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Author(s)	Mike Askew, Margaret Brown, Valerie Rhodes, Dylan Wiliam & David Johnson
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Effective Teachers of Numeracy in Primary Schools: Teachers' Beliefs, Practices and Pupils' Learning.

Mike Askew, Margaret Brown, Valerie Rhodes, Dylan Wiliam, David Johnson
King's College, University of London

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Abstract

This paper reports on part of a study examining the links between teachers' practices, beliefs and knowledge and pupil learning outcomes in the development of numeracy with pupils aged five to eleven. From a sample of 90 teachers and 2000 pupils, we developed detailed case studies of 18 teachers. As part of these case studies we explored the teachers' beliefs about what it means to be numerate, how pupils become numerate and the roles of the teachers. From the data three sets of belief orientations were identified: connectionist, transmission and discovery. Results from pupil assessments suggest that there was a connection between teachers demonstrating strong orientation to one of these sets of beliefs and pupil numeracy gains.

1 Aims of the study

The aims of the study Effective Teachers of Numeracy, funded by the UK's Teacher Training Agency (TTA) were to:

1. identify what it is that teachers of five to eleven year olds know, understand and do which enables them to teach numeracy effectively;
2. suggest how the factors identified can be more widely applied.

The working definition of numeracy used by the project was a broad one:

> Numeracy is the ability to process, communicate and interpret numerical information in a variety of contexts.

Evidence was gathered from a sample of 90 teachers and over 2000 pupils on what the teachers knew, understood and did and outcomes in terms of pupil learning.

Studies have pointed to the importance of establishing of a particular classroom culture (Cobb, 1986) , raising the issue of teachers' belief systems about mathematical knowledge, how it is perceived as generated and learnt, and the impact upon pupils' learning. It may be that beliefs about the nature of the subject are more influential than mathematical subject knowledge per se (Lerman, 1990; Thompson, 1984) .

Many studies, particularly in the USA, focus on effective classroom practice and routines (Berliner, 1986) but research demonstrates the difficulty that teacher experience in adopting new practices without an appreciation of and belief in the underlying principles (Alexander, 1992) . Further, teachers may have adopted the rhetoric of 'good' practice in teaching mathematics without changes to their actual practices (Desforges & Cockburn, 1987) . While teachers' classroom practices and subject knowledge were also foci of this research, this paper concentrates on the findings related to teachers' belief systems. (For full details of the research see Askew et al., 1997).

2 Identifying effective teachers of numeracy

Careful identification of teachers believed to be effective in teaching numeracy was crucial to this study. The idea that effective teachers are those who bring about identified learning outcomes was our starting point for the project. **We decided that as far as possible the identification of effective teachers of numeracy would be based on rigorous evidence of increases in pupil attainment, not on presumptions of 'good practice'.**

From an initial sample size of all the primary schools in three local education authorities (some 587 schools), together with Independent (private) schools, we selected eleven schools, providing a sample of 90 teachers. We selected the majority of these eleven schools on the basis of available evidence (national test scores, IQ data, reading test scores and baseline entry assessments) suggesting that the teaching of mathematics in these schools was already effective.

A specially designed test ('tiered' for different age ranges) of numeracy was administered to the classes of these 90 teachers, first towards the beginning of the autumn term 1995, and again at the end of the spring term 1996 (classes of five year olds were only assessed the second time). Average gains were calculated for each class, providing an indicator of 'teacher effectiveness' for the teachers in our sample.

In order to broadly classify the relative gains, the teachers were grouped into three categories of *highly effective*, *effective*, or *moderately effective*. This classification was made by putting the classes in rank order within year groups according to the average gains made (adjusted to take into account the fact that it was harder for pupils to make high gains if their initial test score was high). The cut-off points between high, medium and low gains were made on pragmatic grounds, so that classes in each year group fell into three roughly equal groups but avoiding any situation where classes with nearly equal adjusted gains were allocated to different groups. The groups were not based on any predetermined quantitative differences between the classes based on expectations of what a 'medium' gain should be.

3 Teacher case study data

Research on the links between knowledge, beliefs and practice suggested a mix of techniques to elicit teachers' knowledge and understanding backed up by classroom observation to examine actual practices. From the sample of 90 teachers we worked closely with 18 teachers who formed our case study teachers providing data over two terms on classroom practices together with data on teacher beliefs about, and knowledge of, mathematics, pupils and teaching. These teachers were identified in advance of the second round of pupil assessment, and chosen through discussion with head teachers and, where appropriate, with advice from the LEA inspectors and advisors. While the emphasis was on identifying effective teachers, the group of 18 were chosen so that their pupils were evenly distributed across ages 5 to 11 (year groups 1-6).

3.1 Classroom observations

In total, 54 lessons were observed, three for each of the case study teachers. Data gathered included a focus on:

- organisational and management strategies - how time on task is maximised, catering for collective and individual needs, coping with range of attainment
- teaching styles - intervention strategies, questioning styles, quality of explanations, assessment of attainment and understanding, handling pupil errors
- teaching resources - sources of activities, range of tasks, resources available, expected outcomes
- pupil responses - ways of working, evidence of understanding.

