to be able to articulate their own theories and study them critically. Can they do this without an awareness of the literature on learning theories and the underlying philosophical and ethical perspectives which govern prescriptions on successful practice? This article was partly prepared before the 1994 *Annual AMET conference where some of the issues were discussed in a workshop. I am indebted to those who participated in the workshop for their contributions to the debate and hence this paper.*

Theory in Initial Teacher Education

Despite the frequent attacks on Higher Education for perpetuating a divide between theory and practice within initial teacher education, the days have long gone in most Institutions when the curriculum was organised into chunks of "history of education", "sociology of education", psychology of education", teaching method, and so on. The advent of 'partnership in training' occurred well before the declarations of Circular 9/92 (1992). Much attention has been paid over the past two years to the nature of practical teaching skills and their description via competence profiles. Such detailed specification has been helpful in articulating and unpacking rather vaguer and more global descriptors of, say, "plans lessons effectively".

This attention on the craft of teaching deflects attention from the notion of teaching as an intellectual activity. The purpose of this paper is to focus debate on the latter issue for a while and in particular to question whether we have thrown out too much of the theory in our attempts to make Initial Teacher Education CITE) relevant and school-based.

Many ITE courses have in recent years focused training around the concept of the reflective practitioner, and centred learning around issues within education. Such issues then form a basis for the introduction of theory and its relationship to practice. The notion of the reflective practitioner has been debated at length (see for example: Fenstermacher, 1988; Schon, 1983, 1987; Van Manen 197; Zeichner, 1983). As Copeland et al (12993) point out:

> 'Teacher educators appear to be eager to promote reflectivity in their students'… Most of this activity, however, has preceded disciplined inquiry into the teachability of reflectivity as a professional stance.'

That it is desirable for our students to become reflective practitioners is, I would suggest, a shared belief amongst mathematics education teachers. What we mean by the phrase 'reflective practitioner' and what we do to help our students become reflective practitioners forms much of our debate. The nature of *our own* beliefs about mathematics learning and teaching inevitably influences both the content and the way we organise the curriculum for intending teachers of mathematics.

Being a reflective practitioner does not in itself imply adherence to a particular set of beliefs about learning, nor of a specific underlying knowledge of theories of learning and teaching. It does presume that the student teacher will engage in reflection upon learning and teaching and will acquire by so doing a set of skills, understanding and awarenesses which will enable them to improve the quality of what they offer children.

The practice of action research within the classroom assumes this notion of reflective practitioner, actively engaged in planning action, implementing the planned action , observing, reflecting and replanning further action in the light of observed behaviours. However, the observation, reflection and interpretation of behaviour can only be done in the context of the set of beliefs and "theoretical perspective" on learning and teaching held by the action researcher.

Smyth (1987) argues strongly that reflection is a form of political action and that a view of

reflective activity without the concept of the teacher as a critical and intellectual person leads merely to reflection on the best choice of what is offered by so-called experts and leaves the teacher as technician, manager or efficient clerk of prescribed practice. Reflection necessarily embodies emancipatory action.

In the light of the current debate which leaves politicians formulating teaching and learning policy and procedures, frequently from a "common sense" perspective which implicitly supports a transmission theory of learning, ordinary classroom teachers are left powerless and devoid of recourse to such argument if they have no knowledge or understanding of their own perspectives nor theoretical or research evidence by which to back this up.

How then do student teachers explore their own beliefs, formulate their own theories, make explicit the reasons for their interpretations?

And what does that imply for us, mathematics education teachers, working with our students soon to become teachers.

Within my own Institution, colleagues and I have shared heated debates about the extent to which students need to have explicit input on learning theory. It is these debates which prompted me to raise the issue within AMET.

Discussions at the 1994 AMET conference confirmed that many of us believe strongly in the need for students to read contemporary writings about teaching of the sort published in 'Mathematics Teaching' and 'Mathematics in School'. Most of us would go further than that and expect students to read chapters from books such as 'Mathematics, Teachers and Children' (Pimm, ed, 1988) or older favourites like 'How Children Learn' (Holt, 1967). Reference to major popular research findings such as CSMS (Hart, ed, 1981) was also common.

At my own institution, such writings might relate to an issue under consideration. So, for example, when considering gender issues in mathematics learning, students would be invited to read related material and share their interpretations. They might relate to an aspect of practice. So, when looking at the teaching of number, research findings, articles from the professional journals and reflections on teaching would form part of the overall considerations informing student choice of appropriate classroom activity for their children.

Few colleagues at the conference felt it was appropriate, particularly for one year PGCE students, to delve in depth into more theoretical writing about different theories of learning either in general or mathematics specific. I was left with a sense (perhaps wrongly - and if so many apologies to those who were there) that explicit awareness of developmental or cognitive psychology, of radical constructivism, social constructivism, or information processing theory was generally not seen as relevant or appropriate at the stage of initial teacher training. A study of the work of particular individuals - Piaget, Bruner, Vygotsky - was generally not supported. I am not convinced that this should be the case.

As teacher educators, we read contemporary work with a personal history of experience. Our interpretation of such writings are embedded in what else we know about "theory"- knowledge which by and large our students do not own. Our interpretations are also embedded in the breadth and depth of our experience as teachers - experience which by and large our students do not share.

Contemporary writing on mathematics learning and teaching varies significantly in style, context and intellectual challenge. My own experience is that mathematics students, particularly those who have already gained a degree in mathematics and are following a 1 year course, find reading a comparatively difficult and somewhat alien activity at first. Indeed, some one year students claim to hate it and give this as a reason for studying mathematics - to get away from reading. The language and concepts of most writing on learning theory is new to most students and many find it difficult to interpret. The language of professional journals is often easier and there is no doubt that such writing is often much more accessible to student teachers of mathematics. The focus of

writing on specific issues often grounded in practical experience frequently enables student teachers to identify with its context even if they disagree with the content. To what extent do we too often opt for classroom focused writings because our students find them more accessible? Do we do enough to help them read the more theoretical writing?

To what extent do we encourage our students to read 'critically'?

Surely any critical thinking implies that we demand of students that they articulate their own personal beliefs about mathematics, about how children learn, about what constitutes effective teaching, about their philosophic, political and social perspectives? Being able to do so implies an ability to use the language of social, political and philosophical discourse. This in turn demands an expectation that students consider writing which moves beyond the classroom practical context into the dialectic.

Do we expect students to formulate and articulate their own personal theories? Or do we merely expect them to reproduce appropriate sections of relevant articles in support of choices about activity type or teaching approach? To use the language of Marton and Saljo (1984), are we encouraging a 'deep approach' to pedagogical learning or merely a 'surface approach'.

I raise the question therefore, as to whether consideration of contemporary literature grounded in a practical classroom context provides students in training with sufficient depth of awareness of theoretical perspectives for them to build upon when they leave.

I would suggest that most student-teachers engage in c1assroombased reflective activity - talking about their work, evaluating lessons, deciding what to do, when to do it and how to do it - but remain largely unable to deconstruct their practice at a theoretical and ethical level.

Some would argue that given the time constraints and the overwhelming public emphasis on the craft aspects of teaching it is not possible to cover all that we would wish to cover, particularly on a 1 year PGCE Course. But then we never have been in the business of training teachers, we can only begin the training process. We must decide what to begin. Now that the responsibility for the beginning development of many of the craft aspects of teaching has been devolved to schools, we have an opportunity to focus our work with students on teaching as an intellectual activity. We have the opportunity to concentrate more pointedly on reading, critical reflection and the articulation of personal beliefs and theories.

Introducing a Theoretical Dimension

Some courses (Cheltenham & Gloucester CHE, for example) send out a course reader prior to the start of the course. The new Open University PGCE demands that students read Wood (1988) on learning theory at the start of the course and the student's first assignment demands some reflection on its main points. Is the OU alone in setting learning theory awareness so high on the agenda so early?

At my own institution, in common with many other Institutions, we expect students to read a range of pedagogical material and use this to support their assignments. We use reading seminars where pairs of students are given reading and share their synopses with the whole group. We discuss views on the nature of mathematics and invite students to examine the views reflected in the schools in which they work.

Last year we set our PGCE students an entire assignment solely on reading and reflection which was set up by four members of staff each giving a 20 minute presentation of an area of study. All four areas required students to delve into theoretical literature at some depth. The students commented very positively on the value of this to them. It was rated much more highly than the second assignment which had a school based curriculum development focus - many students stating that this was the worst aspect of the course.

But we are still learning ourselves. Sessions earlier on in the course with I-year PGCE students which focused specifically on various theories of learning with some comparative analysis of a range of theories was not so successful. Perhaps it was a case of too much too soon and in too concentrated a period? I am sure in retrospect I could have chosen a more appropriate selection of writing. Flow charting an article – identifying the main arguments, and presenting the ideas in flow chart format - is a technique which helped students to pick their way through more difficult work. Practice at reading also helped.

The students who are most widely read and appear to be most able to 'make sense' of pedagogical writing are our 2-year paCE students who often have a background at degree level which is more centrally located in the arts and social science fields. Year one students on a 4-year BEd, coming straight onto the course from a school or college background at 18/19 and I-year paCE students appear, by contrast, least able to make sense of such writings.

More recently, we have introduced an explicit introduction to the nature and philosophy of mathematics and to learning theories, within the final year of our new ITE programme. Students are asked to write an essay which discusses different philosophical positions, different theoretical stances on learning and classroom episodes. Students have found this a hard task - 'more like a Masters Unit' to quote one.

