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Research Review

Adult numeracy: review of research and related literature

Diana Coben, University of Nottingham
with contributions by: Dhamma Colwell;
Sheila Macrae; Jo Boaler, Margaret Brown and
Valerie Rhodes; King's College, London

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- FENTO/ABSSU Dissemination Events in Birmingham, London and Newcastle, April-July, 2002
- The 9th international conference of Adults Learning Mathematics - A Research Forum (ALM9), Uxbridge, July 17-20, 2002
- ***Skills for Life*** conferences in Manchester and London, November 2002
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Diana Coben
September 2003

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Dedication

For Callimachus, Librarian of Alexandria,
the father of bibliography.

Executive Summary

- Adult numeracy is fast-developing but under-researched, under-theorised and under-developed. It is a deeply contested concept which may best be considered as mathematical activity situated in its cultural and historical context. Research and capacity-building are required in: theory; policy; teaching and learning; teacher education; communication between stakeholders; international comparative studies.

- Surveys reveal low levels of adult numeracy in England, with deleterious effects on individuals, the economy and society. The measurement of adult numeracy skills is problematic, especially for adults with lower ability levels (including special educational needs and dyscalculia) and/or reading or language difficulties.

- The need for adult numeracy/mathematical skills, including the communication of information based on mathematical data, is being progressively extended throughout the workforce as a result of the pressure of business goals and the introduction of IT. Employees increasingly need to have broader general problem-solving skills, interrelating IT with mathematics.

- Research on adults' 'numerate practices' suggests that they are diverse – as are learners themselves - and deeply embedded in the contexts in which they occur and that 'transfer' of learning between contexts may be problematic, posing a challenge for teachers attempting to relate the curriculum to learners' contexts.

- Evidence on the impact of adult numeracy tuition is sparse and unreliable. Detailed studies are required, including longitudinal studies. School sector projects employing constructivist theories of learning and with a 'connectionist' orientation to teaching and learning, making connections with the world beyond the classroom and with other elements of mathematics, demonstrate improvements in attitude and attainment.

- Adult numeracy teacher education is currently undergoing major transformation. Some teachers' inadequate subject knowledge is a continuing concern. Studies with children suggest that: initial and ongoing teacher education increases subject knowledge, facilitates career development and encourages future research and development; effective teaching correlates with engagement in continuing professional development (CPD).

Introduction

We used to think if we knew one, we knew two, because one and one are two.
We are finding that we must learn a great deal more about 'and'.
Arthur Eddington (early 20th century) A. L. MacKay (ed.) **Dictionary of Scientific Quotations**.

The aim of this project is to review what is known about adult numeracy, to identify gaps in our knowledge and understanding, draw out the implications for practice and make recommendations for further research. Outcomes of the project comprise the present paper ('the report') and a bibliography with annotations, available as a searchable database.

This report begins with an overview of the scope of the review, followed by reviews of: conceptual issues in adult numeracy; mathematics education as a research domain; epistemologies of mathematics and mathematics education, including absolutist and fallibilist epistemologies of mathematics and constructivist and sociocultural epistemologies of mathematics education, feminist epistemologies, and ethnomathematics; other relevant reviews of research; and surveys of adults' numeracy skills in the UK and international contexts. The second chapter focuses on notions of context and transfer between contexts and at research on mathematics in the workplace and everyday life, including financial literacy. The third chapter looks at issues in learning and teaching adult numeracy, policy and provision of adult numeracy in England; curriculum development and approaches to teaching and learning, including elements of the curriculum and literacy, language and ICT in relation to numeracy, multiple intelligences and critical pedagogies, adult numeracy learners, including adults with learning difficulties and disabilities, gender and age. Research on teacher education in numeracy, with adults and children, is examined in this section together with discussion of the National Numeracy Strategy (NNS) in primary schools. Recent research in the Leverhulme Numeracy Research Programme is also reviewed. The fourth chapter considers factors affecting learning. These are: affective factors - attitudes, beliefs and feelings, including a section on research undertaken by a team at King's College London on attitudes to mathematics; a review of research on mathematics anxiety and a section on dyscalculia and the functioning of the brain in mathematical activity. Finally, Chapter 5 looks at the range and balance of research methods used in the studies reviewed in this report and at methodological issues in research on adult numeracy more broadly, and draws together the main points from the review in answer to the questions: what do we – teachers, researchers, policy-makers and adult learners with an interest in adult numeracy – know, and what do we need to know about adult numeracy – and what should we do about it?

The scope of the review

The review spans English-language sources covering research from around the world judged to be relevant to, as well as directly about, adult numeracy/mathematics teaching and learning and teacher education, mainly at the levels of mathematics encompassed by the Adult Numeracy Core Curriculum (i.e. from Entry Level 1 through to Level 2) (BSA, 2001a). These sources come in various forms and accordingly a selection of sources from the following categories has been reviewed:

- academic literature;
- professional literature;
- government/official reports;
- electronic publications (webpages, etc.);
- 'grey' literature, e.g., non-confidential reports produced by organisations for limited circulation.

For the purposes of this report, research is defined as "a critical process for asking and attempting to answer questions about the world" (Dane, 1990). As such, it encompasses qualitative and quantitative investigations and critical commentary. Also included in the report and the database are relevant policy documents. These, while not 'research' in the above definition, are included because they help to define the area in which researchers labour. The review and database are as comprehensive as possible, with over 2,500 references in the bibliographical database. I hope it may be updated in future so that it may become an ongoing resource for researchers, practitioners and policy-makers, enabling them to keep track of this important and fast-developing area of work.

But what is 'numeracy', the concept at the heart of this area of work? This question is addressed in the next section, and it is a peculiarly tricky one. While the importance of adult numeracy is increasingly recognised, it is acknowledged to be seriously under-researched (Brooks et al. 2001). It has been described as a moorland, rather than a bounded field (Wedege, Benn, & Maaß, 1999) because, like moorland, the edges are undefined and the land is uncultivated. The aim of this report is to orientate readers as they explore the moorland, taking in distant features as well as those close at hand. What are the landmarks that may enable travellers to find their way? We look first at conceptual issues in mapping the moorland: what is meant by 'adult numeracy'?

Adult numeracy - conceptual issues

'Numeracy' is a deeply contested and notoriously slippery concept, the subject of lively debate by commentators concerned with the education of adults (Baker & Street, 1994; Coben, 2001a; Evans, 1989, 2000b; FitzSimons, Jungwirth, Maaß, & Schlöglmann, 1996; Gal, 2000a; Manly & Tout, 2001; O'Donoghue, 1995, 2003; Tout, 2001; van Groenestijn, 1997; Willis, 1998; Withnall, 1995b; Yasukawa & Johnston, 2001). Concepts of numeracy which will be discussed in this section include computational (Glenn, 1978; Matthijsse, 2000) and functional (Riley, 1984) concepts, as well as ideas of numeracy as social practice (Baker, 1998; Kelly, 1997). The implications of these conceptualisations for the teaching and learning of adult numeracy are outlined in Chapter 3, 'Learning and teaching adult numeracy'.

Numeracy is often assumed to be the outcome of a sound mathematical education in childhood and innumeracy an indictment of poor schooling. Accordingly, numeracy is often equated with elementary mathematics and considered to be basic, superficial, and commonly understood, a view emphatically rejected by Ma (Ma, 1999:146). The problem is that, as Cooney observes, the level of difficulty is often conflated with the level of understanding, when these are not the same thing (Cooney, 1994:11). Similarly, a 'limited proficiency' vision of numeracy, akin to the (a)rithmetic element of the '3Rs' of Victorian elementary education, with the emphasis on equipping the workforce with the minimum skills required for industry and commerce, has proved remarkably persistent, a view challenged by Evans, amongst others (Evans, 2000b). FitzSimons challenges what she sees as a dangerously limited competence-based agenda for adult mathematics/numeracy education in the vocational context in Australia (FitzSimons, 2002).

The purpose of numeracy is variously considered as being for coping with adult life and work, as in the Cockcroft Report (DES/WO, 1982), or for critical citizenship (Evans & Thorstad, 1995; Skovsmose, 1994, 1998), empowerment and democracy (Benn, 1997a; Johansen & Wedege, 2002). For Straker, "The ability to calculate mentally is at the heart of numeracy" (Straker, 1999:43), an emphasis clearly visible in the National Numeracy Strategy in Primary schools in England, as we shall see in Chapter 3. Although the nature of the relationship between numeracy and context is contested, as we shall see in Chapter 2, in many modern definitions numeracy is seen as contextualised, as in the following definition:

> *To be numerate means to be competent, confident, and comfortable with one's judgements on* ***whether*** *to use mathematics in a particular situation and if so,* ***what*** *mathematics to use,* ***how*** *to do it, what* ***degree of accuracy*** *is appropriate, and what the answer means in relation to the context.* (Coben, 2000b:35; emphasis in the original)

Brown proposes a broad definition of numeracy to include "competence and inclination to use number concepts and skills to solve problems in everyday life and employment" (Brown, 2002). The Australian Association of Mathematics Teachers is more blunt: numeracy "involves using some mathematics to achieve some purpose in a particular context" (AAMT, 1997). Kaye has noted the range of uses and definitions of numeracy used by participants at ALM (Adult Learning Mathematics - A Research Forum) conferences in the decade 1992-2002 (Kaye, 2003). These show that there is a continuing emphasis amongst researchers and practitioners working with adults on the critical and empowering nature of numeracy (Johnston, 1994) and on contextualised conceptions of numeracy (Evans & Thorstad, 1995).

Nonetheless, Evans contends that the 'limited proficiency' vision of numeracy prevails. Against this vision, he offers a "provisional working definition for a reconstituted idea of numeracy" as meaningful social practice:

> *the ability to process, interpret and communicate numerical, quantitative, spatial, statistical, even mathematical, information, in ways that are appropriate for a variety of contexts, and that will enable a typical member of the culture to participate effectively in activities that they value.* (Evans, 2000b:236)

Evans' definition covers a comprehensive range of mathematical and mathematics-related information, similar to some conceptualisations of 'mathematical literacy', discussed below. However, it begs the question of who is "a typical member of the culture" and what are the activities that they value? The answer seems to be determined by the perspective of whoever is making the definition. Johnston and her colleagues categorise such perspectives as follows. They distinguish between concepts of numeracy with narrowly-defined goals or learning outcomes, such as have been adopted by many national and international bodies, which they characterise as approaching numeracy from a human resources or accountability perspective, and approaches which would allow for the development of critical citizenship (Johnston, FitzSimons, Maaß, & Yasukawa, 2002).

Gal approaches the issue of conceptualisation in a slightly different way (Gal, 2000a). He describes three different types of "numeracy situations": "generative", "interpretive", and "decision". Generative situations require people to count, quantify, compute and otherwise manipulate numbers, quantities, items or visual elements, all of which involve language skills to varying degrees. Interpretive situations demand that people make sense of verbal or text-based messages that may be based on quantitative data but require no manipulation of numbers. Decision situations "demand that people find and consider multiple pieces of information in order to determine a course of action, typically in the presence of conflicting goals, constraints or uncertainty" (p15). He sees adult numeracy education as helping students "to *manage* effectively *multiple* types of numeracy situations" (p24). He characterises numeracy as a semi-autonomous area at the intersection between literacy and mathematics (p23) and asserts that conceptions of numeracy should address not only purely cognitive issues, but also students' dispositions and cognitive styles (p21).

The relationships between numeracy and mathematics and between numeracy and common sense are particularly problematic. Adults may underestimate their mathematical abilities because of a tendency to dismiss the mathematics they can do as 'just common sense', reserving the term 'mathematics' for that which they cannot do (Coben, 2000a). Indeed, White discusses the view that numeracy is really 'common sense': people may not be as innumerate as they appear to be from tests of their computational skills. He argues that rather than asking how many people are innumerate we need to ask in what contexts they are innumerate (White, 1974). Mathematics may be seen as either encompassing numeracy, as stated in the description of Adults Learning Mathematics - A Research Forum (ALM), or vice versa, as in the Australian adult numeracy teacher education pack, **Adult Numeracy Teaching - Making Meaning in Mathematics** (ANT), where numeracy is seen as "not less than maths but more" (Johnston & Tout, 1995; Yasukawa, Johnston, & Yates, 1995). This view, which is said to be commonly held in Australia, is explained by one of the authors of the ANT pack as follows:

> *We believe that numeracy is about making meaning in mathematics and being critical about maths. This view of numeracy is very different from numeracy just being about numbers, and it is a big step from numeracy or everyday maths that meant doing some functional maths. It is about using mathematics in all its guises - space and shape, measurement, data and statistics, algebra, and of course, number - to make sense of the real world, and using maths critically and being critical of maths itself. It acknowledges that numeracy is a social activity. That is why we can say that numeracy is not less than maths but more. It is why we don't need to call it critical numeracy - being numerate is being critical.* (Tout, 1997:13)

O'Donoghue also avers that numeracy and mathematics are not interchangeable terms and sees numeracy as encompassing some elements of mathematics, rather than vice versa:

> *Mathematics and numeracy are not congruent. Nor is numeracy an accidental or automatic by-product of mathematics education at any level. When the goal is numeracy some mathematics will be involved but mathematical skills alone do not constitute numeracy.* (O'Donoghue, 2003:8)

Another member of the ANT team, Johnston, writing with Yasukawa and Warren, defines numeracy as "the ability to situate, interpret, critique and perhaps even create mathematics in context, taking into account all the mathematical as well as social and human complexities which come with that process" (Yasukawa et al. 1995:816). Johnston and Yasukawa define it as a way of negotiating the world through mathematics (Johnston & Yasukawa, 2001).