3.2 Case study teacher interviews

Fifty-four interviews were conducted, three for each case study teacher:

- background interview: providing evidence on training and experience as well as information on beliefs, knowledge and practices in teaching numeracy; teachers own perceptions of what has made them successful teachers of numeracy, and reasons for factors identified
- 'concept mapping' interview: this interview was based around a task that explored the teachers understanding of aspects of mathematics related to teaching numeracy.
- 'personal construct' interview: this interview was structured around a task that focused on the particular group of pupils that the teacher was currently teaching in order to explore the beliefs and knowledge about pupils and how they came to be numerate.

The data were analysed using qualitative coding methods and the constant comparative method to build up models of belief systems (Lincoln & Guba, 1985; Miles & Huberman, 1984; Strauss & Corbin, 1990)

4 Orientations in teachers beliefs.

From the analysis of the case study data three models of sets of beliefs that emerged as important in understanding the approaches teachers took towards the teaching of numeracy:

- connectionist - beliefs based around both valuing pupils' methods and teaching strategies with an emphasis on establishing connections within mathematics;
- transmission - beliefs based around the primacy of teaching and a view of mathematics as a collection of separate routines and procedures;
- discovery- beliefs clustered around the primacy of learning and a view of mathematics as being discovered by pupils.

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	connectionist	**transmission**	**discovery**
Beliefs about what it is to be a numerate pupil	Being numerate involves: • using both efficient and effective methods of calculation ; • confidence and ability in mental methods;	Being numerate involves: • the ability to perform set procedures or routines; • confidence and ability in paper and pencil methods;	Being numerate involves: • finding the answer to a calculation by any method; • confidence and ability in practical methods;

	• selecting a method of calculation on the basis of both the operation and the numbers involved;	• selecting a method of calculation primarily on the basis of the operation involved;	• selecting a method of calculation primarily on the basis of the operation involved;
	• awareness of the links between aspects of the mathematics curriculum;	• confidence in separate aspects of the mathematics curriculum;	• confidence in separate aspects of the mathematics curriculum;
	• reasoning, justifying and, eventually, proving, results about number.	• able to 'decode' context problems to identify a particular routine or technique.	• being able to use and apply mathematics using practical apparatus.
Beliefs about pupils and how they learn to become numerate	Becoming numerate is a social activity based on interactions with others. • Pupils learn through being challenged and struggling to overcome difficulties.	Becoming numerate is a individual activity based on following instructions. • Pupils learn through being introduced to one mathematical routine at a time and remembering it.	Becoming numerate is a individual activity based on actions on objects. • Pupils need to be 'ready' before they can learn certain mathematical ideas.
	• Most pupils are able to become numerate.	• Pupils vary in their ability to become numerate.	• Pupils vary in the rate at which their numeracy develops.
	• Pupils have calculating strategies but the teacher has responsibility for helping them refine their methods.	• Pupils' strategies for calculating are of little importance - they need to learn standard procedures.	• Pupils' own strategies are the most important: understanding is based on working things out yourself
	• Misunderstandings need to be recognised, made explicit and worked on.	• Misunderstandings are the result of failure to 'grasp' what was being taught and need to be remedied by reinforcement of the 'correct' method.	• Misunderstandings are the result of pupils not being 'ready' to learn the ideas.
Beliefs about how best to teach pupils to become numerate	• Teaching and learning are seen as complementary. • Numeracy teaching is based on *dialogue* between teacher and pupils to explore each others' understandings.	• Teaching is seen as taking priority over learning. • Numeracy teaching is based on *verbal explanations* so that pupils understand teachers' methods.	• Learning is seen as taking priority over teaching. • Numeracy teaching is based on *practical activities* so that pupils discover methods for themselves.
	• Learning about	• Learning about	• Learning about

mathematical concepts and the ability to apply these concepts are learned alongside each other.	mathematical concepts precedes the ability to apply these concepts	mathematical concepts precedes the ability to apply these concepts
• Connections joining mathematical ideas needs to be acknowledged in teaching.	• Mathematical ideas need to be introduced in discrete packages.	• Mathematical ideas need to be introduced in discrete packages.
• Application is best approached through challenges that need to be reasoned about.	• Application is best approached through 'word' problems: contexts for calculating routines	• Application is best approached through using practical equipment

Table 1: Key distinctions between connectionist, transmission and discovery orientations towards teaching numeracy.

These orientations are "ideal types". No one teacher is likely to fit exactly within the framework of beliefs of any one of the three orientations. Many will combine characteristics of two or more.

However, it was clear that those teachers with a strong *connectionist* orientation were more likely to have classes that made greater gains over the two terms than those classes of teachers with strong *discovery* or *transmission* orientations.