It is not always easy constructively to challenge students' views and opinions. We need to deconstruct our own practice, to place ourselves within the dialectic and to share our own positions and perspectives with student teachers. Are we explicit enough with them? We too need support in developing our own skills and our own critique.

For me the feedback from the last few years confirms that students find the intellectual theoretical dimension valuable and important. They need support in beginning to view teaching in this way. Our 2-year paCE students appear to have a significant advantage from the start. We might question whether I-year students straight from a Mathematics degree are disadvantaged. If they are, compared to graduates in other disciplines, perhaps we should be also challenging our Mathematics departments in the University sector over the demands they make of students as undergraduates.

The challenge we face is to construct an intellectualising curriculum which places reading, critical questioning and a growing awareness of theoretical and ethical perspectives at the centre of our contribution to the beginning education of teachers of mathematics. The pressures are to marginalise this, to omit the difficult bits and help to prepare students for the craft of teaching.

"Theory" is important - let us raise its status.

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Learner Empowerment through a Problem-Centred Course

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In this paper it is asserted that students and teachers often work towards a *restricted set of goals which do not encompass higher-order learning objectives. This situation, it is argued, may be addressed through* a *problem-centred course in which students are made aware of the full range of learning objectives and thus empowered to take on the responsibility for their learning. There follows the description of a teaching experiment involving a group of second year BEd (Primary) students, the course of which took a surprising and rather unusual turn.*

Empowerment and Awareness of Learning Objectives

I want to start by making an assertion, based on observation, which may be contentious:

I believe that the generality of learners evaluate their own learning against instrumental criteria and further, many teachers, from their own experiences as learners, evaluate their students' learning against the same instrumental criteria.

'Instrumentalism' arises partly out of our culture which appears to put the highest value on 'objective' assessment - this is generally understood to mean timed, unseen examinations - and partly out of the means by which we are able to test our own understanding that is by exploring what we can *do.* Learning objectives have been variously identified. One significant source articulates these as facts, skills, conceptual structures, general strategies and personal qualities (HMVDES 1985). Instrumental criteria focus upon the first two in this list. They are relatively easy to observe in ourselves and to test in others. The remaining three in the list are, by contrast, quite difficult to observe and yet possibly of much greater importance because they are about changes in the actual person of the learning subject. This, after all, is our ultimate goal in education, as El'konin (1961) observes:

"The basic unit (cell) of educational activity is the educational task. '" An educational task differs fundamentally from other types of problems in that its goal and its result consist of a change in the acting subject himself, not in a *change in the objects on which the subject acts."*

(Quoted by Davydov and Markova 1983 p. 60).

There has, of course, been a trend to introduce course work assessment in schools as part of GCSE so that objectives in addition to facts and skills may be assessed. However teachers have been able to reduce even these tasks to *system* and *routine* so that students are subsequently assessed on their knowledge of routine course work-skills rather than the *higher order objectives* of conceptual structures, general strategies and personal qualities.

Many problems are encountered when we try to evaluate even our own conceptual structures. What we understand, believe or conceive may fit with the totality of our accommodated experience but it may not match *conventional knowledge* (carelessly labelled 'truth' by some) which arises from the accommodation of a much wider body of experience by the *informed community.* Even new experiences may be perceived in narrow, idiosyncratic dimensions because of our 'orienting schema' (Neisser 1976) which provide a mental context or conceptual framework for our exploration. As Fleck observed sixty years ago *"Evidence conforms to conceptions just as often as conceptions conform to evidence."* (Fleck, 1935, pp. 27-8). This is a problem which I believe all learners need to confront and surmount. Further, I believe it is especially important for teachers to be able to address the problem. Consequently, as a teacher it is my aim to make my

students aware of the problem of evaluating *all* aspects of their own knowledge. As a teacher of student-teachers I also aim to help them to become sensitive in turn to the learning needs of their pupils.

My approach to this task is to challenge students with significant conceptual problems, to make them *aware* of the limitations of their own understanding, *aware* of their own uncertainties and *aware* of their own feelings of panic, despair or happiness as they grapple with the problems. Incidentally, I believe there is a difference between suffering various emotional states which may impede thinking and performance and being aware of these states as human reactions to particular situations. It is only when a learner's awareness is evoked in these ways that they are in a position to set themselves goals towards which they can work and learn. Ernest (1991, p. 291) describes *"a problem posing pedagogy"* as *"a powerful emancipatory teaching approach* [which] *encourages active knowing and the creation of knowledge by learners."* Studens setting their own learning-goals is also consistent with constructivist teaching (if there is such a thing!) as Lochhead observes:

"The constructivist teacher must ... (have) a *willingness to provide students with the opportunity to devise their own learning unimpeded by teachers' helpful suggestions."*

(Lochhead, 1992 page 551)

It is not sufficient only to *provide* challenges and problems, these need to be set within a supportive and open environment where students are encouraged to reflect upon their activity and feelings and in which they feel able to express their feelings however negative these may appear. Although I am concerned with the development of personal qualities I do not view some of the social graces, such as stoicism, as appropriate or desirable in my classroom. Mason (1987) indicates that support is central to the task. He outlines three requirements *"to educate awareness":*

- *support for positive (non-judgmental) reflection;*
- *support for noticing moments when they (students) could have acted differently, or wished they had acted differently;*
- *support for preparing themselves to notice similar possibilities in the future.*

(Mason, 1987, p.31)

This approach can lead to uncomfortable moments for the teacher such as that provided by the following reflection submitted by a BEd student with an assignment:

I have completed the first part of the exercises given on the sheet, but if I'm honest, I don't know why!

I have not done 'A'level or even 'AS'level maths, and I had not met calculus before the start of this module. We *have another thirteen weeks of lectures before I* am *due to sit an exam* - 1/8 *of my degree. At the moment, I feel I'd be better off not even showing for the exam, as I have nothing to write .... I don't understand calculus· I don't even have any rules I can learn and repeat!*

I am *hoping that, between now and the end of May, I will have some insight into this module· but until then I'll just keep on doing these exercises in the hope that something will "click". As for the article* [an article on calculus upon which the assignment was based], *well, it might as well be written in Chinese for all the good it's doing.*

I have a great deal of sympathy for this student, not least because I, the teacher, hold a radically different conception of learning mathematics. The examination is important, of course, but the student reveals *their* conception of mathematics assessment as something that may be overcome by memorising rules. The student omits to mention that the rules will be forgotten very quickly

after the examination and that the course content and examination merely represent, for *them*, necessary and important hurdles that need to be crossed before going entering the teaching profession where the *rules* will have little or no value. This student needs time, patience and support, and a sympathetic approach to the examination. The student forcefully articulates the notion of 'instrumentalism' with great clarity. The challenge to me is to awaken the student's awareness of learning during the following *thirteen weeks* while at the same time making sure that they *are* properly prepared for the examination.

A Teaching Experiment

I want to share a teaching experiment which I undertook in the course of a module entitled 'Foundations of Mathematics' with a second year BEd (Hons) Primary group studying mathematics as their main subject. Part of the assessment for the module is an essay on number. In previous years a list of possible titles has been provided and students invited to write an essay on their choice. This has revealed a number of shortcomings. Some students have chosen a topic and reproduced much of what has been covered in class, and thus have not been able to get a very good mark. Others have chosen a demanding topic which has required considerable reading and research but not really given themselves the opportunity for assimilation of new ideas to the extent that a convincing essay can be written. Others have written good essays but 'played safe' and avoided any demanding mathematics, so that again their assessment has been limited.

The central aim of the experiment was to set a challenging assignment which provided opportunity for the demonstration of imagination and insight, but at the same time was fair to all students and accompanied by adequate support. This rationale was shared with the students together with the aims, objectives and task description as set out below:

***Aims**:*

To provide o stimulating, challenging assignment which develops: (i) awareness of the nature of mathematics, (ii) an understanding of a piece of mathematics and (iii) an opportunity to demonstrate personal achievement through an essay.

Objectives:

To share problems in understanding mathematics text and through discussion reach some sense and then be able to articulate the sense made;

To develop an understanding of the meaning and properties of irrational numbers;

To write with clarity and imagination about irrational numbers.

Task:

I am giving you all a copy of a short chapter from Hardy and Wright's momentous tome "The Theory of Numbers". It is Chapter 4 *"Irrational Numbers". You may observe at first glance that it looks difficult, opaque and 'user hostile'. If this is the case it's not surprising because for ordinary mortals like most of us, self included, it is! I want to spend some of our class time in the next few weeks using this chapter as the basis for seminar discussion - we will work slowly through it, trying to unravel the meaning and make sense of the content. In the last week of the semester I will invite you to write a short essay on "irrational numbers" - about 1600 words; this essay should include some of the mathematics that you have 'discovered' in the seminars - re-presented* so *that it demonstrates your own understanding and communicates well to an 'ordinary' numerate reader.*

You will be expected to prepare for each of these seminars by reading thoughtfully a section of the chapter, we may assume that we will progress sequentially through it, noting the points where

understanding is clear, doubtful or absent, so that you can take an active part in class discussion. I am convinced that the more effort you put into this preparation then the better will be the quality of your essay at the end.

At the end of each session students were required to write an account of what had happened, how they felt and what they intended to go on to do before the next session. I also imposed the same discipline on myself. For the students this made them reflect upon the session and gave them a record of what they had done, I photocopied their 'accounts' for my own evaluation purposes and gave each of the students a photocopy of my own account so that they were fully involved in my own reflection and evaluation. Especially with student-teachers I believe we must share our own professional approaches, insights, judgements and evaluation. I believe this is important with learners at all levels if we are truly to *empower* them.