So what does it take to negotiate the world through mathematics? What areas and levels of mathematics are implied in the term 'numeracy'? Here it becomes apparent that we are dealing with a moving target, since, in the UK at least, there has been a steady decline in the level and extent of mathematical skill, knowledge and understanding signified by 'numeracy' over the last four decades, as shown in the use of the term in various public documents detailed in the following paragraphs. Ironically, the same period has seen growing public concern about the extent of innumeracy.

The term 'numeracy' was coined in the Crowther Report (DES, 1959:para. 398) as the "mirror image of literacy" to mean a relatively sophisticated level of what might nowadays be called scientific literacy. This was to be inculcated in young people staying on at school after the then earliest statutory leaving age of 15 and was intended to help bridge the perceived gap between literary and scientific cultures. Twenty years later there were signs of a diminished, utilitarian usage when, in an article originally published in 1978, Girling briskly contended that being numerate involved the sensible use of a 4-function calculator (Girling, 1992). Such views prompted Le Roux's "alternative definition", echoing Crowther, in which numeracy was the ability of mathematicians and non-mathematicians to communicate with each other (Le Roux, 1979).

In 1982 the Cockcroft Committee, charged with the task of considering "the mathematics required in further and higher education, employment and adult life generally" in England and Wales, published its report. This stated:

> ***We would wish the word 'numerate' to imply the possession of two attributes.*** *The first of these is an 'at-homeness' with numbers and an ability to make use of mathematical skills which enables an individual to cope with the practical mathematical demands of his everyday life. The second is an ability to have some appreciation of information which is presented in mathematical terms, for instance in graphs, charts or tables or by reference to percentage increase or decrease. Taken together, these imply that a numerate person should be expected to be able to appreciate and understand some of the ways in which mathematics can be used as a means of communication...* ***Our concern is that those who set out to make their pupils 'numerate' should pay attention to the wider aspects of numeracy and not be content merely to develop the skills of computation.*** (DES/WO, 1982:para.39, p11; bold text in the original)

By this time a utilitarian spirit prevailed and the mathematics required to cope with the practical mathematical demands of adult life was not seen as particularly high in level or wide in scope, as is evident from the Cockcroft 'Foundation list of mathematical topics' (para. 458, pp135-140). The list includes: number; money; percentages; use of calculator; graphs and pictorial representation; spatial concepts; ratio and proportion; and statistical ideas. The Cockcroft Report seems to have been influential: the Foundation list formed the basis for the National Curriculum (NC) for Mathematics in schools and hence also the Adult Numeracy Core Curriculum (BSA, 2001a) of ***Skills for Life***. Post-Cockcroft, numeracy has come to refer to the mathematics at the lower end of the Mathematics NC (see Chapter 3, below, for a fuller discussion of the National Numeracy Strategy in Primary schools).

This view has been challenged by Noss and others who have objected to the narrow concentration on 'visible' self-evident mathematics, at the expense of the mathematics that "lies beneath the surface of practices and cultures" (Noss, 1997:5). In 1997 the authors of a major study of effective teachers of numeracy defined the term more broadly as 'the ability to process, communicate, and interpret numerical information in a variety of contexts' (Askew, Bibby, & Brown, 1997). As one member of the research team, Askew (Askew, 2001b:106), points out, this last definition is similar to that used in other parts of the world, in particular, in New Zealand, and resonates with the way in which 'number sense' is understood in the United States (McIntosh, Reys, & Reys, 1992). Indeed, an interesting example of how the 'domain of numeracy' has expanded culturally in certain places and periods, for example, in the notion of discounted cash flows, are given in Cline-Cohen's book, **A Calculating People: The spread of numeracy in early America** (Cline-Cohen, 1982).

From the 1980s on, and especially since 1999, following the Moser Report, **Improving Literacy and Numeracy: A Fresh Start** (DfEE, 1999), the term 'adult numeracy' has become established in England as referring to an essential, but lowly, 'basic skill' (although the term 'adult basic skills' appears to be being phased out in favour of more explicit formulations, such as 'literacy, numeracy and ESOL' - English for Speakers of Other Languages). In the Moser Report, and subsequently in the government's ***Skills for Life*** strategy to improve adult basic skills in England (DfEE, 2001), numeracy is the ability "to use mathematics at a level necessary to function at work and in society in general" (DfEE, 1999). In ***Skills for Life***, the scope of adult numeracy has been established more closely than hitherto. It seems likely, given the high public profile of the strategy, that the definition of the term will tend to stabilise, at least in England. If so, it will be as a relatively limited set of low-level (by comparison with the Crowther conceptualisation) uncontextualised mathematical skills, systematised in the Standards for Adult Literacy and Numeracy (QCA, 2000) and operationalised in the Adult Numeracy Core Curriculum (BSA, 2001a) the associated Subject Specifications for adult numeracy teacher training (DfES/FENTO, 2002) and teaching/learning materials (DfES Readwriteplus, 2002).

In the realm of practice, concepts of numeracy have arisen pragmatically with reference to the contexts in which adult 'basic skills' education has developed perhaps more than with reference to official reports or researchers' analyses. In some areas of provision in England - especially Local Education Authority (LEA) and voluntary sector provision in local communities - that context has been shaped primarily by the adult literacy campaign of the 1970s. Literacy has remained the dominant element, with numeracy provision often managed by a literacy specialist. The relationship between literacy and numeracy teaching and learning remains a subject of debate (Lee, Chapman, & Roe, 1996) – and that between numeracy and ESOL has barely begun to be explored - but there is little doubt that numeracy has been the 'poor relation' (Coben, 1992).

The areas of mathematics included in different formulations vary according to the context in which they are used: in some contexts 'numeracy' refers to basic number computation only (the 'four rules' of addition, subtraction, multiplication and division with whole and rational numbers), in others it includes geometry and algebra, data handling, statistics, or problem-solving. In UK Higher Education (HE), where mathematics is taught as a service subject as well as a subject in its own right, the provision of mathematics support for students who may be struggling with the mathematics requirements of their undergraduate courses is not necessarily called 'numeracy'. This may be because the term is now associated with a restricted diet of low-level number work, although the disciplines in which mathematics is applied are still called the 'numerate disciplines', in the spirit of Crowther (London Mathematical Society, Institute for Mathematics and its Applications, & Royal Statistical Society, 1995).

In the UK in the 1980s the need for applicants and would-be applicants to meet mathematics and English language and literacy entry requirements for further and higher education and training led to the development of an access movement promoting 'second chance' education (Benn, 1997a). These 'access to mathematics' courses are more likely to use the term 'mathematics' than 'numeracy' in their titles. In vocational education and training courses offered by Further Education (FE) colleges and other training providers in what is now known as the 'learning and skills' sector, 'numeracy' often means the mathematics deemed necessary to support students in pursuit of their primary aim of a vocational qualification; in the 1990s it became synonymous with the core (later key) skills 'application of number' syllabus. There has also been a tendency for 'Numeracy', or 'Basic Mathematics' in FE to be used to denote lower levels of mathematics provision, with 'mathematics' reserved for the higher levels, while both are called 'maths' informally, by students and tutors. It may be that the ubiquity of the Adult Numeracy Core Curriculum will lead to greater use of the term 'numeracy' in such provision, as providers follow the lead of policy-makers and funders.

In the National Numeracy Strategy in primary schools (DfES, 2002b), and, later, in the mathematics strand of the Key Stage 3 Strategy in secondary schools (DfES, 2001), the terms 'numeracy' and 'mathematics' are used almost interchangeably, although whether this is justified is a vexed question (Brown, 2002; Brown, Askew, Baker, Denvir, & Millett, 1998; Noss, 1997). Whichever term is used, numeracy in state schools is seen as the mathematical foundation to be taught to all state-educated children, including those who will go on to specialise in mathematics. In this it differs from the Adult Numeracy Core Curriculum (ANCC), which culminates at Level 2 of the National Qualifications Framework. At this level the ANCC is assessed by a test covering a narrower range of number (as distinct from broadly mathematical) skills, so that arguably it does not give such a sound basis for further study in mathematics. The National Tests are discussed further in Chapter 3.

The result of this patchwork of terms and forms and levels of provision has been that adult numeracy practitioners in England have developed different conceptions of numeracy based on their professional experience and any teacher training they may have had. As Brown and her colleagues state, the meaning of numeracy is determined by its use in the social context (Brown et al. 1998) and this is as true in the contexts in which numeracy is taught as it is in society at large.

In some countries and contexts the term 'numeracy' is not well established (or perhaps actively avoided). For example, in the USA, the term 'quantitative literacy' (QL) is commonly used to refer to text-based activities with numbers, as in the Organisation for Economic Cooperation and Development's (OECD) International Adult Literacy Survey (IALS). In IALS, QL is defined as:

> *the knowledge and skills required to apply arithmetic operations, either alone or sequentially, to numbers embedded in printed materials, such as balancing a check-book, figuring out a tip, completing an order form, or determining the amount of interest on a loan from an advertisement.* (OECD, 1997)

A problem with this, as with any text-based conceptualisation, is that individuals' reading ability – their ability to decipher the text – may impede their ability to handle the quantitative operations specified in the test. Also, the insistence on 'printed materials' means that other written forms such as hand writing or electronic texts, to which adults may be routinely exposed, are not considered.

Steen argues that students need both mathematics, which he contends requires a distance from context, and QL, which "is anchored in real data that reflect engagement with life's diverse contexts and situations" (Steen, 2001:58). In a similar vein, QL has also been distinguished from the broader term 'mathematical literacy' (used by, for example, Helme & Marr, 1991; Hoyles et al. 2002; Milner, 1995; van der Kooij, 2001) by the US Quantitative Literacy Team (Quantitative Literacy Team, 2001). Indeed the term 'mathematical literacy' is used by the US National Council of Teachers of Mathematics to refer to the outcome of a good secondary mathematics education (NCTM, 1989). However, the British-based educationalist Howson argues that there is no essential dichotomy between numeracy and mathematical literacy (Howson, 2002).

Other formulations also utilise 'literacy' in a symbolic sense, linked to other terms, to indicate mastery of various mathematical or quasi-mathematical skills and understandings. These include 'criticalmathematical literacy' for political awareness (Frankenstein, 1996). For Frankenstein, 'criticalmathematical literacy' (with 'criticalmathematical' variously written as one or two words) involves "the ability to ask basic statistical questions in order to deepen one's appreciation of particular issues... critical understanding of numerical data thus prompts individuals to question taken-for-granted assumptions" (Frankenstein, 1990). There is also 'statistical literacy' (understanding and interpreting data), which Gal argues is essential for an informed democratic citizenry (Gal, 2000b), and 'financial literacy' (Schagen & Lines, 1996) (discussed in Chapter 2, below) which aims to encourage a solvent populace. Yasukawa proposes 'technological literacy', in which different types of mathematical knowledge are needed. These include:

- recognising what mathematical actors exist in a technological system, and what their intended and unintended roles are, especially in relation to the impacts of the system on people's practices and lives, and the environment;
- understanding the technical function served by the mathematical actors, and its significance in relation to the system's goal;
- being able to identify, use, and in some cases develop mathematical techniques or models to produce alternative components in the technological system which can lead to a more desirable goal;
- appreciating the connections between the mathematical components and the various human actor groups and the political significance of these connections; and
- being able to generate and ask the questions which bring the points listed above to the surface.

In addition, Yasukawa insists "there must be a focus on making connections between different types of practices and knowledges which exist in different and changing communities" (Yasukawa et al. 1995:40).

Other formulations use the term 'mathematics' or its derivatives. For example, D'Ambrosio writes of 'matheracy': "the capability of drawing conclusions from data, inferring, proposing hypotheses and drawing conclusions" as one of the 'new trivium for the era of technology', together with literacy and 'technoracy' (the latter meaning "critical familiarity with technology") (D'Ambrosio, 1998:10). Hoyles, Wolf, Molyneux-Hodgson and Kent also stress the importance of the technological dimension; they contend that what is needed for modern life is 'techno-mathematical literacy' (TmL), a concept fusing ICT (information and communication technology), mathematical and workplace-specific competencies (Hoyles et al. 2002). Elsewhere, Hoyles, Noss and Pozzi analyse what they call adults' 'mathematising in practice' in different work contexts (Hoyles, Noss, & Pozzi, 1999) and Skovsmose champions 'mathemacy', signalling a broad mathematical focus and a form of mathematical education geared towards democratic ends (Skovsmose, 1998). He argues that mathemacy is "a competence by means of which we become able to interpret and to understand features of our social reality"; as such it is as important as literacy (Skovsmose, 1994:208).

But numeracy refuses to disappear. For example, Skovsmose's compatriots, Lindenskov and Wedege, have introduced *'numeralitet'* as a direct Danish translation of 'numeracy', with a focus on functional mathematical competence in the changing social and technological context (Lindenskov & Wedege, 2001); Wedege defines it as "a math-containing everyday competence" (Wedege, 2001a:27). *Numeralitet* has now been adopted by the Danish Ministry of Education (Wedege, 2002). In a recent conference paper, Wedege develops a broader conceptualisation, 'sociomathematics', encompassing numeracy, as:

- *a problem field concerning the relationships between people, mathematics and society;*

- *a subject field encompassing ethnomathematics, numeracy, mathematics-containing qualifications, etc.*
  (Wedege, 2003)

Earlier, Yackel and Cobb discussed 'Sociomathematical norms, argumentation, and autonomy in mathematics' (Yackel & Cobb, 1996).