Analysis of the data revealed that some teachers were more predisposed to talk and behave in ways that fitted with one orientation over the others. In particular, Anne, Alan, Barbara, Carole, Claire, Faith (the teacher initial matches the school code, so Anne and Alan are from same school), all displayed characteristics indicating a high level of orientation towards the *connectionist* view. On the other hand, Beth and David both displayed strong *discovery* orientations, while Elizabeth and Cath were both clearly characterised as *transmission* orientated teachers.

Other case study teachers displayed less distinct allegiance to one or other of the three orientations. They held sets of beliefs that drew in part from one or more of the orientations. For example, one teacher had strong *connectionist* beliefs about the nature of being a numerate pupil but in practice displayed a *transmission* orientation towards beliefs about how best to teach pupils to become numerate.

	Highly effective	Effective	Moderately effective
Strongly Connectionist	Anne, Alan Barbara Carole, Faith		
Strongly transmission			Cath Elizabeth
Strongly discovery			Beth David

No strong orientation	Alice	Danielle, Eva Dorothy, Fay	Brian Erica

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Table 2. The relation between orientation and effectiveness

The connection between these three orientations and the classification of the teachers into having relatively high, medium or low mean class gain scores suggests that there may be a relationship between pupil learning outcomes and teacher orientations.

5 Links between orientation and practice

5.1 Orientation and the role and nature of mental strategies in pupils becoming numerate

All the teachers, whether leaning towards a *connectionist*, *transmission* or *discovery* orientation saw some aspects of mental mathematics as important. Knowing basic number bonds and multiplication facts provided a baseline of expectations within all three orientations.

However, the *connectionist orientated* teachers viewed mental mathematics as going beyond this recall of number facts. Mental mathematics did not involve simply knowing number bonds but having a conscious awareness of connections and relationships to develop mental agility.

This mental agility meant that for the *connectionist* teachers mental mathematics also involved the development of flexible mental strategies to handle efficiently number calculations. Working on mental strategies, they believed, laid foundations that extended the pupils' levels of competency. Developing confidence in flexible mental methods meant that pupils would be able to tackle calculations for which methods had not been taught.

5.2 Orientation and teacher expectations

The *connectionist* orientated teachers placed strong emphasis on challenging all pupils. They believed that pupils of all levels of attainment had to be challenged in mathematics. Being stretched was not something that was not restricted to the more capable pupils. They had high levels of expectations for all pupils irrespective of ability. Intelligence was not seen as static and all pupils were regarded as having the potential to succeed.

In contrast the *transmission* and *discovery* orientated teachers may provide challenge for the higher attaining pupils but structured the mathematics curriculum differently for lower attaining pupils.

5.3 Orientation and style of interaction

The *connectionist* teachers' lessons were generally characterised by a high degree of focused discussion between teacher and whole class, teacher and groups of pupils, teacher and individual pupils and between pupils themselves. The teachers displayed the skills necessary to manage effectively these discussions. The teachers kept pupils focused and on task by organising these discussions around problems to solve, or sharing methods of carrying out calculations.

In school A, one of the *most effective* schools, there was a consistent approach to interacting with pupils throughout the years. Right from age five pupils were expected to be able to explain their thinking processes. Because the pupils were explaining, rather than simply providing answers to questions that the teacher already knew the answer to, the lessons were characterised by dialogue. In this discussion both parties, teacher and pupils, were having to listen carefully to what was being said by others. The result was pupils who, by eleven, were confident and practised in sharing their thinking and challenging the assumptions of others.

5.4 Orientation and the role of mathematical application

For the *discovery* or *transmission* orientated teachers, application of knowledge involved pupils putting what they had previously learnt into context. Problems presented 'puzzles' where the pupils already have the required knowledge and the challenge is only to sort out which bit to use. Alternatively, problems were a means of demonstrating to pupils the value of what they are learning.

The *connectionist* orientated teachers also recognised the importance of being able to apply computational skills. But over and above this they did not see it as a necessary pre-requisite that pupils should have learnt a skill in advance of being able to apply it. Indeed, the challenge of an application could result in learning.

6 Discussion

The importance of these orientations lies in how practices, while appearing similar may have different purposes and outcomes depending upon differences in intentions behind these practices.

We would suggest that these orientations towards teaching mathematics need to be explicitly examined in order to understand why practices that have surface similarities may result in different learner outcomes. While the interplay between beliefs and practices is complex, these orientations provide some insight into the mathematical and pedagogical purposes behind particular classroom practices and may be as important as the practices themselves in determining effectiveness.

Other teachers may find it helpful to examine their belief systems and think about where they stand in relation to these three orientations. In a sense the *connectionist* approach is not a complete contrast to the other two but embodies the best of both them in its acknowledgement of the role of both the teacher and the pupils in lessons. Teachers may therefore need to address different issues according to their beliefs: the transmission orientated teacher may want to consider the attention given to pupil understandings, while the discovery orientated teacher may need to examine beliefs about the role of the teacher.

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