As expected the students found the text very challenging. In particular they were meeting specialised symbols for the first time and the text makes many assumptions about the readers' knowledge which did not match that of the students. It was pleasing to see that the 'experts' in the class, ie those who had recently completed A-level, were not able to coast along on the strength of their instrumental knowledge. Their understanding was challenged. But the biggest problem perceived by the students was not the hostility of the text but the assessed essay that was to be written at the end.

In the seminars students were encouraged to share their partial knowledge and understanding with each other to allow them to reach the intended meaning at their own pace and in their own direction. I was not always very successful in remaining at the sidelines of the discussions.

I arrived slightly late to the fourth session and found it already underway (I interpret this as indicative of their acceptance of responsibility for their activity). I had warned the students I may be delayed. Not wishing to impose my agenda on the class, who had taken on the responsibility for this, I asked to be enlightened as to their discussions to that point. They had been sharing their concerns regarding the essay, so I had another opportunity to try to put their minds at ease on this issue. I then enquired if they had any other concerns, no response, not just silence but heavy, pregnant silence! So I told the class that I would leave them again and wait outside until they were ready to share what was on their minds, at which time they were to call me in. I expected to be out of the room for about five minutes, it was twenty and when they invited me back in it was explained very courteously that they thought they would get on better without me! They found my presence intimidating, that I sat in judgement on their contributions, that they would feel more free to voice their misunderstandings and share their insights if they did not feel they were being 'assessed' by an expert. On the understanding that I was in my study ready to be called back immediately if they wanted any input from me I 'graciously' withdrew. I reproduce my account written at the end of that session:

"Learners should take responsibility for their learning – I believe this - but it is *a bit difficult when put into practice! ~ I question now what my role in this learning enterprise is - do I indeed have a role? Given that only learners can do the learning - the teacher, no matter how competent, cannot do this for them - if the learners say "OK. we don't need you" then fine. This task is about* <u>learning.</u> *not about teaching - but do I still have ajob? Or organised in this way would it be possible to teach several groups simultaneously? And there's a thought - if this is perceived as successful then why not - if it helps divide the group into smaller sub-groups differentiated according to their needs?*

I feel I've lost control - I don't know what has happened in my absence - I don't know what learning has taken place, what experiences have been encountered. But then I question, was I ever really in control, was it just an illusion? - I felt as if I was because I retained my position of "power" from the front but is it ever possible really to control learners interpretation of their experiences. Do I ever know what learning has taken place - I can't see it or *feel it - I can only imagine on the basis of my perceptions and is my interpretation of what I perceive valid? Do I ever know how learners interpret the learning experiences encountered - no, I cannot ever be sure*

that the "picture" I see is the same as that seen by others.

So, I reflect, is anything really any different? Only that I am now sure of the uncertainty we face as teachers!

This account, as usual, was copied and distributed to the students. Not all the students were totally happy with the decision for me to leave for the whole session as one commented:

"I'm not really convinced at this moment that 'prolonged' group work without Simon will work. Though I do feel that discussion for, say, a few minutes will be beneficial."

Others made positive comments regarding the decision such as:

"I feel that this session has been the most useful so *far as there didn't seem to be the pressure to understand everything as there has been in the past week or so. We decided as a group that if we didn't understand something we were to stop and "get things clarified" as it helped those who didn't understand to understand and those who did to clarify their thinking by having to explain to other people* so *that they understand."*

The group continued to be very supportive of each other's needs. It was also evident that individuals set themselves very clear, specific goals to achieve before they met again. The assessed essay has been mentioned above and in students' comments, generally in a negative spirit. But I question whether this experience would have been successful if there had not been this extrinsic motivation to engage with the task.

I rejoined the group for the final session before the essay writing, really to make sure that there was an opportunity to clear up any details. But it was clear that I had lost my place in this group. I wasn't unwelcome so much as surplus to requirements!

The essays were delightful in many respects. In particular they were *alive* with the students own conceptions, rather than weighed down with recast, regurgitated passages from other texts. The essays were clearly a reflection of the students expressing their own understanding of the subject. It must also be accepted that they were flawed by divergence from conventional conceptions. I try to avoid using the word 'misconception'. As Confrey remarks:

"Labelling a *student's model* as a *misconception fails to take into consideration the perspective of the student, for whom the belief may explain all instances under consideration and fail only in cases to which* s / *he* is *not privy. "*

(Confrey, 1991, page 121)

Assessment of the essays proved a little difficult, but sharing the confidence of the second marker and external examiner helped to ensure validity and that the students were fairly treated in the process.

Discussion

It is my contention that the students involved in this small experiment were empowered to take on the responsibility for their own learning because they were made aware of their own needs. They were able to decide for themselves what they required and then set themselves their own learning goals. The nature of the activity broke down the instrumentalism nurtured by the examination system to which the students have been subject for many years and they could perceive themselves as learners in the fullest sense concerned not only with facts and skills but also with conceptual structures, general strategies and personal qualities.

It could also be argued that if students want facts and skills then the *imposition* of problem-solving content which is directed towards developing conceptual structures, general strategies and personal qualities is not empowerment. It is rather an exercise of the teacher's power and domination, and the students' awareness is that of being forced through a regime in which they feel little or no ownership. Freire (1972) makes the point that real empowerment occurs when the weak become critically aware of their own

situation and take on the struggle for empowerment for themselves. In the experiment described above the students did take on for themselves the responsibility for their own learning. However, if the means to this end causes students to write as the one quoted at the beginning, it may be questioned whether they were empowered or brought to a point where they had no option but to respond in the way described.

The dilemma described in the above paragraph together with the significant emotional burden entailed in sharing students' *angst* makes this approach rather less than attractive. But I am convinced that it is justifiable and- more importantly - faithful to the needs of the students and the nature of mathematics.

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From Teaching Mathematics to Training Teachers

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This article outlines some of the experiences and opportunities which occurred when the author moved from teaching secondary school mathematics to teaching mainly initial teacher education students at a higher education institution. It attempts to highlight some of the difficulties and to suggest a possible route towards more effective induction procedures.

Introduction

While there are many studies of initial teacher education courses, HMI (1991), Sands and Bishop (1993), Bramald and Wood (1994), and a growing number about mentoring, Booth (1993), Watson (1994), Nolder, Smith and Melrose (1994), there seem to have been fewer attempts to bring these two perspectives together; in other words, to consider the experience of moving from being a teacher of secondary mathematics to being a secondary mathematics tutor in initial teacher education. This article, based upon my own recent experience, may illustrate some of the underlying problems related to the transition, as well as opening up perspectives for further reflection.

Some Issues

At one level, moving from classroom teaching to initial teacher education can be seen simply as an extrapolation of twenty years of classroom experience being handed on to others: a simple transfer of skills synonymous with effective teaching. This, of course, is oversimplistic; it is insufficient for trainees to be taught merely to 'do what I did'. My own experience as a secondary mathematics teacher although long (20 years) and relatively wide (having been involved with many school mathematics departments as a teacher, research assistant, teaching practice supervisor and mentor) is, in one sense, anecdotal, in that it cannot possibly cover the full range of experiences trainees may encounter in schools. But such extrapolation is always potentially redundant in a rapidly changing educational context.

As a classroom teacher who is also a mentor, articulated reflection upon one's own lessons is integral to the learning process of the trainee teacher. Yet there seems to be a fundamental difference in that reflection when one becomes an initial teacher education tutor. This difference involves an additional layer of reflection upon even the most reflective classroom teaching. There is another stage at which the initial teacher educator steps back further to articulate objectively that reflection, thereby inevitably invoking theories of teaching and learning. Hence one has to touch, however intuitively and unsystematically, on the theoretical aspects of teaching and learning.

There are potential hazards for both trainees and new tutor here: once the tutor alerts trainees to the theoretical models which inform one's own classroom teaching, there is a very real danger of moving away from the pragmatic experience of teaching. Over-reliance on theoretical models of teaching and learning can create a double crisis of confidence. On the one hand the new tutor must acquire an awareness, at the very least, of the problematic territory of research into mathematics education, with which one's familiarity is intermittent, at best. My background is privileged to some extent; having been involved in a small-scale research project and a number of mathematics education conferences; nevertheless, my own theoretical knowledge was severely limited at the start of this new career in higher education and this had implications for confidence levels. On the other hand there can also be a crisis of confidence for trainees, torn between investing an enormous amount of time in theoretical debates about teaching and learning whilst at the same time having to engage in a prosaic way about their current school placement.

Research and academic writing are important elements of any post in higher education. These aspects may cause considerable concern for someone who has spent the majority of her working life teaching in secondary mathematics classrooms. The positive side of this is that the tutor has much empathy for trainees who are faced with writing assessed assignments in essay form when the last essay many of them wrote was for GCSE English.

There is an extent to which one of the problems of transition from school teaching to university

teaching is one of the awkwardness involved in providing help for the new tutor, particularly in the areas mentioned above. The university teacher who has been involved in this kind of work for many years is constrained. The culture in which academic research life is embedded, particularly in

non-scientific subjects, is an individualistic activity. There is also a potential difficulty of implied seniority. New recruits to initial teacher education posts have had seniority within another profession, classroom teaching: it could seem patronising to offer help to a colleague with much experience of that branch of education, the role shifting necessary may be complex and/or subtle. Effective sharing of experiences is difficult due to the unrelenting accretion of pressures on university staff in recent years. Induction courses for new staff are organised on a university-wide basis and seem more effective for colleagues new to teaching *per se.* There has been a change of emphasis with the introduction of partnership schemes for initial teacher education; more former classroom teachers are moving into the higher education sector. Perhaps there is a need for higher education institutions to think more about appropriate transitional mechanisms for such colleagues.