Maguire and O'Donoghue have presented an 'organising framework' for gauging the sophistication of concepts of numeracy. These range from the 'formative' phase (where numeracy is considered as basic arithmetic skills), through the 'mathematical' phase (where the importance of making explicit the mathematics in daily life is recognised), to the 'integrative' phase, with each phase envisaged as stages in a continuum of increasing levels of sophistication. The continuum culminates in the integrative phase, in which numeracy is viewed as a complex, multifaceted and sophisticated construct, incorporating the mathematics, communication, cultural, social and emotional and personal aspects of each individual in context (Maguire & O'Donoghue, 2003).

In the successor to IALS, the Adult Literacy and Lifeskills Survey Numeracy Framework 2000 (ALL, 2002), numeracy is named as such and defined as the "knowledge and skills required to effectively manage the mathematical demands of diverse situations" (Manly & Tout, 2001:79) and "the bridge that links mathematical knowledge, whether acquired via formal or informal learning, with functional and information-processing demands encountered in the real world" (Numeracy Working Group, 1999). Steen refers to various goals associated with five different dimensions of numeracy:

> ***Practical****, for immediate use in the routine tasks of life;*
> ***Civic****, to understand major policy issues;*
> ***Professional****, to provide skills necessary for employment;*
> ***Recreational****, to appreciate games, sports, lotteries;*
> ***Cultural****, as part of the tapestry of civilization.*
> (Steen, 1997:xxii)

These may be read as the goals of putative individual adult learners, but the issue of whose purposes numeracy should serve - the individual's or society's or both (Wedege et al. 1999), is not always clear. As FitzSimons and her colleagues observe,

> *most researchers nowadays eschew purely functional aims for numeracy in favour of empowering learners through numeracy - however the term 'empowering' may be understood. However, the teleological purposes are not always made explicit - whether they are for individual, democratic, or adaptive development of the learner.* (FitzSimons, Coben, & O'Donoghue, 2003:122)

The expression 'purely functional' here may be read as referring to what Evans (Evans, 2000b) calls the 'limited proficiency model', i.e., numeracy as a restricted set of 'coping skills'. However, as Tomlin has pointed out (private communication, December 2002), there are different notions of function in play in different conceptions of numeracy and these may be signaled in discussions only through contextual clues. For example, in the 'limited proficiency model' numeracy may be seen as functional in terms of coping with the demands of everyday life, and these demands may be considered to be at a fairly low intellectual level (although this may be to oversimplify the demands of everyday life), or as functional in the changing social, political and economic context in ways which imply a critical notion of numeracy and a broader range and perhaps higher - or deeper - level of mathematical capabilities on the part of the individual. In other words, there are many senses in which numeracy may be considered to be functional: the question is, functional with respect to what context and purpose, for whom and from whose perspective?

Such considerations would appear to sanction a pluralistic conception of numeracy, or rather, 'numeracies', varying according to context. This conceptualisation may be seen as analogous to the plural form 'literacies', which has been debated in the 'New Literacy Studies'. In the New Literacy Studies language and literacy are seen as social practices rather than technical skills to be learned in formal education (Street, 2001:17). Since there is a multiplicity of these social practices, it might be argued that there is also a multiplicity of literacies (although this view has been challenged by Kress (Kress, 1996), who argues that this is to atomise literacy, an argument that could be applied with equal force with respect to numeracy).

Another tenet of the New Literacy Studies, Street's distinction between 'autonomous' and 'ideological' models of literacy (Street, 1984) may also be relevant here. In the 'autonomous' model literacy is seen as having consequences in and of itself, irrespective of context. By contrast, in the 'ideological' model,

> *literacy not only varies with social context and with cultural norms and discourses regarding, for instance, identity, gender and belief, but... its uses and meanings are always embedded in relations of power. It is in this sense that literacy is always 'ideological' - it always involves contests over meanings, definitions and boundaries and struggles for control of the literacy agenda.* (Street, 2001:18)

Does Street's distinction work for numeracy? Are 'autonomous' and 'ideological' models of numeracy implicit in the conceptualisations reviewed here? Are the New Numeracy Studies emerging in parallel to the New Literacy Studies? The answer seems to be that the distinction works up to a point. It is certainly possible to see computational concepts of numeracy, such as that proposed by Glenn (Glenn, 1978) or Girling (Girling, 1992), as 'autonomous' in Street's sense. Similarly, concepts of numeracy that view it as social practice, varying according to context, may be seen as 'ideological' in Street's sense (indeed the word 'numeracy' could be substituted for 'literacy' in the above quotation and it would still make perfect sense to proponents of that view). However, the distinction has not been widely applied to numeracy and it is interesting to ask why this might be, especially given the close links between literacy and numeracy practice and provision in the UK and, for example, Australia, two countries where the New Literacy Studies have made an impact.

There are exceptions: Johnston builds on conceptions of literacies developed in the New Literacy Studies in her discussion of 'numeracies' (Johnston, 1999); Baker argues that the Adult Literacy and Basic Skills Unit (now the Basic Skills Agency, BSA), has promulgated an autonomous model of numeracy as culture- and value-free and that this is the dominant model. He argues that the existence of multiple numeracies must lead to the questioning of standards based on this model (Baker, 1998). Also, work on schooled and community numeracies by a team of researchers (including Baker and Street) working on the Leverhulme research project on low achievement in numeracy had as one of its dimensions the consideration of how far a social literacies approach could be applied in the field of mathematics education (Baker, Street, & Tomlin, 2000:159). Tomlin, writing with Baker and Street, casts doubt on how far this may be possible, given the invisibility of many 'numeracy events' and practices (Tomlin, 2002c). Ethnomathematics (the mathematics of cultural groups, a phenomenon discussed below) has affinities with Street's approach, as might be expected, given their common roots in anthropology. Nevertheless, it remains the case that proponents of a social practices approach to adult numeracy do not necessarily couch their research in terms of the New Literacy Studies and debates within ethnomathematics have largely gone on in a different part of the forest.

The absence of more widespread use or discussion of these approaches in relation to adult numeracy may simply reflect the relatively under-theorised state of adult numeracy by comparison with adult literacy (not to mention by comparison with children's numeracy, or with mathematics education more generally). Alternatively, it could be argued that a view of numeracy as culturally determined and socially formed practice(s) is implicit - and sometimes explicit - in the mainstream research and critical literature on adult numeracy, but that this view is not usually framed in terms of the New Literacy Studies. It should also be remembered that Street's distinction between autonomous and ideological literacy was made in reaction against the claim that literacy is the hallmark of culture, a claim that is rarely made for numeracy, especially since it fell from the lofty position accorded it in the Crowther Report, so that the need to counter such a view hardly exists.

More generally, numeracy is often subsumed within literacy in educational contexts, a situation challenged by Maguire and O'Donoghue with respect to Ireland (Maguire & O'Donoghue, 2002) and by Cumming with respect to Australia. Cumming states unequivocally that "the inclusion of numeracy as a component of literacy: sometimes explicitly included in literacy agendas, sometimes implicitly, sometimes omitted; is not sufficient" (Cumming, 1996).

All in all, there is an absence of consensus with respect to concepts of adult numeracy, paradoxically alongside a growing recognition of its importance (whatever 'it' is). Successive definitions have been developed by contributors to debates in different policy, practice and research arenas, steering the concept and associated policy and provision in different directions at different times and for different purposes. Governments, and inter-governmental organisations such as the OECD, have bolstered some conceptions of adult numeracy by giving them official blessing in terms of policy directions, or embedding them in forms of educational provision or international surveys. The discourses of researchers, practitioners and policy-makers on the nature and purposes of adult numeracy are at odds with each other, so that it is all too easy for conversations to be at cross purposes. Debate is lively in some areas and stifled in others and there has been insufficient dialogue between researchers, practitioners, policy-makers and learners.

Indeed, the voice of adult numeracy learners has been largely absent from debates about the nature of numeracy. Tomlin's research (Tomlin, 1999, 2002a) is an exception to this general rule, as are various contributions to the Proceedings of Adults Learning Mathematics - A Research Forum (ALM), and a recent study of adults' 'learning journeys' (Ward & Edwards, 2002), but these do not necessarily address conceptual issues in adult numeracy explicitly. Evans' study of adults' mathematical thinking and emotions (Evans, 2000b) centres on adult students and he derives his concept of numeracy from this, but that is unusual, and, as we have seen, his definition rests on a notion of a "typical member of the culture" that may limit its usefulness. It seems likely that debate will continue over the vexed question of 'what is numeracy?' as long as there is no consensus over its purposes or scope and as long as the voices of the intended beneficiaries are barely heard.

But perhaps we look in vain for consensus when a more fruitful way forward would be to seek to understand the tensions between different formulations of numeracy. This is what Kanes tries to do in a recent paper (Kanes, 2002). He looks at numeracy "through three lenses each offering alternative and competing views of the terrain numeracy encompasses". These he terms: visible-numeracy; useable-numeracy; and constructible-numeracy. Visible-numeracy "names the kind of knowledge which is intended when using commonly accepted mathematical language and symbols to formulate mathematical relationships and communicate these to others", for example, in the tradition of the 3R's (Kanes, 2002:341). 'Useable-numeracy' is "the kind of numerical knowledge exhibited when a person is engaged in real-life problem-solving", as happens in the workplace (Kanes, 2002:341-2) and elsewhere outside the classroom. It is "complex, and deeply embedded in the context in which it acquires meaning" (Kanes, 2002:344). It is 'invisible' and often elided with 'common sense' (Coben, 2000a). By contrast, constructible-numeracy is "produced by an individual/social constructive process usually in a learning situation" (Kanes, 2002:342). These are not mutually exclusive and he demonstrates how 'addition', for example, may be seen as an instance of all three types of numeracy. Kanes cites Noss' elaboration of two paradoxes in support of his conceptualisation:

- *If we only look at the "surface of arithmetical activities" in adults' working lives, then we are bound to find only "traces and shadows" of mathematics in actual use. A curriculum based on such a view will become more and more narrow and, paradoxically, less and less useful.*

- *While educationalists are right to identify alienation and a lack of mathematics confidence within the community, in attempting to address this issue school mathematics has tended to turn towards what can be more easily learned and away from "its broader roots in science and technology".*
  (Noss, 1998, cited in Kanes, 2002:346 and paraphrased here)

In Kanes' view,

> *Noss' point is that the very amenability of constructible-numeracy is a trap. The tendency in schools will be to teach what is most easily constructible - and this opens a possible zone of tension between numeracy which is useable though not so easily constructible, and numeracy which is more easily constructible though less useable.*
> (Kanes, 2002:346).

Coben points to a similar paradox in her discussion of use value and exchange value in adult numeracy (Coben, 2002). To restate her argument in Kanes' terms, she argues that what Kanes would call useable-numeracy may have high use value but no exchange value, while, conversely, what he would call 'constructible-numeracy' has high exchange value (for example, it may be readily converted into the 'hard currency' of entry qualifications for jobs or further training) but may have rather less use value.

For Kanes, such paradoxes are not so much a problem as a starting point for further enquiry. He points out that "much of what makes numeracy interesting, challenging and important has to do with the ambiguity of its status among the senses of visibility, useability and constructibility" (Kanes, 2002:342). He then sketches a new way of thinking about numeracy as a cultural historical activity system, a line of theory following in the Vygotskian tradition, developed by Engeström and others (Engeström, 1987, 1999; Scribner, 1984; Suchman, 1996; Wertsch, 1985). In Kanes' formulation, models and idealisations of numerical work are the outcome of the system, as shown in the following diagram:

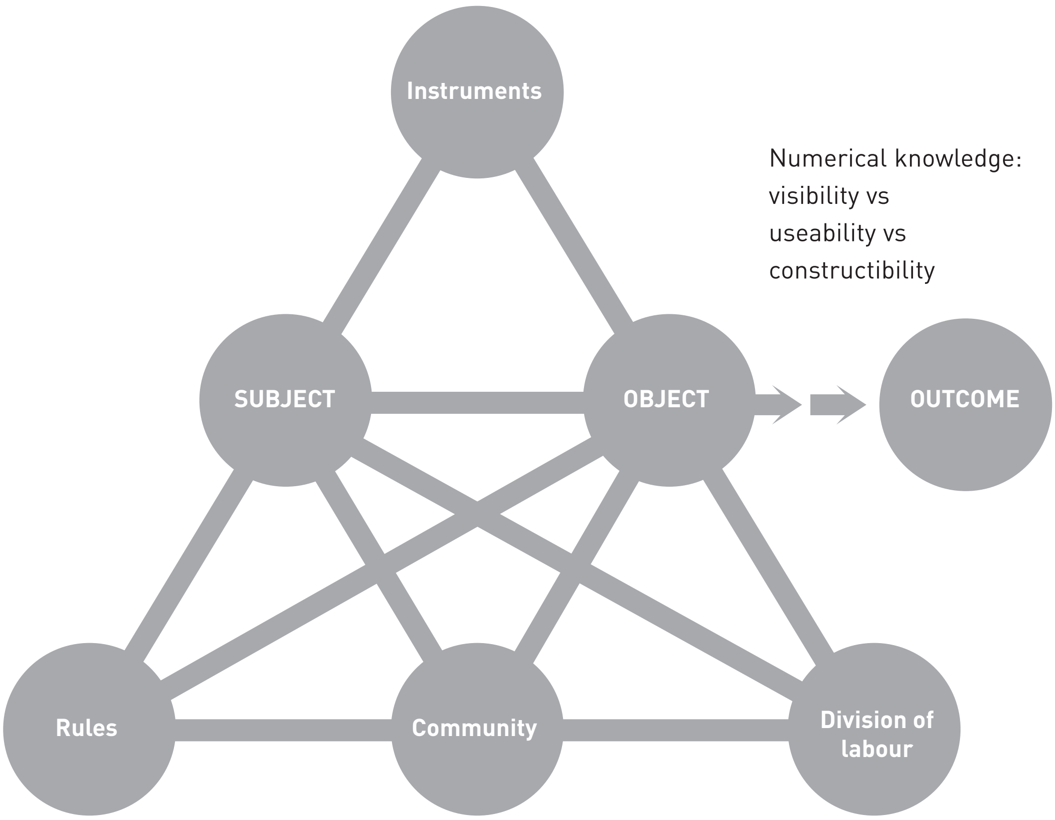

Figure 1. Kanes' model of numeracy as a cultural historical activity system
(Kanes, 2002:348)