The New Entrant's View

It goes without saying that to reflect on my own transition after almost a year in post, is to have to reconstruct its critical stages at some remove from the positive and challenging nature of the experience. Being thrown into the deep end is always more satisfying if one did not drown in the process! For example, writing the institution-based curriculum course in mathematics from scratch was such a challenge. Colleagues at my institution were very supportive, whilst allowing me the freedom to develop whatever activities seemed appropriate. Lack of up-to-date knowledge of current research and academic writing was a problem when attempting to produce relevant reading lists, but advice was available from colleagues, including those in another institution. However, in writing the course handbook, it was clear that many aspects of teaching mathematics could only be covered superficially due to the small amount of time during which PGCE trainees are based at the institution.

Being an ex-secondary school mathematics teacher straight out of a comprehensive school was an undoubted bonus in terms of initial professional credibility, both in trainees' eyes and those of the teachers with whom one works. That credibility went some way towards alleviating an initial insecurity; the first few teaching sessions induced all the same feelings that I remember vividly from the start of my career as a secondary teacher! However, that same credibility was not a panacea, especially in the early stages of the institution-based course. Trainees wanted recipes and managed to redirect discussions all too often into 'What would you do…?' In retrospect I responded too often to that recuperative question. At the same time, perception of credibility with trainees is likely to decrease in proportion to the length of time since the tutor was actually teaching in a school!

My first group of mathematics PGCE trainees come from a wide variety of backgrounds, as one would expect. Several graduated last summer whilst some are beginning a second career. It was to be anticipated that many would view mathematics as a series of skills to be learned and practised, *ad infinitum,* but one might also have expected the most recent graduates to have received a more en Iigh tened form of mathematics teach ing! Their prior experiences of being a pupil in mathematics lessons constrained their images of teaching mathematics. Leinhart (1988) and Calderhead and Robson (1991) have shown that these images are very hard to change. One way in which to disabuse trainees of their belief in the effectiveness of 'drill and practice' was to teach them the 'square root algorithm' at the beginning of a session. Fortunately none could remember it prior to the teaching. The remainder of the session dealt with other issues but they were asked to calculate the square root of a given number, using the algorithm, just before the session ended. Only two trainees were successful. That activity seemed to convey a powerful message which was mentioned frequently throughout the course.

As a teacher I had been involved with: supervision of trainees on teaching practice (pre-partnership days), selection of students for PGCE courses at two local training institutions, teaching sessions at those institutions and hosting 'recent and relevant' teaching for staff. Hence links with tutors at the two local training institutions were very strong. Those colleagues have been very helpful and supportive. Forging similar strong relationships with mathematics teachers across our partnership is a slow process; opportunities to meet are limited and the distances involved are large, but it is to be hoped that such relationships will continue to develop over time. I was surprised to find that the teachers involved in our mentor meetings did not, in general, know each other. That, together with lack of experience of running such meetings, made it difficult to initiate effective discussion. To be cast in the role of expert is to be expected to

provide all the answers! It was disappointing to receive little requested feedback following the meeting, although, on reflection, I should have remembered how intrusive such requests for feedback often were when I was a busy head of department.

During my career as a school teacher I was privileged to have opportunities to visit and work in many other schools. That was a great asset both to my own personal development and to that of the mathematics departments of which I was head. There is some exciting mathematics teaching and learning occurring in secondary schools. At the same time, it is depressing to listen to some trainees saying that they have seen very little other than whole class teaching or lessons that are 'textbook bound'. Opportunities for teachers to share good practice and exchange ideas across schools within the same county seem very limited now; this has perhaps had a negative effect on potential effective curriculum and staff development within some mathematics departments. This same sharing and learning from colleagues, if seen as a priority for school INSET budgeting, could benefit teachers in developing their mentoring skills; some of whom still appear to see school experience within a partnership framework as synonymous with teaching practice.

There is a more mundane side to starting a career in higher education, for example: setting up filing systems, learning how the administrative systems work, getting to grips with a different IT system, acquiring keys for one's office and teaching rooms, learning how to use the photocopier (so much more sophisticated than the one available to me as a schoolteacher!), finding out about budgets, how to order resources and so on. Established staff are well aware of all the procedures; these can be overwhelming for the new entrant who is conscious of continually bothering busy colleagues with what may appear to be trivial questions. Because all this can become bewildering for the new entrant, it is unnecessarily time-consuming. Perhaps a concise written guide to such aspects of settling in might alleviate some of the anxieties involved.

Relationships between tutors in higher education and their students are different from those between teacher and pupil in schools. My students are all adults and as such are aware of responsibility. They are developing professionally, but are not yet colleagues within the teaching profession. They must be allowed responsibility, but at the same time need encouragement and reassurance: beginning teaching can appear quite daunting and it may be that, for the first time in their lives, there is the possibility of failure. In these ways the relationships involved are similar to those forged with teenagers in classrooms. Trainees can be just as demanding and as insecure. They can also be just as poor at being adequately prepared, at handing in assignments. What does the tutor do about the trainee whose file is atrocious, or the one who arrives late to every university-based session, but who is always on time at school? It does not seem possible to change trainees' personalities, but it is possible to discuss such issues within a professional framework, to suggest time management strategies which may help and to set pragmatic goals for trainees which are relevant to those expected of teachers in school.

Assessment in higher education is very different from that employed in mathematics courses in schools. Essay writing is uncommon within the secondary mathematics classroom and I found it very difficult to mark trainees' written assignments against what appear, to a mathematics teacher at least, very broad criteria for assessment. Marking assignments for undergraduate education courses is problematic: degree classification descriptions seem vague to the uninitiated, and knowing the difference in quality between one assignment worth 67% and another worth 63% appears unquantifiable at this stage of a new career. I remain extremely reliant upon my colleagues' help and experience in this area.

Feedback to students and trainees is another area where the new entrant is unsure: should each written assignment have oral and written feedback; what type of written feedback? Time restrictions limit the opportunities available for oral feedback on written assignments, although I see any trainee who asks to discuss their work following written feedback. With written assignments wellworn habits from school-teaching days are continued: much is written on each script! Trainees and other students say they find the amount of written feedback very valuable: it has huge disadvantages for the tutor in that it is very time-consuming, although experience may lead to increased speed. Nevertheless, the investment of time is worthwhile. I feel strongly that if there is insufficient time to discuss a trainee's work with that trainee individually, then the tutor must make a visible, worthwhile (to the trainee) effort in writing. Trainees are no different from teenagers in secondary school in this respect: the tutor's written comments provide the tangible evidence of the worth afforded by the tutor, to the trainee's efforts. Teenagers who have spent time producing a piece of work expect to see evidence that their teacher has also spent time on that work: so do trainees.

In almost two decades as a secondary mathematics teacher, there have been innumerable changes in the curriculum, its assessment and almost every other aspect of secondary school life. This length and breadth of experience in mathematics classrooms gives a sound practical perspective of mathematics teaching and learning from which to approach teacher education. It is also a sufficiently long time span to ensure that the day-to-day practicalities of teaching mathematics are neither forgotten nor minimised. Working effectively with other practising teachers over the same period produces an ideal background for working within a partnership initial teacher education course. I still miss teaching teenagers, but thoroughly enjoy working with trainee teachers.

Conclusions

The new initial teacher education tutor who has come into higher education straight from the classroom needs retraining to be able to engage effectively with the latest research into teaching and learning. This research is inevitably almost unrecognisable with what that person learned when he/she was trained. Even if the new tutor has had some research experience during his/her career, it is unlikely to be up-to-date. Pragmatically, it is impossible to provide a complete retraining cou,rse for the new tutor; indeed, any effective induction situation must prove economic. The proliferation of research, driven by the present context of funding, makes it very difficult for any tutor to be described as truly up-to-date. However, a bridging mechanism of induction may prove effective in providing a solution to the new tutor's question: 'How do I catch up before I start teaching my first group of trainees?'

As more and more initial teacher education tutors are being appointed 'straight from the classroom', perhaps a national interinstitutional bridging course could be set up each year, prior to new entrants taking up their teaching duties. Such a course could be thought out in a fundamentally different way from 'yet another conference', so that experience can be transferred in a pragmatic manner, in both directions.

The new initial teacher education tutor is likely to have a research obligation. This involves taking on a new professional role. New professional obligations in research-directed institutions are not just linked to one's own career progression but also to one's professional status. An ex-classroom teacher turned initial teacher education tutor is likely to have few, if any, publications in refereed journals and little or no research experience. The new tutor needs more than simply advice. Most importantly, he/she needs to overcome his/her own scepticism of research: after all, he/she has probably spent a large proportion of the previous two decades in situations where issues such as: 'How do I get Wayne Jones to come into school?' are much more important than reading the latest publication of a particular journal. There is a need for a culture shift in which the new tutor recognises the value of research to him/herself, to teachers in school and to trainees.

The kind of research which such new entrants are perhaps best qualified to undertake may be that which seeks to bridge the gaps which exist between classroom teaching and initial teacher education teaching.