Kanes concludes his paper with the following comments:

> *At the heart of the activity theory framework is a transformation of our understanding of the tensions among visible, useable and constructible numeracies. These should not be seen as extrinsic eventualities, that is, potentially correctable by suitable means or ways of thinking about numeracy. Instead, they are better seen as intrinsic to the nature of numeracy in its current state of cultural development. Noss's double-bind situations are not anomalies to be overcome so much as keys to understanding the cultural basis of numerical activity. In activity theory language, these anomalies afford primary contradictions underscoring efforts to move numeracy in any given direction.* (Kanes, 2002:348)

The intention in this report is neither to prescribe nor proscribe any particular concept of adult numeracy, rather it is to indicate the complexity of the issue and to encourage consideration of the significance of any chosen concept for key decisions about what is taught, to whom, under what circumstances, and for what purposes, while recognising that some definitions carry more weight than others because they are enshrined within powerful policy formulations. Kanes' formulation seems to offer a way forward to help us understand the complexity inherent in conceptualising numeracy; it may even help us to live with the uncertainty surrounding the term, although his focus on numerical activity, rather than mathematical activity more broadly, may be an unnecessary limitation. Perhaps Skovsmose's term, 'mathemacy' (Skovsmose, 1998), would be more useful after all: with 'mathemacy' substituted for 'numeracy' in Kanes' formulation, and with mathematical knowledge as its object.

Kanes' threefold distinction allows us to move beyond what FitzSimons calls "an arbitrary, judgement-based binary division within the discipline of mathematics (i.e., according to the viewer's perception of the usefulness or otherwise of the contextual situation)" which is often linked to concepts of numeracy (FitzSimons, 2002:38). It is interesting to note here that Kanes' category associated with the use of numeracy is termed 'use*able*-numeracy' not 'use*ful*' numeracy, implying agency on the part of the user, rather than judgement on usefulness by another. Kanes' conceptualisation also supports findings from the literature on situated cognition (discussed in Chapter 2) which expose ideas of numeracy as essentially 'easy', 'simple' or 'basic' as irrelevant. What is easy to one person in one situation (Kanes would say: in one cultural-historical activity system) may be difficult for another person, or for the same person in another situation.

The decision to include sources relevant to, as well as directly about adult numeracy in this review indicates that a broad concept of numeracy as an aspect of lifelong mathematics education is in play here. Accordingly, the following section outlines mathematics education as a research domain, with particular reference to adults learning mathematics, in order to set a framework for the rest of the report.

(Adult) mathematics education as a research domain

Niss maintains that mathematics education is "a massive and complex phenomenon", deserving scholarly attention as an object of scientific study worldwide (Niss, 1996:9). Despite its size it is undergoing 'a search for identity', as recent commentators have noted (Sierpinska & Kilpatrick, 1998; Steen, 1999). Ernest has sought to map the domain from a philosophical standpoint. He puts forward a comprehensive postmodern perspective in which mathematics education is constituted by a multiplicity of practices at all levels, including learning out of school, with the following as primary objects of research:

(a) the nature of mathematics and school mathematical knowledge;

(b) the learning of mathematics;

(c) the aims and goals of mathematics teaching and schooling;

(d) the teaching of mathematics, including the methods and approaches involved;

(e) the full range of texts, materials, aids and electronic sources employed;

(f) the human and social contexts of mathematics learning/teaching in all their complexity;

(g) the interaction and relationships between all of the above factors.

Following on from these primary objects, he proposes the following secondary objects:

(a) the nature of mathematics education knowledge: its concepts, theories, results, literature, aims and function;

(b) the nature of mathematics education research: its epistemology, theoretical bases, criteria, methodology, methods, outcomes and goals;

(c) mathematics education teaching and learning in teacher education, including practice, technique, theory and research;

(d) the social institutions of mathematics education: the persons, locations, institutions (universities, colleges, research centres), conferences, organisations, networks, journals, etc. and their relationships with its overall social or societal contexts.
(Ernest, 1998a, paraphrased in FitzSimons, 2002:50)

Ernest's 'objects of research' may be readily applied to adult mathematics education. In one form or another this review touches on them all, while making it clear that the adult research domain is much less well-developed.

While work continues on the development of mathematics education in general as a research domain, adult mathematics education is beginning to challenge the hegemony of school mathematics education. Nonetheless, adult mathematics education is still under-theorised and under-researched, so that the emerging research domain is "ill-defined - or wide open, depending on one's point of view" (Coben, 2000d:47). In her review of research in mathematics education, FitzSimons notes that until recently there has been a lack of interest in adult and vocational education on the part of the international mathematics education research community (FitzSimons, 2002:56) amongst whom it was of "marginal importance" (FitzSimons, 2002:51).

Against this background, some preliminary observations extracted from the **Second**

International Handbook of Research on Mathematics Education may be helpful in setting the scene with respect to adults' mathematics education as a research domain. The authors suggest that:

- *the raison d'être for work in this domain is that adult mathematics teaching and learning deserve attention in their own right;*
- *practice and research in adult mathematics education demand a broad conception of mathematics that is not limited to specialized mathematics (e.g., Wedege, 1999; Wittmann, 1998);*
- *there is a coalition of interests in the field across a wide spectrum of related or contributing disciplines;*
- *there is a recognition that research must be closely linked with practice in a field where development and improvement in practice have priority status; and*
- *the community of researchers is truly international, a fact that is corroborated by the lists of contributors/participants in ALM conferences and ICME working groups.* (FitzSimons et al. 2003:117)

There has been a burgeoning of research activity from the 1990s on, a period that coincides with important initiatives in the field, such as the development of the ABE Mathematics Standards Project in the USA (Schmitt, 1995), the publication of the 'ANT' numeracy teacher training pack in Australia (Johnston, Marr, & Tout, 1997; Tout & Johnston, 1995) and the founding, in the UK, of the international research forum, Adults Learning Mathematics - A Research Forum (ALM, 1994-present), and the national Numeracy and Mathematics in Colleges (NANAMIC) group, as well as what is now the Adult Numeracy Network, (ANN, 1994-present) in the USA, and, in Australia, the Adult Literacy and Numeracy Australian Research Consortium (ALNARC, 1999-present).

A significant body of research and reflections on practice in adult mathematics education has been published over the last decade. This includes: the proceedings of successive annual ALM international conferences (Coben, 1995a, 1995b, 1997b; Coben & O'Donoghue, 1998; Johansen & Wedege, 2002; Johnson & Coben, 2000; Schmitt & Safford-Ramus, 2001; van Groenestijn & Coben, 1999); the proceedings of the 'first international seminar' on adult numeracy, held near Paris in 1993 (CUFCO, 1993); the conference on **Adult Mathematical Literacy** in the USA in 1994 (Gal & Schmitt, 1994) and the Proceedings of subsequent ANN/ANPN meetings. Also, to date, the Proceedings of two meetings of the International Congress on Mathematics Education (ICME) 'adult' Working Groups have been published (FitzSimons, 1997b; FitzSimons, O'Donoghue, & Coben, 2001). A number of books has also been published, including **Perspectives on Adults Learning Mathematics: Research and Practice** (Coben, O'Donoghue, & FitzSimons, 2000), Gal's edited book **Adult Numeracy Development: Theory, research, practice** (Gal, 2000c), Benn's **Adults Count Too** (Benn, 1997a), Evans' **Adults' Mathematical Thinking and Emotions: A study of numerate practices** (Evans, 2000b), van Groenestijn's study of numeracy in adult basic education in The Netherlands, **A Gateway to Numeracy** (van Groenestijn, 2002) and FitzSimons' study of adult and vocational mathematics education, **What Counts as Mathematics?** (FitzSimons, 2002).

In the UK, earlier published research commissioned for the Cockcroft Report (DES/WO, 1982) includes that on adults' use of mathematics in everyday life (ACACE, 1982; Sewell, 1981), on mathematics in work (FitzGerald & Rich, 1981; University of Bath School of Mathematics, 1980) and in medicine (Pirie, 1981).

Despite - or perhaps because of - its underdeveloped state, there is lively debate about adult mathematics education as a research domain, for example, at successive recent ALM conferences (Wedege, 1998, 2001b; Wedege et al. 1999). One of the participants in these debates, Wedege, locates research and practice in adults learning mathematics "in the border area between sociology, adult education and mathematics education" (Wedege, 1999:57) and asks 'could there be a specific problematique for research in adult mathematics education?' (Wedege, 1998). As we have seen above, Benn (another participant in the debate) describes the research domain as a moorland (Wedege et al. 1999), placing adults learning mathematics at the centre, with the closest disciplines identified as adult education, mathematics education, and mathematics. Wedege, drawing on the work of Niss (Niss, 1999), describes the research domain as encompassing three superordinate subject areas: teaching, learning and knowing mathematics. She summarises the conclusions of the debate in ALM (i.e., both the organisation of that name and the field - or moorland - that it represents) as follows:

> *(1)* ***Preliminary place in the scientific landscape:*** *The ALM community of practice is accepted as a research domain within the didactics of mathematics;*
>
> *(2)* ***Subject area:*** *The learner is the focus of the ALM studies and her/his 'numeracy' is understood as mathematics knowledge.*
>
> *(3)* ***Problem field:*** *Didactic questions are integrated with general adult education questions in ALM and the studies are interdisciplinary.*
>
> *(4)* ***Two perspectives:*** *The duality between the objective and subjective perspective is implicit, or explicit, in all ALM problematiques.*
>
> *(5)* ***Justification problem:*** *The general aim of ALM practice and research is 'empowerment' of adults learning mathematics.*
> (Wedege, 2001b:112, bold italics in the original)

Coben (Coben, 2000d) also reviews the debate and extends Benn's list of contributing disciplines to include political and anthropological theory, citing, as examples, her own and Knijnik's work (Coben, 1999, 2000a; Knijnik, 2000). She characterises adults learning mathematics as

> *an emerging research domain, interdisciplinary within the social sciences (as is its 'parent' field, education) and spanning the sub-fields of mathematics education and adult education. 'Mathematics' is taken to mean mathematics learned and taught at any level, including the most basic and, in Wedege's terms, it includes 'numeracy', or mathematics in the social context.* (Coben, 2000d:50-51)

Following on from this, FitzSimons, Coben and O'Donoghue present a case for developing the research domain along interdisciplinary lines. They argue that it is important to examine the problematic relationship between the related disciplines and the core of the research domain - adult mathematics education - in order that it should not dissolve into them; neither should the core be constituted from a simple aggregate of inputs from related disciplines. Instead, "what is needed is a field-specific framework (or frameworks) for adult mathematics education that integrates all contributions from the core and elsewhere", with adults and mathematics giving specificity to adult mathematics education as a research enterprise. They contend that this enterprise is likely to include questions on:

- *the nature of mathematics and the relationships between various forms of mathematics;*
- *the measurement of adults' mathematical ability and performance;*
- *research into adult numeracy and workplace mathematics;*
- *attitudinal and affective factors in adults mathematics learning;*
- *issues in teacher training for adult mathematics education.*
  (FitzSimons et al. 2003:116)

They envisage the relationship between research and practice as interactive, mutually beneficial and supportive, with research and development leading to improved practice in the field of adult mathematics education.

This is the approach taken in this review: sources are selected from the relatively small, but growing amount of research on adult numeracy per se and on adult mathematics education more broadly, as well as from the much larger amount of research in related disciplines; and research and practice are seen as having the potential to be mutually illuminative and supportive of adults learning mathematics.

Research in mathematics education in general may have much to teach adult educators, although there are significant differences between the education of children and adults in terms of persistence, motivation and agency, the purpose of what is learned (and to some extent the content also) and patterns of participation. However, as Bishop notes, the process should be two-way: "we can expect to find from research on adult learners, data and thoughts which will inform and extend our constructs and concepts of mathematics learning in general" (Bishop, 1997:3). FitzSimons, Coben and O'Donoghue contend that this is already happening:

> *Adult mathematics research has shed light on, and helped chart new visions for work and mathematics (Hoyles, Noss et al. 1999; Kanes, 1997; Noss & Hoyles, 1996b; Sträßer, 1999; Wedege, 2000b, 2000c), school mathematics and everyday and work practices (Harris, 1991b; Schliemann, 1999), and adults' common sense knowledge of mathematics within their wider experience of life (Coben, 2000a; Wedege, 1999).*
> (FitzSimons et al. 2003:121)

Kanes' formulation, discussed above with respect to conceptualisations of numeracy, may be helpful here (Kanes, 2002). Much of the research on adults' everyday and work practices and their common sense knowledge of mathematics would fall into his category of 'useable' adult numeracy, embedded in various contexts. Research on 'visible' numeracy, in Kanes' terms could include, for example, Foxman's, Hart's and others' work on children's strategies and errors in calculation, discussed in Chapter 3 (Foxman & Beishuizen, 1999; Hart, 1984; Kerslake, 1986). Investigations in Kanes' category of 'constructible' numeracy, studying the process of adult learning and teaching, viewed as "an individual/social constructive process usually in a learning situation" (Kanes, 2002:342) are fairly well represented in the adult mathematics education literature, perhaps reflecting the numbers of practitioners and former practitioners engaged in adult mathematics education research. Examples may be found in ALM and ICME 'adult' Working Group proceedings and include analyses of practice in the UK (Elliott & Johnson, 1997) and USA (Safford, 1998).

Epistemologies of mathematics and mathematics education

We turn now to consider two sets of competing and incompatible epistemologies of mathematics, and of mathematics education, which, FitzSimons argues, influence every area of activity in the adult mathematics education research domain (FitzSimons et al. 2003). These are: absolutist and fallibilist epistemologies of mathematics (Benn, 1997a; Ernest, 1991); and constructivist and sociocultural epistemologies of mathematics education (Cobb, 1994). We shall also consider feminist epistemologies which have had an influence in research, teaching and learning in mathematics and numeracy.

While these are presented here, and are often presented by their proponents, as competing models, increasingly researchers in mathematics education emphasise the value of having several competing theories (Jaworski, 1999; Kirshner, 2002; Sfard, 1998; Anderson, Greeno, Reder & Simon, 2000; Boaler & Greeno, 2000). It should also be remembered, as Lerman found, that teachers' epistemologies do not necessarily translate into particular teaching approaches (Lerman, 1990).

Absolutist and fallibilist epistemologies of mathematics

The absolutist view of mathematics is based on belief in the certainty and neutrality of mathematics, while the fallibilist view treats mathematics as a social construct, a view amenable to those researchers who see numeracy as social practice. One such, Benn, argues that approaches based on a fallibilist view are more inclusive and lead to more andragogical, or adult-friendly teaching and learning; by contrast, the absolutist view is associated with the product view of mathematics, in which mathematical skills and concepts are seen as external to the learner (Benn, 1997a). FitzSimons contends that the absolutist view underpins vocational and further mathematics education in Australia and that this is unhelpful since it does not take account of what she calls the 'technologies of power' embedded in adult and vocational education (FitzSimons, 2002).

In her review of research about learning mathematics over the past 25 years, Kieran describes a major shift from a time when learning mathematics was associated with immediate recall, retention and transfer, and understanding was equated with achievement in tests or the performance of tasks. Writing in the mid-1990s, she finds that learning mathematics is regarded as 'learning mathematics with understanding'. She argues that this reflects a change from behaviourist research perspectives on learning mathematics, where evidence of learning is sought in changes in behaviour, to constructivist perspectives where learning is seen as understanding constructed by the learner - the so-called 'turn to constructivism', a phenomenon we consider next (Kieran, 1994).

Constructivist and sociocultural models of mathematics education

Constructivist epistemologies of mathematics education view mathematics as a process, rather than a product, whereby knowledge of mathematics education is gained by doing mathematics. Constructivist educators focus on ways in which the individual learner makes sense of mathematics (after Piaget) or, increasingly, see learning as an activity in which shared mathematical meanings are constructed socially (after Vygotsky) (Dossey, 1992; Sierpinska & Lerman, 1996). Jaworski points out that debates between 'radical and 'social' constructivists discussed by Ernest (Ernest, 1994b) parallel debates between protagonists of these two positions (Jaworski, 1994).

Although both the Piagetian and Vygotskian influences date from the first half of the twentieth century, debates on constructivism in mathematics education research circles gained pace from the 1980s on (Benn, 1997a; Burton, 1993; Cobb, 1994; Ernest, 1998b, 1994a; Gal, 2000a; Jaworski, 1994; Johnston, Marr et al. 1997; Nunes, 2001; Steffe & Kieren, 1994; von Glasersfeld, 1989, 1992; Zevenbergen, 1996). Protagonists of these debates include several who are active in adult mathematics education research, including Benn in her book **Adults Count Too** (Benn, 1997a), Safford on building a theoretical framework for mathematics education with adults (Safford, 2000b), FitzSimons on **Teaching Mathematics to Adults Returning to Study** (FitzSimons, 1994) and Johnston and her colleagues writing about the development of the adult numeracy teacher development pack, **Adult Numeracy Teaching** (ANT) (Johnston & Tout, 1995), in which they use a 'critical constructivist' approach (Johnston, Marr et al. 1997).

In adult mathematics education the individual construct position in constructivism has made some headway amongst researchers and practitioners. The other main constructivist approach, which sees the learning of mathematics as happening through social interactions, emphasises the role of context in the process of learning facts, concepts, principles and skills, often through problem solving. This view is also well represented in the literature on adults. However, constructivism has its critics, including Klein, who argues from a post-structuralist perspective that it may militate against the development of agency on the part of the learner (Klein, 1999), and Skovsmose, who bewails the absence of a critique of mathematics as an institution in constructivism (Skovsmose, 1994).

Sociocultural epistemologies of mathematics education (Atweh, Forgasz, & Nebres, 2001) are making headway in the adult mathematics education research domain, rooted as they are in respect for adults' 'common sense' knowledge in their everyday contexts. For example, the work of Lave (Lave, 1988), Lave and Wenger (Lave & Wenger, 1991), and others in theorising 'situated cognition' has been influential, together with studies of informal mathematics practices, including those in Brazil reviewed by Carraher (Carraher, 1991). Evans' work on the transfer of learning also stems from a sociocultural constructivist perspective (Evans, 2000c), as does much research on ethnomathematics (Powell & Frankenstein, 1997), discussed in a later section of this chapter.

Feminist epistemologies

Feminist epistemologies have been influential in mathematics education and mathematics education research, especially in gender studies, reviewed in Chapter 3 and discussed in relation to attitudes to mathematics in Chapter 2. The plural form 'epistemologies' is used deliberately in order to avoid the suggestion that there is only one feminist epistemology, or that all feminist researchers in adult numeracy or mathematics education agree with each other: such is not the case and the intention here is to sketch some of the main lines of research using broadly feminist epistemologies.

Becker uses a model of two types of 'knowing' developed in feminist research: 'separate' (associated with men) and 'connected' knowing (associated with women), which she characterises as follows:

Separate Knowing	Connected Knowing
Logic	Intuition
Rigour	Creativity
Abstraction	Hypothesising
Rationality	Conjecture
Axiomatics	Experience
Certainty	Relativism
Deduction	Induction
Completeness	Incompleteness
Absolute Truth	Personal process tied to cultural environment
Power and control	Contextual
Algorithmic approach	
Structure and formality	

Figure 2: Becker's model of separated and connected knowing in mathematics
(Becker, 1995).

Becker suggests that girls have traditionally been disadvantaged in mathematics and science because these subjects value a type of separate knowledge over connected knowledge. She also suggests that if mathematics were to be taught in a more experiential way, with more discussion and open work connected thinking would be more valued. This, in turn, would mean that more girls would enjoy mathematics and choose to study mathematics to advanced levels. Becker contends that the success and improved attitudes of girls who are taught in a 'connected' way supports this idea (Becker, 1995).

Burton analyses moves 'towards a feminist epistemology of mathematics' in an article for **Educational Studies in Mathematics** (Burton, 1995). In the 1980s, Walkerdine and her colleagues at the Girls and Mathematics Unit at the Institute of Education examined and put into historical perspective claims about women's allegedly 'unmathematical' minds and the bases of assumptions about girls' performance in mathematics. They presented examples of mathematics education with pupils, their teachers and families, both at home and in the classroom, and discussed the problems and possibilities of feminist research in **Counting Girls Out** (Walkerdine, 1989).

Elsewhere, researchers who do not necessarily identify their approach as 'feminist', including, for example, Askew et al. (Askew, Brown, Rhodes, Wiliam, & Johnson, 1997), have argued that a 'connectionist' way of teaching is beneficial to both males and females. Also, Boaler links experiential, exploratory and creative mathematics education to girls' success (Boaler, 1994; Boaler, 2000).

Ethnomathematics

Ethnomathematics encompasses "the mathematics which is practiced among identifiable cultural groups" (D'Ambrosio, 1997:16) and educational approaches geared to engagement with these forms of mathematics. It is a field of anthropological, political and educational research and practice championed by the Brazilian educationalist, D'Ambrosio, from the mid-

1970s and since developed by Gerdes, Knijnik and others (Powell & Frankenstein, eds., 1997). The identifiable cultural groups in question could include, for example, workers in particular industries as well as ethnic groups. Although mathematics is sometimes claimed to be a universal language, as Ascher points out, much of mathematics education depends on Western assumptions and values (Ascher, 1991). Indeed, traditional 'academic' or 'school' mathematics could also be considered a form of ethnomathematics, practised by the identifiable cultural group of 'traditional' (in a Western context) mathematics teachers and academicians. Ethnomathematics challenges the hegemony of this Western model of mathematics and much of the research in the field is informed by a strong commitment to social justice (Powell & Frankenstein, 1997).

The development of ethnomathematics as an active area of research and practice has encouraged a growing recognition that mathematics may be embedded in a range of activities and practices (D'Ambrosio, 1997; Gerdes, 1997b; Saxe, 1991), an idea further developed in Chapter 2. Bishop has systematised these in the form of six 'pan-cultural' mathematical activities: counting; locating; measuring; designing; explaining; and playing (Bishop, 1991). FitzSimons has demonstrated how these activities occur in a pharmaceuticals factory in Australia and uses them as a basis for curriculum development with workers at the factory (FitzSimons, 2000a).

As FitzSimons and her colleagues point out, it is common for researchers to advance a social view of mathematics in their work and such a view necessarily raises questions related to values, power, social justice and responsibility (FitzSimons et al. 2003). Examples include Benn's feminist critique of issues surrounding mathematics education for adults (Benn, 1997a), FitzSimons' discussion of gender issues in vocational mathematics education (FitzSimons, 1997a), Knijnik's critical account of her work in mathematics education with the landless people's movement in Brazil (Knijnik, 1997b), and the work of Frankenstein (Frankenstein, 2000) and Gal (Gal, 2000b). Knijnik describes her 'ethnomathematics approach' as follows:

> *the investigation of the traditions, practices and mathematical concepts of a subordinate social group... and the pedagogical work which is developed so that the group will interpret and decode its knowledge; acquire the knowledge produced by academic mathematicians and establish comparisons between its knowledge and academic knowledge, thus being able to analyze the power relations involved in the use of both these kinds of knowledge.* (Knijnik, 1996:101)

All of these writers seek to empower adults, albeit from different political perspectives and in different contexts, although some of them might refute the term 'empowerment', arguing that power cannot be passed to another person but must be achieved by the individual or group concerned.

Working in a similar vein, Mellin-Olsen has explored 'folk mathematics' (i.e., the mathematics people use outside the specialised discipline of mathematics, and which involve the use of mediating artifacts) (Mellin-Olsen, 1987). Folk mathematics is also explored by Maier (Maier, 1991). For Mellin-Olsen, this exploration led to his adaptation of Activity Theory, a powerful theoretical framework in the tradition of Vygotsky. Activity Theory, in the form of Cultural Historical Activity Theory, CHAT, (Engeström, 1987) is also used by Kanes in his elaboration of the concept of numeracy, referred to earlier (Kanes, 2002) and in his research on factory workers' uses of mathematics (Kanes, 1997).

We look next at one of the ways in which a research domain may be exemplified, with a brief outline of reviews of research relevant to adult numeracy and mathematics education.

Reviews of research

There has been a recent flowering of reviews of research on adult numeracy and mathematics education, reflecting increasing concern with, and activity in, the area. These include a review of 'lifelong mathematics education' for the **Second International Handbook of Mathematics Education** (FitzSimons et al. 2003) whose authors attempt to develop a synthesis of research in the field of adult mathematics education from an international lifelong education perspective. The intention is to provide a critique of the current situation that captures the specificity of adult mathematics education as a research domain.

Tout and Schmitt's review for the US National Center for the Study of Adult Learning and Literacy (NCSALL) is entitled the 'Inclusion of Numeracy in Adult Basic Education' and it is a sad reflection on the neglected state of adult numeracy that this case still had to be made as recently as 2002 (Tout & Schmitt, 2002). The review has a US and international focus and the authors find that there has been "minimal" research, although they note that the picture is changing fast.

A British review of research in adult basic skills (which notes the "considerable ferment and debate within the numeracy field, including attention to out-of-school learning") was published by the DfEE in 2001 (Brooks et al. 2001). The key findings, which apply to numeracy as to literacy, may be summarised as follows:

- *There is an absence of intervention studies exploring what factors in teaching basic skills cause progress in learning basic skills.*
- *Very little is known about adults with special educational needs in basic skills provision.*
- *The major motive for attending basic skills provision is a desire for self-development, whereas the main reason for parents attending family learning is to help their children.*
- *Adults involved in family learning have higher attendance, retention and completion rates than adults in general provision and their progression to further study and/or employment is high.*
- *Little is known about what basic skills teaching is like on the ground.*

Meanwhile, Gal's chapter 'The numeracy challenge', gives an overview of the numeracy terrain, including a wealth of references to recent research, especially in the USA (Gal, 2000a), following on from his earlier comprehensive review of **Issues and Challenges in Adult Numeracy** (Gal, 1993). Johnston reviews twenty years of Australian adult numeracy in her report for the Australian Adult Literacy and Numeracy Consortium (ALNARC) (Johnston, 2002b). Safford-Ramus presents work in progress on her review of research dissertations on adult mathematics education in North America (Safford-Ramus, 2001). Research on literacy and numeracy in vocational education and training (VET) in Australia has been reviewed by

Watson and colleagues (Watson, Nicholson, & Sharplin, 2001) and by Falk and Millar (Falk & Millar, 2001) in two reports commissioned by the Australian National Centre for Vocational Education Research (NCVER); however, the focus is mainly on literacy. FitzSimons and Godden present a comprehensive international review of research on adults learning mathematics in a range of contexts, including VET (FitzSimons & Godden, 2000).