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College Ideals and School Practice

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Many student-teachers have commented upon their perception of a *strong difference between the views of mathematics teaching propounded by the university-based teacher trainers and those propounded by teachers in their practice schools. This apparent dichotomy might be characterised* as *college tutors being seen to be advocating strong but idealised positions and approaches whilst the influential teachers in school are characterised* as *being more pragmatic and practical. If there is* a *substantial element of truth in this perception then this must arguably lead to some confusion for the student-teacher who has to try to satisfy the apparently conflicting university and school based requirements (as well* as *attempting to meet pupil needs, parental and their own professional aspirations). Through discussions with student-teachers I know that this confusion often arises, but have been less clear about how the issue is resolved. Do student-teachers tend to support the college ideals or the school practice? This article outlines* a *small-scale study of this question.*

Aim of the Study

Two questions are addressed in the study. First, is there a gap between college ideals and school practice in terms of advocated mathematics teaching styles? Secondly, if so, how is this difference perceived by student-teachers?

Data Collection

To inquire into these questions I undertook a survey of all 21 students on our one-year Post-Graduate Certificate in Education Mathematics course. This was undertaken at two points in the year. At the time of the first survey the students had only spent six full days in secondary school mathematics departments. At the time of the second survey, the students had completed Semester 1, culminating in a five-week block teaching practice. Perhaps surprisingly, there was no statistical significant difference between the opinions expressed at these two times. In the discussion which follows I have used the results from the first survey, since this represents the view of the entire cohort, before the loss of one student who left the course and the loss of data from two who were absent at the time of the second survey.

Results

In response to the question "Do you feel that there is a close relationship between college views about the nature of mathematics teaching and what you observe to be in practice in schools?", the majority replied in the negative. (4 Yes, 15 No, 1 replying that it depends upon the school and 1 non-responder). **In** a follow up question, students were asked to give reasons for their responses.

For the few that found a close relationship between college ideals and school practice, this proximity seemed to diminish further up the school:

"There is a *general proximity in teaching style adopted in years* 7, 8 *and* 9 *to that advocated by college tutors especially in the investigative, self directed and self assessment encouraged by the teachers of those years. Years 10 and* 11 *are more traditional exposition and practice, reason being that it needs to be that way for GCSEs."*

Teachers were seen to be

" *... constrained by practical difficulties in doing less than what they would see* as *ideal."*

"Some teachers would like to do more investigations etc. but don't have the time to develop many workable ideas."

And teachers were seen to be constrained by the curriculum:

"I believe the views to be the same but the practical application, due to the needs of the school to cover a *large syllabus, is different. "*

For the majority, who found some disparity between college ideals and school practice, the following quotations illustrate their views:

"In college, the emphasis is on investigative work and appropriate practical work , .. "

"So far in schools all I have seen is teaching by SM?, where pupils work from booklets .. , "

Six out of the 21 students made similar observations.

"College views on maths teaching encourage more variety ... "

"I have only seen teacher exposition ... "

"In school, activities and practical work seem to be regarded as a *necessary thing to do twice* a *year. It is considered* a *waste of time and doesn't achieve exam results ... In college activities seem to be the main emphasis."*

"The vast majority of what I observed up to now ... has been the traditional teacher standing at the front explaining and going through examples followed by practice by the pupils from a text book. I did see one year 7 mixed ability class using a data base to analyse a *data field ... "*

Students were asked to consider the Cockcroft report, paragraph 243. This well known paragraph advocates that teaching at all levels should include opportunities for exposition by the teacher; discussion between teacher and pupils and between pupils themselves; appropriate practical work; consolidation and practice of fundamental skills and routines; problem solving and investigative work. Many of the students were not clear about the difference between problem solving and investigative work. The group as a whole were offered a view that problem solving is work which might start in a number of ways, but which often proceeds towards a narrowly defined end point. By contrast, investigative work generally' has a clearly defined starting point, from which pupils can proceed in a number of different directions and may produce a relatively wide variety of outcomes. The student-teachers were asked to estimate the percentage of lesson time that was spent on each of the Cockcroft 243 categories of exposition, discussion, practical work, routine practice, problem solving and investigation.

This distribution was requested in three different ways: (i) as an estimate of time spent in practice by teachers of mathematics in schools (this request produced 17 usable results, with 1 non reply and a further 3 students bracketing categories together without indicating the balance for each component); (ii) as an estimate of the lesson time that college tutors advocated (this produced 19 usable responses, with a further 2 students bracketing categories together); (iii) as an estimate of their own intended distribution of time in their teaching (18 useabel responses, with a further three students bracketing categories together).

The 'usable' results were placed in a 6 by 3 matrix:

	Time in schools	*College advocated*	*Own intentions*
Exposition	20.88%	12.24%	15.20%
Discussion	8.71%	19.14%	16.53%
Practical work	9.47%	15.92%	15.70%
Routine practice	45.88%	11.19%	19.93%
Problem solving	9.76%	16.51%	17.92%
Investigation	5.29%	24.98%	14.65%

Analysis

The chi-square test for associatively was conducted, showing a chisquare total of 49.24 on 10 degrees of freedom and SP<0.005. The various contributions to the chi-square total are shown below.

	Time in schools	*College advocated*	*Own intentions*
Exposition	1.41	0.93	0.05
Discussion	2.50	1.28	0.21
Practical work	1.31	0.36	0.29
Routine practice	15.91	8.17	1.28
Problem solving	1.68	0.21	0.69
Investigation	6.27	6.68	0.01

Hence there is strong evidence of association, with the major contributions being discrepancies in the views on 'routine practice' and 'investigation' categories.

Subsequent two-way analysis was undertaken to consider any potential relationship between students' perceptions of school and college views. Here, the chi-square total was 43.42 on 5 degrees of freedom, with SP<0.005. This shows strong evidence of association. The major difference is in the views of 'routine practice' with students perceiving more routine practice in school than they perceive college tutors to be advocating. The second area of difference in perceptions is in 'investigation' with students perceiving less investigative work in school than college tutors appear to he advocating.

Analysis was undertaken to compare students own intentions with their perception of school practice. Again, there was strong evidence of association (chi-square total 21.89, SP<O.005). The main area of difference being that students would aspire to place less emphasis upon routine practice and more upon investigation. There was no significant difference between the perceptions of tutors advocacy and the student-teachers own intentions.

Further Observations

Student-teachers were also asked to comment upon any other aspects of the inquiry questions. There was a lot of support for the view that ....

" .... the more traditional methods of teaching are used particularly with more able pupils. However, more investigative tasks are given to lower ability pupils ... "

and some support for the view that.. ..

. *" .... teaching styles vary greatly from one teacher to another ... "* with two students commenting:

"College appears to give the impression that Activities are the answer to mathematics teaching.

However, I feel that they are counteracting a *lack of this style in practice with the hope that student-teachers will use this* as *part of their range of styles"*

"In order to pass exams ... practice makes perfect ... Practice exposes children to a *wide range of problems and instils confidence and reveals children's weak points. Investigations may not stretch* a *child sufficiently."*

Discussion and Conclusions

These views are based upon the limited experience of these student-teachers in the school environment. However, they point out that there is a gap in the perception of what is being advocated by college tutors and what is perceived to be going on in many of our local schools. How do students resolve these contradictions? Do they decide that tutors are impractical theorists with no idea how to teach in a real classroom? On the other hand do they decide that the practices they observe in school are, for whatever reason, dire and dull? A partial answer is that these particular student teachers at this moment in their careers give strong evidence of those perceived as being advocated by college staff than to what they perceive to be going on in school. Both college staff and student-teachers appear to be agreed on the need for increased investigative work and less routine practice.

Clearly there are limitations to the generality of this small-scale study. Among other considerations, we must ask whether the perceived views are a fair representation of reality. In other words do student-teachers share a common understanding of the Cockcroft 243 terminology, do tutors really advocate such a distribution of teaching time, and do teachers really distribute their time as it appeared to these student-teachers? How reliable is the evidence? How typical are these students, schools and tutors?

Setting aside these questions and accepting the evidence at face value, the conclusions drawn are as follows.

i) These particular student-teachers ally their views closely to the perceived views of their college tutors. It is reasonable to speculate that once these students become full time teachers, this initial influence may fade over the years.

(ii) These particular student-teachers regard school teachers of mathematics to be doing too much routine practice work and insufficient investigative work. They appear to be convinced of the desirability of engaging their pupils in active learning tasks although one or two seem to be indicating that tutors are overstating the case in an effort to counterbalance school practices. My own observation is that in practice, this difference of opinion does lead to difficulties for student-teachers who try to introduce more active learning into lessons where the pupils are unfamiliar with such approaches and the student-teacher feels that staff are less supportive of such approaches. On the other hand, most schools seem to expect student-teachers to be keen to tryout new ideas.

(iii) Many of these student-teachers are aware of school teachers adopting different ways of working with different ability pupil groups. This is largely an observation on the part of these students, not a point that has been very strongly made in the taught course.

A final thought: these student-teachers were happy to distinguish between the Cockcroft 243 teaching styles, which might be considered to be an encouraging sign. However, less encouraging is the observation that none of the sample ventured to comment that there might be more than one style in operation at anyone time.

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What are Assignments for?

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This paper gives an account of our attempts this year to Ilse university-based PGCE assignments to achieve three distinct aims. First, there is the aim of using assignments to achieve curriculum objectives. Secondly, there is the aim of developing study skills, both for use during the course and later. Finally, there is the aim of sharing what students ·have learned in order to help in their professional development, and possibly in that of school-based mentors also. IT is central to each of these aims.

Background

I take it as axiomatic that assessment should grow out of the curriculum rather than the other way round. (Of course, this begs the question of where the curriculum came from in the first place!)