An indication of the growth in research in this area is given by the fact that a review of research in adult literacy and numeracy produced for the Adult Literacy and Basic Skills Agency (ALBSU, now the Basic Skills Agency, BSA) in the UK in the mid-1990s found relatively few sources to include on numeracy (44) and fewer still on adult numeracy/mathematics (24) (ALBSU, 1994). Thorstad included just 10 sources in her **Index of Summaries of Research into Adult Numeracy**, 6 of which were from the UK (Thorstad, 1992). Recent reviews confirm that much remains to be done, but they show a significant increase in activity in the UK and internationally, especially in North America and Australia, since the first review to deal with adult numeracy was undertaken for the National Institute of Adult Education (England and Wales) (now NIACE) by Withnall and her colleagues in the early 1980s (Withnall, Osborn, & Charnley, 1981).

In mathematics education generally recent reviews of research (in roughly chronological order) include a review of research on numeracy in the primary sector by contributors to Askew and Brown's edited book for the British Educational Research Association (BERA) and the British Society for Research in the Learning of Mathematics (BSRLM) (Askew & Brown, 2001). This may be of particular interest to adult educators in England, since the new Adult Numeracy Core Curriculum owes so much to the National Numeracy Strategy (discussed below in Chapter 3), which was first implemented in primary schools. Askew and Brown's book also includes de Abreu's useful review of British research into school numeracy in relation to home cultures (de Abreu, 2001). Magne's monumental "bibliography with some comments" gives comprehensive coverage of literature on Special Educational Needs in mathematics in several languages (English predominates), at all ages, from early childhood to post-secondary and from several disciplines. Magne reveals the paucity of published research on adults with special educational needs with respect to mathematics (Magne, 2001). A review of mathematics education sources listed on the ERIC database and published between 1982 and 1998 confirms the neglect of research on adult mathematics education within mathematics education as a whole. The authors found "a body of research that gives considerable focus to cognition and achievement, primarily in Grades K-12, with significant attention to integers and problem-solving; in relation to equity, the results appear mixed" (Lubienski & Bowen, 2000:631).

Meanwhile, Hill has reviewed the lessons to be learned about numeracy from the literacy experience, focussing on work with children in Australia (Hill, 2000). Nickson provides a (school) teachers' guide to recent research and its application that includes much that may be relevant to work with adults (Nickson, 2000). Adda (Adda, 1998) gives a "glance over the evolution of research in mathematics education" in Sierpinska and Kilpatrick's edited book, **Mathematics Education as a Research Domain**, tellingly sub-titled: **A search for identity** (Sierpinska & Kilpatrick, 1998). Gerdes presents a survey of current work on ethnomathematics, with a comprehensive bibliography (Gerdes, 1997b). The section on attitudes to mathematics from Osborne et al.'s review of research on attitudes to science, mathematics and technology is extracted in Chapter 4 of this report (Osborne et al. 1997). The first and second International Handbooks of Mathematics Education, published by Kluwer Academic Publishers (Bishop, Clements, Keitel, Kilpatrick, & Laborde, 1996; Bishop, Clements, Keitel, & Leung, 2003) give a comprehensive overview of mathematics education research, following on from Grouws' earlier **Handbook of Research on Mathematics Teaching and Learning** (Grouws, 1992). Sikula's **Mathematics Teacher Education: Handbook of research on teacher education** (Sikula, 1996) reviews the topic of teacher education, a topic discussed in Chapter 3 of this report. Askew and Wiliam have reviewed research in mathematics education for 5-16 year olds and drawn out implications for practice (Askew & Wiliam, 1995). The 25th Anniversary Special Issue of the **Journal for Research in Mathematics Education**, published in1994, includes a wealth of reviews on key areas of research activity in mathematics education published in that journal on: learning (Kieran, 1994); teacher education (Cooney, 1994); affect (McLeod, 1994); gender (Fennema & Hart, 1994); problem-solving (Lester, 1994); technology (Kaput & Thompson, 1994); an international perspective (D'Ambrosio & D'Ambrosio, 1994); research methods (Schoenfeld, 1994); and radical constructivism (Steffe & Kieren, 1994). Ruthven has also published a useful review of British research on developing numeracy with technology (Ruthven, 2001).

Earlier reviews include that by Bacon and Carter, who present a review of the literature on culture and mathematics learning (Bacon & Carter, 1991). Harris and Evans review research on mathematics and the workplace (Harris & Evans, 1991) and the same authors (Evans & Harris, 1991) review 'theories of practice' in mathematics education in another chapter in Harris's edited book **Schools, Mathematics and Work** (Harris, 1991c). They find that research in England and Wales in the field of mathematics and employment is under-developed and uninformative by comparison to research by Scribner (Scribner, 1984) and Lave (Lave, 1988), and the work described by Carraher in Brazil (Carraher, 1991). Earlier, in a two-part **Review of Research in Mathematical Education**, Bell and colleagues reviewed research on learning and teaching (Part A) (Bell, Costello, & Kuchemann, 1983) and Bishop and Nickson reviewed research on the social context of mathematics education (Part B) (Bishop & Nickson, 1983).

Annotated research bibliographies include those by Gates (Gates, 1997) and Ernest (Ernest, nd) on mathematics education, a bibliography of mathematics assessment alternatives (Assessment Resources Library, 1998), Wilson et al.'s **Annotated Bibliography of Multicultural Issues in Mathematics Education** (Wilson, Mosquera, Strutchens, & Thomas, 1994) and the aforementioned bibliography of Special Educational Needs in mathematics (Magne, 2001).

We turn next to a review of attempts, through surveys, to ascertain the extent of adults' numeracy (or innumeracy) (updated and extracted from Coben, 2001a).

Survey evidence of adults' numeracy skills

There has been a succession of international surveys of mathematical ability and performance in recent years, although as O'Donoghue points out, citing a study of international comparisons in mathematics education (Kaiser, Luna, & Huntley, 1999) "it is not always clear what these measure or indicate, or whether they apply to adults" (O'Donoghue, 2003:3).

Recent surveys include a series of studies undertaken by the International Association for the Evaluation of Educational Achievement (IEA). IEA studies in mathematics to date are: the First and Second International Mathematics Studies (FIMS, 1964 and SIMS, 1981); and the two-stage Third International Mathematics and Science Study (TIMSS or TIMSS-95) in 1995 and

TIMSS-R (or TIMSS-99) in 1999. TIMSS-95 surveyed students in more than 40 countries in grades 3, 4, 7 and 8 and the final year of secondary school in 1994-95. They were tested for science and mathematics knowledge related to their school curricula. This was followed up with TIMSS-99 in 1998-99 by a survey of students in grade 8; all were tested for mathematics and science knowledge related to their school curricula. England has participated as follows: in FIMS and SIMS at age 17+; in TIMSS-95 at Years 4, 5, 8 and 9; in TIMSS-99 at Year 9 (age 13+). A comparative study of the 12 education systems (including England) which participated in SIMS-1981, TIMSS-95 and TIMSS-99 has been undertaken by Robitaille and Taylor (Robitaille & Taylor, 2002). The next TIMSS is taking place in 2003.

Also surveying children's mathematics, but designed to assess their readiness for life beyond school, is the Programme for International Student Assessment (PISA). PISA is an international survey of 15 year olds in different industrialised countries, conducted under the auspices of the Organisation for Economic Cooperation and Development (OECD). With respect to mathematics, PISA assesses mathematical knowledge and ability and collects data on: mathematical thinking, reasoning and argumentation; posing and solving problems; using mathematical representations; working with symbolic, formal and technical elements of mathematics; communication; use of mathematical aids and materials. The First PISA survey was undertaken from March-April 2000 in countries in the Northern Hemisphere; reading literacy was the major domain of interest in this survey, with mathematical and scientific literacy minor domains. The second PISA assessment, in 2003, will focus on mathematical literacy and a third PISA assessment, in 2006, will focus on scientific literacy.

England has generally scored about average in these studies. In PISA 2000 England did well. The reasons for this may include the fact that the sample studied was all children aged 15 rather than all children at a particular grade-level and because of the emphasis, in the PISA survey, on mathematics in context, which was the basis of the post-Cockcroft mathematics curriculum in England; TIMSS has more non-contextualised items.

The most recent large-scale international survey of adults to report is the International Adult Literacy Survey (IALS, soon to be superceded by ALL, the Adult Literacy and Lifeskills survey). IALS surveyed a sample of adults aged 16-65 in industrialised countries. Like PISA (and like ALL), the IALS survey was conducted under the auspices of the OECD. The UK came third from the bottom on 'quantitative literacy' – defined, as we have seen, as, "the knowledge and skills required to apply arithmetic operations ... to numbers embedded in printed materials" (OECD, 1997), ahead of Ireland and Poland (NCES, 1998; OECD, 1997; OECD & Canada, 1996; Statistics Canada, 1996). More than half the UK adult population was estimated to be performing below the minimum required for coping with the demands of life and work in the knowledge society (Houtkoop & Jones, 1999:36), with 23.2% at the lowest level (Level 1) and 27.8% at Level 2 (OECD, 1997:151).

The IALS findings bear out those of recent national surveys of adults, including those based on data from the UK Cohort Studies, undertaken by a team led by Bynner and following up cohorts of children born in 1958 (the National Child Development Study, NCDS), 1970 (BS70) and 2000 (the Millennium Cohort) respectively. For example, evidence from adults in the NCDS found 23% of those tested having "very low" and 25% "low" levels of numeracy (Bynner & Parsons, 1997a). An international survey by the Opinion Research Business (ORB) for the Basic Skills Agency (BSA), put UK respondents bottom of the league of seven industrialised countries surveyed (BSA, 1997). Only 20% of people who took part in the ORB survey in the UK completed all twelve numeracy tasks accurately (BSA, 1997:6). A far higher percentage in the

UK sample (13%) refused to answer any questions without even seeing them, than elsewhere (where refusals ranged from 0%-6%) (BSA, 1997:20), indicating just how sensitive the subject is for many adults.

Individuals' difficulties in acquiring basic skills may be deep-rooted, dating back to childhood, as Bynner and Steedman found (Bynner & Steedman, 1995). The Third International Mathematics and Science Study (TIMSS, 1994-95 and 1998-99) showed the strong impact of parental education on children's mathematics achievement (Beaton et al. 1996). Indeed, the picture of UK adults' low achievement in numeracy revealed by surveys has changed little in recent decades since surveys associated with the Cockcroft Inquiry reported in the early 1980s (ACACE, 1982; Sewell, 1981).

But as we have seen, numeracy is a deeply contested concept. Conceptions of numeracy, survey methodologies and assessment instruments accordingly vary from survey to survey, making it sometimes difficult to compare findings. Space does not permit a review of the range of conceptions of adult numeracy used in surveys, and specialist surveys, for example on financial literacy, are considered later in this report under the appropriate headings. Instead, we shall focus on the largest recent survey of adults in the industrialised world, the IALS, and its successor, the Adult Literacy and Lifeskills Survey (ALL, 2002), both developed in cooperation with the OECD, which may give some indication of the difficulty of achieving a clear picture of adults' levels of attainment in numeracy.

The International Adult Literacy Survey (IALS)

The IALS surveyed three dimensions of adult literacy ('prose', 'document' and 'quantitative'; the latter, QL, is defined above) in 1996. According to two members of the IALS survey team, it was difficult to find tasks for assessment at the lowest level, Level 1 (Houtkoop & Jones, 1999:33). In the event, only one task (requiring the reader to complete an order form, totalling figures given on the form) was used at Level 1; nine tasks were used at Level 2 (OECD, 1997:123). Clearly, further work is needed in order to gather reliable data at Level 1.

The narrow focus on arithmetic, rather than a broader focus on mathematics, is also problematic, since important areas, such as problem-solving, spatial awareness or algebra were not considered. The tasks outlined in the IALS are problematic on several other counts. Firstly, the identification and selection of appropriately mathematical 'everyday' skills is fraught with difficulty (Evans, 1999; Schliemann, 1999). Adults' everyday lives vary and the place of mathematics in their lives varies (Coben & Thumpston, 1996). Also, as Noss points out, "mathematics is not always visible" (Noss, 1997:5). It may therefore be missed by researchers, and their research subjects, leaving the way open for restricted conceptions based on superficial understandings of the place of mathematics in adults' lives. This is a possibility that Kanes warns against, as we have seen (Kanes, 2002). Secondly, the difficulty of transposing a task from 'everyday life' to a test situation poses serious problems for the design of survey methodologies and assessment instruments. Thirdly, the presence of text as a medium for the communication of information involving mathematics is a further complicating factor, making it hard to disaggregate difficulties in reading and interpreting text from difficulties with mathematics, as Houtkoop and Jones point out (Houtkoop & Jones, 1999:32).

There is also the problem of overlap within the survey domains, which may lead to difficulties in interpretation. Numeracy tasks are not only contained within IALS questions on 'quantitative literacy': the IALS definition of 'document literacy' includes such 'numeracy' skills as locating and using "information contained in… job applications, payroll forms, transportation schedules, maps, tables and graphics" (OECD, 1997:14). Finally, the validity and reliability of the IALS data have been queried, for example, by Blum, Goldstein and Guérin-Pace (Blum, Goldstein, & Guérin-Pace, nd). They undertook a detailed analysis of the survey instruments, demonstrating the cultural specificity involved and critiqued the data modelling techniques employed. They formulated alternative analyses, arguing for extreme caution in interpreting results the IALS results in the light of the weaknesses of the survey.