Throughout this paper, 'the course' refers to the one year PGCE (Post Graduate Certificate in Education) for secondary subject specialists. Here at Sheffield University the university-based part of the course is split into EPS (Education and Professional Studies) and Curriculum Studies. Students have to write two essays for the EPS course and these tend to relate to broad school issues, such as bullying. Subject-based assignments differ a little from subject to subject, but generally consist of four essays and various forms of coursework. There is also a major school-based collaborative enquiry which can draw on either of these components. My intention here is to describe the assignments for the mathematics course.

This year, we have organised the mathematics curriculum component of the course around five major themes: (1) Teaching Methods in Mathematics; (2) Topics in School Mathematics; (3) IT in Mathematics Teaching and Learning; (4) Issues in Mathematics Education; (5) Background to Teaching Mathematics.

Broadly speaking, themes (1) to (3) receive greater emphasis in the earlier parts of the course. Student assignments (essays and coursework) are linked to each of these themes. It is not my intention to examine each theme, but rather to use examples from some of them to exemplify how

Achieving Curriculum Objectives

Using assignments to achieve curriculum objectives is perhaps the experience that we are all most familiar with. Nevertheless, there are always benefits in sharing practices with each other, so I will give some examples from our experience at Sheffield.

For the assignment in the 'IT in Mathematics Teaching and Learning' component of the course, students have to undertake school-based work using IT. We found that when students first arrive, they often have had little experience of using computers (or graphical calculators) and may even display the kind of phobia towards IT that might normally be associated with nonmathematicians. It might be noted in passing that our students are relatively young (average age 22 - 23) and almost all have recently completed a first degree in mathematics. In the past, despite introducing students to the mathematical uses of spreadsheets, databases, Logo and so on, many of them were reluctant to put these ideas into practice.

This year, our belief that becoming familiar with IT is an important part of teaching mathematics led firstly to the creation of the distinct IT theme, and secondly to the assignment on this theme. The assignment itself requires that the students review the literature relating to their chosen area

of IT, and undertake work with children in school using IT for the learning of mathematics. It is thus our vehicle both for ensuring students take IT on board, and for linking theory with practice.

The 'Teaching Methods in Mathematics' module uses a series of 'coursework' tasks to achieve other curriculum objectives. One such task is for student-teachers to mount a wall display of children's work. Our school-based mathematics mentors play an important part in this and clearly there are benefits for the children, the department, and the student teachers themselves. Another coursework task requires students to explore different ways of encouraging pupils to present written records of their work in mathematics. The evidence for these coursework tasks, together with the students' reflections, later forms the core of a seminar where students share their experiences.

This notion of sharing is central to the university-based part of the course. We have tried to get away from the notion that assignments are simply written for their tutor to read. The students must also produce a summary, along with bibliography, to share with the other members of the course. Moreover, each assignment is accompanied by a presentation to their peers. In this way, we intend the prospective teacher to begin to build up a portfolio of material that they can draw on in the future.

At different points in the course we ask them to teach an aspect of elementary mathematics to their peers in a way that their fellow student teachers find interesting and stimulating. Generally, this takes the form of group work, practical tasks, investigations or some combination of these. Not only does this allow students to rehearse innovative teaching in a (relatively) friendly environment, it also allows them to build up their resource file (another coursework requirement). No doubt colleagues elsewhere have similar examples.

Study Skills

I turn now to the second objective outlined above, namely, developing study skills, which I shall i11ustrate by drawing on the theme 'Topics in School Mathematics'.

'Topics in School Mathematics' is the first assignment (2500 words) which the students have to undertake. They have to review the research literature on a topic of their own choice, such as Decimals, Area, Graphs, Algebra, and so on. The assignment comes early in the course (late October) and thus sets the scene for future work. The full aims, as outlined for the student teachers, are set out below.

Assignment 1: Topics in School Mathematics

The aims of this assignment are:

- to encourage you to read the research literature on your chosen topic;
- to acquaint you at a very early stage of the course with the study skills of using the library, and the on-line facilities such as STAR and ERIC for acquiring information for your area of research;
- to make you aware at an early stage of the existence and nature of the major mathematical journals;
- to encourage you, in the light of your reading, your personal background, and your practical experiences to consider how you might utiJise what you have learned in your SEl school;
- to share what you have learned with your fellow students.

It is doubtful if this is very much different to the practice of other departments of education. However, it is in the writing of the assignment that the study skills come in. The assignment has to be word-processed, and there is a need to use the computer to connect up to the library's on-line facilities. Each of these requirements means that the course has to provide initial introductory

sessions to these facilities. Since neither of them are essential for writing an essay, the question arises: "Why impose them in the first place?"

The justification for this insistence lies in the notion of 'incremental learnability', the idea that what is learnt in one context has a 'pay-back' in another. One argument in favour of word-processing is that a second draft of an assignment can easily be constructed (cut and pasted) from a first draft, unlike a handwritten version. But, perhaps a stronger case concerns the skills they begin to develop through learning to word-process documents. As part of the IT component of the course, students design their own mathematical texts (worksheets), an area which as Shuard and Rothery (1984) have observed, merits attention. For this, they need to become familiar with the drawing facilities and the mathematics editor of the word-processing package. There is thus a direct pay-back from the assignment. Our school mathematics mentors have been complimentary about the students' productions. This reinforces the value in learning this skill and adds to their confidence when creating worksheets for their class. In the latter part of the course, these word processing skills stand them in good stead in constructing CVs and writing job application letters.

Perhaps of equal value is the attitude they develop towards using other computer applications. This year there seems to be less fear and greater use of other software. For example, one group undertook their collaborative enquiry on using the Mechanics in Action software [Mechanics in Action Project, Dept of Applied & Computational Mathematics, University of Sheffield, Sheffield S10 2UN] for which they trialled and produced a series of well-designed worksheets and teachers' notes.

So, what about the case for using the computer to connect up to network services? Our library, like many other university libraries, is often very busy with long queues to get on the computer terminals to access the library database. Using the computers in the separate education building, the students can log in remotely and so avoid the queues. They can also access the ERIC database, thus enabling them to find journal articles relating to their area of interest. We have been impressed this year with the wider and deeper bibliographies appended to their assignments.

That is not to say that all of this has occurred without problems. Indeed, at the beginning of the course, we wondered whether we had bitten off more than we could chew. There was the problem of initial learning or 'minimum threshold' (Hammond, 1994) which students had to cross. Having students turn up in the first weeks saying "We couldn't find anything" was a bit disconcerting. There was also the problem of our library not having the full range of books and journals in stock. Accessing a computer database such as ERIC is quite different to looking at what's on the library shelves. The latter tells you what's in stock. The former tells you what could (should?) be in stock. Our blushes have been spared both by having another university (Hallam) library close by and by having an excellent librarian at our own university who quickly ordered what we needed.

Sharing and Professional Development

It seems absurd that student teachers leave their course with little more than their own assignments or coursework as mementoes. As mathematics educators, we know how good some of these can be, but too often the benefits are restricted to the student herself. Rather than going away with an essay on, say, Decimals, would it not make sense if they could also take away their fellow students' efforts on Area, Graphs, Algebra, and so on? A student on a course of 20 students could leave with a resource of 80 assignments rather than four. Regardless of how well some of these are written - and we have to acknowledge variable standards - the minimum benefit they would gain is the acquisition of a large number of bibliographies. This in turn would give them greater access to the literature when they take up their first appointment.

Sharing is not restricted to other students. Our mentors have been closely involved in the construction of the university-based part of course. We are now trying to involve them in its assessment. Some of the coursework requirements, for example the wall display, have been created as a direct result of their input. Recently, we asked our school-based students to give one

of their assignments to the mentor to read before a meeting at the university. We saw the benefits of doing so as being two-way. Students could see their productions as being valued and useful and mentors mlght gain professionally from reading them. However, this was not as successful as we had hoped. It might be better next year to give mentors a summary rather than the full essay.

Finally, the practical questions involved in dissemination have to be faced. Photocopying the whole of each person's assignment for their peers is unlikely to be a practical option, so how can students share what they have learnt amongst each other? We have tried th ree methods so far this year: photocopying summaries of the assignments, sharing the whole assignment by both e-mail and floppy disk. In theory, the e-mail option should have been the simplest: attach the assignment as a document and send it to fellow students and tutors. In practice, we still have technical difficulties (storage space, incompatibility between different e-mail facilities, and so on) to overcome. The procedure with which we had most success is placing assignments on a designated section of the computer network which others can then copy to floppy disk.

Summary and Conclusions

This paper has described our attempts to exploit student teachers' assignments as a means of promoting the curriculum objectives which we, the university tutors and school mentors, feel to be worthwhile. Alongside this objective we have tried to show how we have framed our assignments in ways which enable the students themselves to see added advantages. Primarily, these were concerned with gaining study skills and furthering their professional development. We think there are benefits for mentors and ourselves from sharing what students have created. In the future, there may well be implications for the nature of the writing itself as student teachers begin to recognise the different purposes and different audiences for which they are writing.