The Adult Literacy and Lifeskills Survey (ALL)

The follow-up to the IALS, the Adult Literacy and Lifeskills Survey (ALL, 2002), formerly known as the International Life Skills Survey (ILSS), aims to overcome some of these difficulties. The ALL survey assesses the level and distributions of the cognitive skills which people need to acquire, use and update in order to participate successfully in a knowledge-based economy and society. It assesses performance in the skill domains of prose and document literacy, numeracy, and analytical reasoning. As the ILSS/ALL Numeracy Working Group point out, the inclusion of numeracy "offers a significant opportunity to develop a new conceptual framework for adult numeracy… covering a much wider breadth of mathematical skills and purposes" than the IALS' 'quantitative literacy' (Numeracy Working Group, 1999). In the ALL survey, numeracy will be considered as "the knowledge and skills required to effectively manage the mathematical demands of diverse situations". For the purposes of the ALL Survey it is proposed that:

> *Numerate behavior is observed when people* ***manage a situation or solve a problem in a real context****; it involves* ***responding*** *to* ***information about mathematical ideas*** *that may be represented in a range of ways; it requires the* ***activation of a range of enabling knowledge****, behaviors and processes.* (ALL, 2002:11; emphasis in the original)

In addition, a scheme of five 'complexity factors' has been developed to account for the difficulty of different tasks, enabling (a) an explanation of observed performance in terms of underlying cognitive factors and (b) the development of a complexity-rating scheme used to guide the construction of assessment tasks. These factors are identified as:

> *(1) type of match/problem transparency;*
> *(2) plausibility of distractors;*
> *(3) complexity of mathematical information/data;*
> *(4) type of operation/skill;*
> *(5) expected number of operations.*
> (Manly, Tout, van Groenestijn, & Clermont, 2001:82-84)

This scheme was presented by members of the ALL Numeracy Working Group at the seventh international conference of Adults Learning Mathematics - A Research Forum (ALM7) (Manly et al. 2001) and in Working Group for Action 6 (WGA6) at the Ninth International Congress for Mathematical Education (ICME9) (Manly & Tout, 2001). The Group insists on a broad focus encompassing different aspects of adults' numerate behaviour. They contend that

> *Numerate behavior obviously includes the ability to calculate or manipulate symbols but is far from being limited to it. In a large-scale survey context, assessment of numerate behavior can be accomplished through tasks couched in realistic non-school settings, with limited usage of formal notations, and with significant presence of text-rich tasks, as well as of some tasks where opinions rather than computation are called for (e.g., when interpreting statistical messages).* (Numeracy Working Group, 1999)

A report on work in progress on numeracy in the ALL survey has recently been published, including sample test items illustrating the team's approach to the assessment of numeracy skills (Gal, van Groenestijn, Manly, Schmitt, & Tout, 2003).

The ALL Survey is shaping up to be rather more sophisticated than the IALS, in that it is attempting to develop a more nuanced understanding of adult numeracy, going beyond the functional and computational conceptions that have characterised earlier surveys (Coben, 2000b). On the basis of the methodology available before they started work in 1999, the Numeracy Working Group question whether there was then a fully reliable and valid basis of comparison between adults in different countries (Numeracy Working Group, 1999). It is the aim of the ALL Survey to "enable policy-makers for the first time to have data about the numeracy levels of the general population and about variables associated with it" (ALL, 2002): an acknowledgement that this has not been available hitherto. In particular, the problem of assessment of adults operating at lower levels of numeracy, or those with reading or language difficulties, remains problematic, as was clear in the discussion at the ALM7 conference of the levels of difficulty of numeracy tasks (Manly & Tout, 2001). It should also be remembered that surveys of industrialised countries tell us nothing about adult numeracy in the rest of the world (Foroni & Newman, 1998; Rampal, Ramanujam, & Saraswati, 1998).

Concluding remarks on surveys

So, while the survey evidence reveals a serious and persistent problem of adult innumeracy, there is no consensus about what the surveys should be measuring, how best to measure it, and whether the results are valid, reliable and therefore truly comparable. Indeed, the UK did not take part in the ALL survey, apparently because of doubts about the benefits and methodology. Dissatisfaction with IALS led the authors of a recent survey of international benchmarking by the National Research and Development Centre for Adult Literacy and Numeracy (NRDC) to ask how it might be possible to replace the IALS data as the international benchmark for adult basic skills in England. They concluded that England should work with other countries to build up the international capacity and willingness to mount a separate, well-designed study (Brooks & Wolf, 2002).

The former Secretary of State for Education and Employment, David Blunkett, has deplored, as "a silent scandal" and "a national disgrace" the fact that up to seven million adults in England lack basic literacy and numeracy skills (Blunkett, 2000), a figure derived from the IALS data. Such statements, together with newspaper headlines such as "Numeracy and literacy standards 'a scandal'" (*Guardian*, 11 March, 1998) feed public anxiety about falling standards. However, a government statement that "Currently, far fewer jobseekers are identified by screening as having basic skills needs than we would expect" (DfEE, 2000:10) may point to weaknesses in current survey techniques with respect to adult numeracy. Light may be shed on such conundrums by the results of a survey of adult basic skills needs in England commissioned by the Adult Basic Skills Strategy Unit; results will be available in Autumn 2003.[1]

Here we turn to a book which, in its sub-title, appears to offer new ways forward in the measurement of adult numeracy in the context of population surveys: **Adult Basic Skills: Innovations in measurement and policy analysis** (Tuijnman, Kirsch, & Wagner, 1997). A

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[1] The survey report was published as this review of research went to press (DfES 2003c). It estimates that 23.8 million adults in England have numeracy skills at or below Level 1, with 15 million of these at or below Entry Level 3 and 6.8 million at Entry Level 2 or below.

chapter in this book by Jones reviews the literature on surveys assessing adult basic skills, but, disappointingly, says little about assessing numeracy (Jones, 1997). However, Jones and his colleagues presented an interesting paper at the ALM5 conference on this topic in relation to IALS (Houtkoop & Jones, 1999). In their ALM5 paper, although they claim that the IALS project was highly successful from both a scientific and a policy perspective, their analysis bears out the argument here that much more remains to be done with regard to surveying adult numeracy, especially at the lower levels of performance.

Notwithstanding the difficulties associated with the enterprise, successive surveys have sought to quantify the extent of adults' numeracy skills in the UK and internationally. More accurate surveys are needed if we are to judge the extent of the incidence of inadequate numeracy. Publication of the outcomes of the ALL survey, following the completion of analysis in 2004, may reveal whether the Numeracy Working Group has made the breakthrough needed in the measurement of adults' numeracy skills, knowledge, understanding and performance in different contexts.

We turn next to examine what research tells us about numeracy - or numeracies - in different contexts.

Numeracy in Context

The aspects of things that are most important for us are hidden because of their simplicity and familiarity. Wittgenstein, **Philosophical Investigations** (1968)

Context and transfer

Numeracy or mathematics learning takes place in a variety of settings, including the home and in cultural and workplace activities. This learning needs to be accommodated in any discussion of adult numeracy research and practice. This section accordingly looks at numeracy in context, focussing especially on the two areas highlighted in the definition of adult numeracy adopted in the ***Skills for Life*** strategy: mathematics in work and mathematics in everyday adult life. It does so mindful of the point made by Wittgenstein, above, and borne out by research findings, that much of the mathematics in adults' lives goes unrecognised (Coben, 2000a; Harris, 1991a, 2000; Noss, 1997) - in Kanes' terms it is 'useable-numeracy' rather than 'visible-numeracy' (Kanes, 2002).

One of the issues exercising adult numeracy/mathematics educators on both sides of the Atlantic, and in both hemispheres, is that of the relationship between learning and context. This is often expressed in terms of the possibility (or difficulty) of transfer of learning from one context to another, especially from the classroom to the work or other 'everyday life' context. A classic study of 'mathematics in the streets and in schools' in Brazil (Carraher, Carraher, & Schliemann, 1985) found that children who made a living selling water melons and sweets in the streets could calculate easily and accurately in that context but could not perform the same calculations when they were presented as 'school problems' (see also Carraher's selective review of studies from Brazil (Carraher, 1991)). This study, and Lave's ground-breaking work with adult shoppers and others, is reviewed below in the section on 'Investigating the use of mathematics in everyday life'. Schliemann concludes that everyday knowledge can be harnessed by teachers so long as meaningfulness and the student's own resources and approaches to deal with problems are the main focus of the teaching and learning activities. She stresses that:

> *Everyday mathematics research has documented how people represent and solve problems through their own invented methods commonly used in specific situations. Schools can and must engage students in situations that are part of their everyday experiences as well as in situations that are new for them. (...) By explicitly recognising these alternative methods of representing and solving problems teachers can understand more clearly how students think and better design situations to help them to advance and to cope with new situations and problems.* (Schliemann, 1999:29)

Wolf addressed similar issues in her work with young people on Youth Training Schemes (YTS) in the 1980s. She developed diagnostic assessment exercises built around actual work tasks:

> *The mathematics used is inherent in the tasks, and the methods are those of the trade in question. However, the tasks are structured in such a way that the trainee's progress and approach are monitored in detail, and detailed diagnostic information obtained whenever the trainee has any problems.* (Wolf, 1984:6)

Sierpinska questions the differences between 'Mathematics: "in context", "pure", or "with applications"' in her 'contribution to the question of transfer in the learning of mathematics' (Sierpinska, 1995). Nunes considers 'Mathematics learning as the socialisation of the mind' (Nunes, 1999).

Cobb and Bowers (1999) discuss 'Cognitive and situated learning perspectives in theory and practice' in their contribution to a long discussion on these competing perspectives, in the journal Educational Researcher (Anderson, Reder, & Simon, 1996; Anderson, Reder, & Simon, 1997; Greeno, 1997; Kirshner & Whitson, 1998; Cobb & Bowers, 1999). Anderson, Greeno et al. draw the debate to a close, concluding that situated and cognitive perspectives are both necessary and will tell us different things (Anderson et al. 2000), a view taken also in this review. Lerman gives a sympathetic but hard-hitting critique of situated theories in his discussion of 'The social turn in mathematics education research' (Lerman, 2000).

Others working with issues of adult learning, mathematics and context include Wedege, who distinguishes between two meanings of 'context': task-context and situation-context (Wedege, 1999). Task-context refers to the wording of the task and the assumptions the learner needs to make in order to solve a problem mathematically. Situation-context refers to the social, cultural, historical, psychological and other circumstances in which the problem is considered and learning occurs.

Evans explores the issue of transfer in depth in his study of adults' numerate practices (Evans, 2000b), drawing on work by: Walkerdine; Lave; Saxe; Hoyles, Noss and Pozzi; and Nunes, Schliemann and Carraher. He acknowledges in particular Walkerdine's work on discursive practice, theorising the boundary between everyday and school knowledge, and on relations of signification. Drawing on ideas from post-structuralism, linguistics and semiotics, as well as on Wedege's distinction between task-context and situation-context, he develops a powerful multi-dimensional notion of context as constituted by discursive practices, infused with the features that characterise those practices and supported and constrained by the material and other resources available.

Evans thereby offers a way of rethinking the 'transfer' of learning. Some researchers, such as Lave (Lave, 1988) and Lave and Wenger (Lave & Wenger, 1991) argue that since all knowledge is situated and context-specific, such transposition is highly problematic, if not impossible. Evans is more hopeful, while recognising the difficulties of what he prefers to call 'translation'. He argues that for anything like transfer to occur, "a 'translation', a making of meaning, across discourses, would have to be accomplished through careful attention to the relating of signifiers and signifieds" in particular chains of meaning (Evans, 2000b). This translation is not straightforward, but Evans contends that it will often be possible. He observes that, "Calling the process translation/ transformation reminds us that the translation can be 'free' as well as 'strict', and that the mathematical tools (such as the procedures for calculating) may themselves be changed in the process" (Evans, 2000b:233). It also opens up the possibility of a role for teachers in facilitating or encouraging 'translation', but Evans points out that much more research is needed into how best to achieve that end.

In the following sections we look at investigations of the use of mathematics in everyday life, includsing selected studies of mathematics in various work practices. We then look more closely at the use of mathematics in employment , especially in modern industrialised societies, and finally at research and development in financial literacy.

Investigating the use of mathematics in everyday life
by Dhamma Colwell

Interest in the use of mathematics in everyday life is often traced back to the work of Luria and other social psychologists in the early years of the Soviet Union. Luria visited rural communities in Uzbekistan and Khirgizia with colleagues in the 1920s to test the inhabitants' abstract thinking (Reed & Lave, 1979). They found that people who had had some schooling were able to categorise, but that people who had had no schooling did not reason in the same way. Instead, they used a situated system of categorisation, saying that an axe, a saw, a hammer and a log were all necessary for cutting wood. In whatever way the researchers asked the question, they could not persuade the participants to make a distinction between the tools and the log: they seemed unable to construct the abstract concept of tools.