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Preparing Student-Teachers for Interview Sally Taverner

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This report is a personal account by a former head of mathematics in *a secondary school of her experiences when selecting candidates for a teaching post. The report details the three main stages of the selection process: the initial enquiry, the official application and finally the interview. Common shortcomings exhibited by candidates are given and some recommendations made as to how candidates could present themselves in a more flattering light.*

Introduction

I write this as a new recruit to the world of Mathematics Education lecturers. Until March 1995 I was Head of Department in a large and successful 11-18 comprehensive school. As Head of Mathematics, among a wide range of other developments both internally and externally initiated, I had overseen the introduction of all three versions of the National Curriculum, seen GCSE coursework change from 40% to 20% of the final mark, change our 'A' level syllabus from linear to modular and survive one of the first OFSTED inspections in November 1993. We must have done well as we were included in Chris Woodhead's list of "gold star schools". During this time there were a number of changes in personnel within my department which meant that I was involved in selecting for interview, and then intervi~wing a large number of people. It is this particular experience that I would like to share with you. I hope it will be both of interest and of use to the reader.

The Initial Enquiry

Some prospective applicants fall at the starting gate, or at least are handicapped for the rest of the race by the poor quality of their initial request for an application form and further information about the post. Office staff comment on poor telephone manner, with the caller unable to state their postcode or where they saw the post advertised. Those who write in often leave tangible evidence of their lack of communication and presentational skills. It is not unusual for a letter to be written on a piece of file paper or even on a page torn from an exercise book. The letter, or note, sometimes does not state for which post they are applying nor where it was advertised. This is hardly the introduction the hopeful teacher-to-be should be making. However, although these first impressions do tend to stick, especially the extreme cases, everyone is entitled to enter the race by completing the application form.

So here is some advice for a student wanting to make a good first impression.

If you telephone the school make sure you have all the information you may be asked for to hand:

- *your full address where the form can be sent*
- a *description of the post applied for including any*

reference number given in the advertisement • where you saw the post advertised.

If you write directly to the school:

- *invest in some decent writing paper with envelopes that match*
- *draft your letter before writing out the final version, make sure you know to whom it* is *addressed*

- *check it for mistakes including grammar and spelling, if necessary ask someone else to proof read it*
- *include details of which post you are interested in and where you saw it advertised*
- *ensure you include your full address and* a *large SAE as many schools distribute* a *great deal of information when they send out their forms.*

The Application Form

I am certain that during their course all students are given help and instruction as to job applications but perhaps it is not realised just how basic the initial training has to be. Are we, as teacher trainers, breaking our own rule of ensuring that the work is set at an appropriate level and takes into account the experience and expertise of the pupil (student) or perhaps it just a repeat of the familiar school scenario when information can be given on a number of occasions and is either ignored or forgotten? I ask this as I was constantly amazed - or should I say concerned - by the poor quality of some application forms. Many had crossings out sometimes with whole sections completed with the wrong information. I appreciate that many students are applying for posts at a particularly busy time in their course, that is during their second teaching placement, but the simple task of photocopying the blank application form and completing that prior to filling in the original seems to be a precaution that many do not take.

In my experience, it is expected that a letter also accompanies the application form. Once again these vary considerably both in quality and quantity. On a basic level the letters often contain spelling and grammatical errors (l am not certain if this is unique to mathematicians!). The former is unforgivable as many of the letters received are word processed and so even if the package does not have a spell check facility it is relatively easy to use a dictionary and edit the letter if necessary. On a higher level the letter often has little direct reference to the specific post applied for. It is quite obvious from reading it that the letter is a standard one which has been sent, without alteration, to any number of posts. It says something about an applicant's level of commitment if, when applying to an 11-16 school, one paragraph is dedicated to the 'A' level teaching experience of the candidate or if a job description specifically mentions the need for IT experience for any mention of it to be conspicuous by its absence.

So there is some advice for students about how to improve their chances of being invited for an interview:

- *photocopy the application form and fill that in first*
- *ask someone to proof read it*
- *if necessary make other photocopies and complete them until you get it right*
- *read the job description and any details sent by the school again*
- *now draft or edit your standard letter so that it is appropriate for this post*
- *ask someone to proof read it*
- *if you are hand writing the final copy use blue or black ink on decent writing paper*
- *if you are word processing your letter make sure you sign it*
- *keep a copy of your form and your accompanying letter*

The Interview

It is not unusual nowadays for an interview to be split over two days even for a main scale post. Candidates are invited in for an "informal" visit to the school and its mathematics department. The word "informal" can be misinterpreted however with candidates arriving inappropriately dressed for an interview. It is not unknown for men to turn up in a sweatshirt or for women to wear trousers- yes I know it should not make any difference but let us be realistic and admit that it does. Most people seem relatively at ease during this stage of the procedure taking an interest in the school as a community and the workings of the mathematics department in particular. This is

not really surprising as the

Majority of candidates will be abel to make real comparisons between the school and at least two other institutions. Indeed they usually have more recent and relevant experience of other schools than any staff at the school where the interview is being conducted. I used to learn a great deal, and pick up some useful ideas, during conversations with candidates at this stage!

But what of the interview itself? Some candidates are so determined to present a relaxed image that they are almost horizontal on the chair, while others perch nervously on its edge and seem at times in danger offaIling om

Students are prepared well for the more obvious questions such as: How is teaching different/similar to what you expected? How do you motivate pupils? Describe the role of IT in mathematics. Describe how you would teach the topic of Trigonometry.

The one question which nearly always brought a look of bemused panic followed by a repeat of the adjective was: What is the most *exciting* piece of mathematics that you have ever corne across? Perhaps the reader may themselves be pausing at this minute to consider how they would react to and then answer this question. The response to this question falls into three main categories: (a) incredulity-the idea that mathematics could be interesting! (b) bewilderment - "quick think of something" (c) real enthusiasm.

Those who are incredulous seemed to be under the misapprehension that this is a joke question asked to lighten the atmosphere at the end of an interview. When the realisation dawns that the questioner is in earnest this group becomes part of the second category of the bewildered. Their minds going into overdrive as they scour their memory for a suitable example. I find this quite disturbing. These candidates are qualified mathematicians who are hoping to spend their career teaching mathematics to school children. How could they hope to develop any love for the subject among their pupils if such a question causes a panic reaction? The final group are a joy to listen to and often need to be interrupted in order to bring the interview to the end. Their genuine enthusiasm for the subject is a delight to behold and often encourages me to find out more about the topic. Answers range from the aesthetic beauty of the work of ~scher and tessellations to the more erudite but amazing fact that $e^{l}\ p = -1$.

So here is some advice to students who want to stand out from the crowd:

- *ask your tutor or mentor for a mock interview, give them* as *much notice* as *possible*
- *read through your application form and letter, think of questions you may be asked on its contents*
- *read through the job description, what questions may be derived from it?*
- *make sure you know where the school is so that you can arrive on time*
- *allow time to park and find the reception (not as easy as it sounds in some institutions)*
- *wear something that is smart and fairly conventional, and iron it the night before!*
- *remember even during the 'informal' part impressions are being made*
- *during the main interview try to look relaxed but interested*
- *be aware of your posture*
- *listen to the questions and think before you reply*
- *remember the interviewers are human too and are unlikely to try to embarrass you with trick questions*
- *if you are not appointed put it down to experience and take advantage of a debriefing session if it is offered.*

Conclusion

So who would be appointed? Even to reach the interview stage candidates have had a large measure of success although it is small comfort to be told this as an unsuccessful candidate. Undoubtedly the response to the final question had a significant influence on my feelings (but not necessarily to others on the panel). Interviews for teaching posts are by their nature somewhat artificial and the idea of all the candidates being together for the duration of the interview process and told of its outcome that day is, I think, unique to schools. I like to believe that the best person has always been appointed to the post and indeed I have no reason to wish that a different decision had been made for any of the appointments to the mathematics department in which I have been involved. However, there is always a nagging doubt between the appointment being made and the successful applicant taking up their post. Will they live up to our expectations? Did we miss a potentially better candidate because they were ill-prepared for the interview or had a poorly constructed letter?

Now the boot is on the other foot. I am preparing students who require help by proof-reading their letters of application and giving them mock interviews. Perhaps passing on my experience may just give them the edge over other candidates and allow them to take their first step on their chosen career.

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Primary Children's Views on Using Calculators in School

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This paper looks at research focused on primary children's views on the use of and the ethics of using calculators in school. Questionnaires about their use of and attitudes towards calculators were given to 243 children and group interviews were carried out with selected samples. The children seemed generally comfortable using calculators but had somewhat constrained views on their use even though the schools in Question had generally positive attitudes towards calculators.

Background

Although articles in journals advocating calculator use in primary schools were in existence in the early to mid-seventies, the first official recommendations did not emerge until the late seventies. In Mathematics 5-11, HMI (1979) stated that:

... systematic studies as are currently available suggest that, far from undermining skills in basic computation, proper use of the calculator can help and encourage children to develop and improve skills. (p.27)

Perhaps the most significant promotion of the calculator was found in Cockcroft (1982) advocating not only the introduction of calculators into the primary school but also the study of how the availability of calculators could change the curriculum as it stood:

It is clear that the arithmetical aspects of the primary curriculum cannot but be affected by the increasing availability of calculators. (p. 113)

Several experimental projects were begun in Britain, notably the Shell project, "A Calculator Experiment in a Primary School" (Bell et aI, 1978) and the ground breaking Calculator Aware Number (CAN) Curriculum project (Shuard et aI, 1991). This programme involved giving primary school pupils unrestricted access to calculators as previous projects had done. However, the major difference was that the pupils were not taught the standard 'pencil and paper algorithms but were encouraged to develop their own methods, particularly mental methods. The various National Curriculum documents contain several references to the need for pupils to be able to confidently use calculators and the non-statutory guidance (1989) states:

Calculators are now an established item of classroom equipment and should be available for pupils to use at all four key stages. (p.E5)

However, a recent report from Ofsted (1993) stated that:

In very few of the lessons in either KSI or KS2 was use made of calculators .... to enhance the experience and performance of pupils. (p.13)

Little work has been undertaken looking at what children themselves think about using calculators in school. A recent study, the Second International Assessment of Educational Progress (Foxman, 1992) did study the attitudes of pupils aged 9 and 13 years but did not question the 9-year-olds about their ownership and use of calculators. The study reported here was an attempt to explore the views of 8 to 10 year old pupils about the use of calculators in the primary school.

Research Method

243 children aged 8-10 from five primary schools in a northern English city were given a questionnaire about their use of and attitudes towards calculators; from three of the schools, twelve small groups of them involving fifty six pupils were given semistructured group interviews to explore their views in more depth. The schools had all replied positively to initial written requests and all used calculators with this age group to a greater or lesser extent.

Pupils' Experience of Calculators

Most of the pupils questioned had access to a calculator. Overall, 73% claimed to own a calculator and only just over 5% neither had one of their own nor had access to one at home. This percentage of pupils owning or having access to calculators is substantially higher than Straker(1985) found although this is a much smaller sample. Straker found a much smaller number of girls owning calculators than boys – this survey noted 68% of girls and 77% of boys owning calculatirs, a noticeably smaller difference.

Asked whether they sometimes used a calculator at home, 81% replied positively. Cresswell and Grubb (1987), in the second International Mathematics Study, found 50% claiming to use one at home while Shin (1978) reported a 77% reply to a similar question. Cresswell and Grubb (1987) found that the most common use made of the calculator was for checking answers and doing homework; we found that the most popular use was to "make up sums" and to "play games" - these being younger pupils who probably do not have the same amount of homework as older pupils.

Pupils often wrote down recreational activities when asked what else they did with their calculators at home, for example:

"1 do some numbers and turn it upside down and see what it spells"

"1 play this game where one person tells them to type in a *number and + or x or - and find the answer."*

"Pretend it's a *police radio"*

Other pupils use the calculator for more mercenary activities:

"Counting your change."

"For working out my pocket money."

One of the most popular activities was that of making words on the calculator by turning it upside down but some pupils named other specific games such as space invaders, codes, sums hangman and ski ttles.

This data provides evidence to suggest that most of these pupils are very comfortable with calculators and obtain some enjoyment from using them. It would appear that mathematics itself becomes more entertaining when using a calculator as so many claimed to make up sums of their own when using them at home. It would be interesting to know whether as many children would have done similar mathematical activities at home before calculators were easily available.

Potential Future Use of Calculators

Although there were no specific questions relating to this topic, several pupils made references, during interviews, to the use of the calculator in their futures. They revealed that

the three areas where they could see themselves using them were at work, at secondary school and higher education and at home.

Pupils mentioned jobs in which calculators might be used as dissimilar as politicians and factory workers but these were one-off examples; the most commonly mentioned jobs were shop assistants and bank cashiers, almost certainly as a result of these having lots of public contact and very visible use of computerised systems. References to using calculators in the secondary school or at colleges and universities were also made during the interviews. This use appeared to be less acceptable than that of using them at work but more acceptable than in the primary classroom. This issue of the acceptability of use in primary schools will be taken up in the next section.

The Ethics of Using Calculators

In response to the question "Do you think that it is a good idea or a bad idea for children to use calculators at school?" there was a clear polarisation of views. Overall, 58% thought it was a good idea and 39% a bad idea with only 3% replying that it could be either depending on the circumstances. The one school in which the most pupils had reported using calculators quite often showed 84% thinking it a good idea with the other schools being fairly evenly split among their pupils. Lloyd and Gressard (1984) in a study of the effect of computer experience on computer attitudes found that more experience of computers resulted in more positive attitudes towards them - it seems reasonable to assume a similar consequence of more positive calculator attitudes resulting from more experience of them.

Pupils were asked to explain why they had responded in the way they did to the question and gave a variety of reasons. The most common reasons given for thinking it was a good idea were : to help people (generally); to help you learn/understand; for hard sums; for future occasions. For putting that it was a bad idea the most common reasons were: it's cheating; they stop you thinking/learning; you should use your brain.

In contrast to the clear split shown in response to that question about using calculators in school, there was a very strong positive feeling that everybody should learn how to use a calculator properly. Asked to agree or disagree with such a statement, 88% agreed, with only 8% in disagreement and 4% being undecided .. Explanations for disagreeing included:

"Because they will then cheat. "

"Because you are cheating at maths."

“Because it’s cheating.”

Cheating

It is possible that the frequent mention of cheating in connection with calculator use could have been influenced by one of the items on the questionnaire being directly on that issue. Pupils were asked to respond to the statement: "Using calculators in maths lessons is like cheating." Overall 60% agreed with this and 22% disagreed, the remainder replying that they were not sure. Although there were marked differences between schools, in all cases there was a clear majority agreeing with the statement. Among the main reasons added for the responses were that you should use your brain and that you aren't thinking, you aren't doing the work yourself and you don't learn (these reasons for yes responses).

In the interviews, three quarters of the groups made specific reference to the idea of cheating and all except one group made comments which implied this idea although not actually mentioning the word 'cheating'. Since the interviews were carried out some months after the questionnaires and most pupils had little recollection of the questions asked before, it would appear that this image of cheating is very

near the top of pupils' minds.

Interviewer *When should you not use them (calculators)?* Boy *In tests .... cheat (undertone)*

Interviewer *Why not?*

Boy *Because you're cheating. (agreement)*

Boy *It's cheating when you use a calculator .... because it's (the test's) to* see *how good you are.*

Girl *I don't think you should (learn how to use a calculator)* Interviewer *Why not?*

Girl *Well they should really, not for school, for working out, 'cos that's cheating, but for when your Mum goes shopping, but not at school.*

Interviewer *Why would you need to learn how to use them?*

Boy *If you need to use one when you get older, when you go to college or secondary school, for your homework.*

Girl *That's cheating.*

Permission

Some of the pupils qualified their responses about cheating or the notion that calculators were a bad thing with comments indicating that it was all right if permission had been given some way, perhaps direct (verbal) or indirect (written in the textbook),

Girl *We don't use calculators to work them out, unless it says so in the book.*

Interviewer *Do you ever use calculators in class?*

Pupil *Not unless you're told to, it depends on what you're doing.*

This notion of permission is an important factor in determining whether pupils are going to use the calculator in mathematics lessons and may indicate that they have reason to be wary about using the calculator at other times. The notion of getting permission to do things is a strong general one in primary school but it seems that when it comes to mathematical apparatus the pupils find it far more acceptable to go and get some counters or blocks than to get a calculator without the teacher's express permission.

Motives

Pupils often made reference to an individual's motive behind their using a calculator. Motives could be seen as positive or negative in the eyes of the pupils. For example, negative motives included using them to cheat, to be lazy and to get all the answers right, whereas positive motives included using them to do the work faster, to help you understand and to check your answers (if permission had been given)

To illustrate this, responding to the statement "People should be allowed to use calculators for very easy sums", some pupils qualified their answers by stating instances in which this would be more or less acceptable on the basis of the motives they felt were behind the decision. Here are some examples of pupils justifying their No response to that statement:

"Because the teacher says that when you use a calculator you are cheating. "

"If you use a calculator for easy sums like 5+5=10 it is very lazy"

"Because you do know them but you're being lazy"

The cases below give examples of the negative motive of getting the right answer and the positive motive of getting the work done more quickly:

lnterviewer *What wouLd happen if you used the caLcuLator and it didn't say so at the top of the page?*

Girl 1 *You'd get told off but it wouldn't make any difference Ln your sums.*

Girl 2 *It would because you didn't have to work it out and you might have got it wrong before.*

Interviewer *Why do you think you would want to know how to use one when you are older?*

Girl *If you get* a *good job when you need to do lots of adding up it'd be faster to use* a *calculator than to do it all in your head.*

Directly linked to the idea of a pupil's motive for using the calculator is that of the purpose or aim of the mathematical task. This also affected pupils' attitudes regarding use in schools:

Interviewer *What's the difference then? Why is it different when you use it in school to when you use it for ajob?*

Pupil You're learning in school, you're learning how to do everything in school and when *you're in* a *job you know how to do everything* so *you can just use* a *calculator if you want to.*

Interviewer *Why do you think you have to learn how to use the calculator?*

Boy *'Cas when you're* a *politician or something they're (the teachers) not trying to make you learn are they, they're trying to get it done* so *I think they'd use* a *calculator then and add all the things up. Because in school they're really trying to make you learn and calculators were really made to help people in maths and things weren't they?*

This idea may be the reason why many children were concerned that using calculators stops you from thinking and learning. **If** they see school as somewhere you go to learn and the calculator as something which prevents this then they are unlikely to think positively of it.

Conclusions

The impression is given that the teachers have, consciously or not, conveyed to pupils the message that calculators are valid in certain circumstances, for example for checking calculations or certain hard sums, but do not have a role in helping children understand mathematical concepts.

Though the children seemed comfortable using calculators and many claimed to play games at horne with them and though access was fairly universal to at least a family-owned machine, they had somewhat constrained views on their use in the primary school even though the schools in question had generally positive attitudes to calculators.

It may be that a broader vision by primary teachers of the potential of calculators as an aid to learning in general rather than as simply a computation machine in particular could have valuable

spin-offs for pupils at a critical stage in their mathematical deve lopmen t.

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