> *Words for these people had an entirely different function from the function they have for educated people. They were used not to codify objects into conceptual schemes but to establish the practical interrelations among things.* (Reed & Lave, 1979:73)

Luria and his colleagues also presented their participants with syllogisms presented in familiar contexts, for example, information about bears, and asked them to say whether the conclusions were true or false. The unschooled subjects refused to express an opinion, saying that unless they were in the situation they could not tell. The subjects with some schooling were able to perform these tasks 'correctly'. Luria concludes that education is essential to develop abstract thinking. However, he is using a deficit model of his participants: instead of studying the kinds of problems the Uzbekis and Khirgizians identified for themselves, he was testing them on the kind of problem he had been educated in. When they were not successful, he concluded that they needed educating in abstract thinking, because he thought of that as a superior kind of thinking. Presumably, his participants did not see themselves as deficient. It is only recently that everyday practices have begun to be seen as valuable and therefore a legitimate field of study and the situated kind of thinking that Luria describes as being as significant as abstract thinking.

Lave provides the first major research undertaken into the mathematics people use in their everyday lives and a ground-breaking theoretical socio-cultural model of learning as active interaction between the learner and their environment (Lave, 1988). She undertook a number of linked studies: the observation of people doing their normal grocery shopping; an experiment where the same participants were asked to decide on the 'best buys' between pairs of grocery items; observations of members of a Weightwatchers club preparing meals in their own kitchens; and interviews with people about how their family money is managed.

Lave found that calculation was only one element in the multiple ongoing activities which constituted everyday life for the participants in her study. The problems were structured in, for example, grocery shopping rather than mathematics. The quantitative relations were not confined within the boundaries of mathematics, but had closer relationships to other things, like providing meals for the family.

Participants often made several attempts before solving their problems. They were able to check whether partial or interim solutions were consistent with reality and whether they were likely to reach a satisfactory answer using their chosen method. They were able to make more attempts until they were satisfied, or to abandon the problem as not being worth spending more time on.

Decisions were often based on qualitative rather than quantitative reasons. For example in the study of how people manage their money, Lave found that conflicts between the interests of the individual and those of the family were solved by moral prohibitions, which reflected the values within the family of promoting the well-being of the collective. Social relationships, feelings and values provide the structure and meaning within which problems were formulated and solved.

During this process the participants maintained control of the situation: they had generated the problems themselves and they decided how to solve them. They did not necessarily require a precise answer: an idea of something being larger or smaller was often enough. In the Weightwatchers study, participants often developed their own systems of measurement, abandoning what they had been taught in the class.

Lave contrasts her team's investigations with a study undertaken by Capon and Kuhn, who set up a table outside a supermarket and asked shoppers to perform 'best buy' calculations on a number of pairs of items, using paper and pencil (Capon & Kuhn, 1979). The results were dramatically different: only 44% answers were correct in the Capon and Kuhn study compared with 93% in Lave's study.

Lave asserts that in the Capon and Kuhn study the participants were given school mathematics questions contextualised as if they were everyday mathematics and the participants treated them like school mathematics questions. In Lave's observations of real everyday life, the participants generated their own problems and used a wide range of strategies to solve them to their own satisfaction.

In Lave's view, everyday cognition is not an inferior kind of knowledge. She challenges the supposition that the results of experiments carried out under laboratory conditions can be applied to life outside the laboratory. This assumption has resulted in false ideas of problem-solving in everyday life and the capabilities of adults. She asserts that investigation of everyday practice needs to be done in situ, not by attempting to simulate it elsewhere.

Lave proposes a socio-cultural model of learning, where cognition is a dialectic between individuals acting and 'the setting' in which they are situated: relationships with other people, feelings, motivation, values, and tools. Cognition is therefore active and dynamic: it changes over time and between situations. It is part of the practices that people are involved in. She sees problems and their solutions as being generated from disjunctions, conflicts and contradictions that occur in the course of people being involved in activity. The solutions to problems may be partial and shifting: often the generation of the problem and the solution happen together. There are no correct solutions, only partially satisfactory ones.

Saxe also investigated how mathematics is used in everyday life (Saxe, 1991). His study of child candy-sellers in Brazil examines the role of culture in the development of cognition (Saxe, 1988). He inquired into how learning happens in a cultural context, examining the interaction of different elements in the culture in the solution of problems in everyday life.

Saxe used observation and interview to investigate the activities of children selling candy in the streets of Recife, Brazil. He found that candy-selling was performed in four stages. The children first decided which kind of candy they wanted to sell. They would then buy a box of the candy from wholesalers, spending about half the money they had made from previous sales. They priced the candy at a convenient currency note or coin, it might be 3 sweets for 10 cruzeiras, so that they would sell the whole box for approximately twice the wholesale price. Then they would go to their pitch and sell the candy.

Social relationships were crucial to their activities. The children were helped by their families and by the clerks in the wholesalers to choose which sweets to buy and sell and how much to charge. Many of the customers also helped the children by buying sweets and helping them calculate the change. But there was also competition between children over the best selling pitches.

The older children, who had been selling candy longer, were better able to handle currency, to give change, and to decide on the best boxes of candy to buy and to price the sweets. Saxe concluded that the children had learnt these calculation skills through work rather than through schooling

Saxe found that the children's cognition was inextricably linked to their culture and social relationships. The activities of the children fitted the four parameter model of the inter-relationship between culture and cognition that Saxe had developed in his previous work with the Oksapmin highland people of Papua New Guinea. The four parameters are 'activity structures'; 'prior understandings'; 'artifacts and conventions'; and 'social interactions'; all interacting with 'emergent goals'.

'Activity structures' are the tasks people perform in everyday life, which are culturally determined in their formulation and their execution. Goals emerge from everyday activities, taking new forms and varying as people use their skills and knowledge in interaction with others and alone to order and construct their environments. Within these goals there will be a number of contributory tasks which will become apparent during the achievement of the general task.

In 'social interactions', other people may both influence the goals a person sets herself and be involved in the achievement of the goals. 'Conventions' are the accepted ways of doing things in the culture, for example writing, calculation algorithms and the idea that money is a fair exchange for goods and services; and 'artifacts' are the tools that are used in the culture, both concrete and mental. Individuals use their 'prior understandings' to both structure goals and find ways to achieve them.

Saxe's socio-cultural model is a useful one for examining activities both outside and within the classroom. He proposes that,

> *culture and cognition are constitutive of one another.... Social conventions, artifacts, and social interactions are cognitive constructions and cannot be understood adequately without reference to cognizing individuals. At the same time, individuals' cognizing activities are interwoven with conventions, artifacts, and other people in accomplishing problems of everyday life.* (Saxe, 1991:184).

Nunes, Carraher and Schliemann conducted a study in Brazil of the mathematics adults use in different kinds of work (Nunes, Schliemann, & Carraher, 1993). The participants were market traders, fishermen, building site foremen, carpenters and their apprentices, and farmers. The authors constructed calculation problems based on their participants' work practices: market traders calculating prices; fishermen calculating the price of caught fish from the retail price of prepared fish; building site foremen using scale plans to calculate sizes for construction; carpenters calculating the timber required for building wooden beds; and farmers calculating the numbers of plants needed for pieces of land of particular sizes. In some cases they made variations from normal practice, and compared the methods the participants used with those used by school children doing similar problems.

In most cases workers performed better than students with similar amounts or more schooling. The calculation methods the workers used were totally different from those used by the students: the workers used mainly oral methods, with the context for the calculations kept constantly in mind. This is in contrast to the methods taught in school: extracting the numbers and operations from the contexts, performing calculations on them, then applying the answers back to the context. In schools there is also an emphasis on using written algorithms. The students attempted to use these methods, but often did not remember them well. Nunes et al. found that the participants in their study were far less likely to make mistakes in the work situation, where the calculation values were meaningful to them, than in a school type of situation.

Notwithstanding their lack of education, the workers were able to calculate ratios which were not met in their working situations and were also able to solve problems which inverted their customary practice. For example, foremen were able to use building plans with unfamiliar scales to deduce the measurements of materials for the construction of buildings. Fishermen were able to transfer their skill of calculating the ratio of how much prepared fish could be made from the fish they caught, to a hypothetical situation with fish of a different yield. The fishermen were also able to calculate ratios in an agricultural context, about the yield of ground cassava from fresh cassava.

In the carpentry workshop the researchers studied workers at different stages of experience and found that the more experienced workers were more able to do the necessary calculations, even though the apprentices had had more schooling. The practice in the workshop was for the experienced carpenters to draw up lists of materials and measurements for the pieces of furniture to be made. The apprentices were then required to cut the pieces on the list. The researchers found that the less experienced apprentices could not calculate appropriately the amount of wood required to construct a bed, but the more experienced apprentices were much better at doing it. Therefore it is probable that apprentices learn the mathematics they need gradually, through their experience of using the carpenters' lists of materials and measurements, rather than through their schooling.

Nunes et al. found a degree of transfer of mathematical knowledge from one situation to another. The pragmatic calculation knowledge learnt in one context did not help the subjects perform mechanical context-free calculations of the same order, but it did help in other similar calculations in a different context, as long as the contexts were meaningful to the subjects.

Harris' work offers another example. She has investigated the mathematics used in by women in their work, both historically and worldwide. She toured the world with an exhibition she constructed, *Common Threads*, which explored mathematics in women's craft work. She collected more examples, ideas and feedback from visitors to the exhibition. She found that the mathematics embedded in spinning, weaving, knitting, sewing and embroidery has not been recognised (Harris, 1997). These activities require an understanding of spatial relationships, as well as number. But in analyses of the mathematics needed for work, it has often been assumed that only arithmetic is required. An examination of the work of designers, nurses and bank employees found a range of aspects of mathematics underlying many practices, but unrecognized by practitioners (Hoyles, Noss et al. 1999).

In another study, Johnston, Baynham, Kelly, Barlow and Marks asked the participants in their study of numeracy in practice, how they would share the cost of a pizza between three friends in real life.

> *Say you went out with some friends, and you had a pizza and you're going to share the costs. When people do that they are going to work out how much they are going to pay in different ways. So say it was you and you went with two friends, and the pizza cost 16.90 dollars, how do you think you would pay for it?* (Johnston, Baynham, Kelly, Barlow, & Marks, 1997:93)

The participants came up with a wide range of responses: one participant said he worked in a pizza shop and could make free pizzas whenever he liked; others said they would take it in turn with their friends to pay; some said they would pay for the group if they were the one with money that day; some did an approximate calculation; some did a rougher estimate to a convenient currency note and said one person would pay the extra; but others did not trust their friends to reciprocate and tried to work out the shares precisely.

The responses they gave were more dependent on social structures than mathematical knowledge: types of friendship, the amount of money they earned and family responsibilities. These varied responses show that in real life situations there is no one correct solution to such a problem. Whether a solution is satisfactory depends on the point of view of the participant.

Johnston examined the measurement of time as social practice, looking at practices in relation to the institutions in which they take place and their ideologies and discourses (Johnston, 2002a). She cites Haug's two contradictory logics of time. The logic of continuous time reduction is applied at work in Western society, where time measurement is used to squeeze more productivity from workers. The opposite logic of extensive time is applied where women particularly are expected to spend time extensively, often unpaid, on humanistic work: nurturing other people and the environment. In teaching there is a continuous struggle to reserve extensive time for parts of the job which are not necessarily productive in measurable ways. In numeracy learning the emphasis on speed tests reveals an underlying reductionist logic.

The implications for mathematics and numeracy education

Lave describes mathematics education as beginning in Britain in the 1750s as mathematics for the marketplace and becoming institutionalised as school mathematics by the 1820s (Lave, 1988). By 1900, an ideology of school mathematics had developed, viewing it as cold, irrefutable logic, having nothing to do with feelings, intuition or expression, yet as being applicable to everyday life.

She suggests that psychology and mathematics education share a common history and social context: a hegemony in which mathematics is seen as an academic discipline, a career, and a body of knowledge. The complex networks which link the academy and schools mean that they share a common view of cognition and of mathematics. Psychologists are particularly interested in investigating problem-solving and mathematics because they see these as a knowledge domain which employs higher level thinking, for example the highest stage of Piaget's formal operations. In the traditional view, types of thinking form a hierarchy with scientific understanding at the top, lay knowledge of science in the middle, and everyday cognition, seen as functional, non-scientific, lower class, primitive, often female or childlike, at the bottom. Nevertheless, everyday cognition is seen as something that the professionals should control and assess.

Lave compares the problems her participants solved with mathematical problems given to students in schools, where problems are constructed by other people, not generated from students' activity. There is usually one solution, a precise quantity, deemed correct by the teacher or text book, and it is not negotiable. The method of solving the problem is very often also prescribed by the teacher. The students may have limited control over its solution.

Lave problematises the idea that learning is transferable from one situation to another and in particular, that mathematics learnt in school is automatically usable in everyday life outside educational institutions. She suggests that studies aiming to prove transfer from school to everyday life are flawed. She therefore challenges the very foundations on which much mathematics education is based, the rationale for providing compulsory mathematics education to all schoolchildren: that learning mathematics in school will provide them with a portable tool-kit which they can produce and use in any situation. Lave found that outside educational institutions the solution of problems is part of a larger context of activity. In schools, the mathematics problem is an end in itself: these kinds of problems are specialised cultural products which belong to particular social practices, those of mathematics education.

Lave's research provides a challenge to concepts like 'basic skills' or 'key skills' of numeracy that can be learnt separately and then applied to any vocational area or everyday practice, as unrealistic.

In her critique of mathematics education, Harris argues that while purporting to be value free, mathematics plays a powerful social role in politics and economics and in classifying individuals and allowing or denying access to further and higher education (Harris, 1997). Ideas of what constitutes mathematics and how it should be taught in the West have been spread across the world in a remarkably homogenised form. Two thousand years of Christian education and social conditioning in the UK has positioned most women as unable to learn mathematics. Until the last 30 years of the twentieth century, schools restricted most girls' access to mathematics and made them learn needlework instead.

Harris argues that mathematical education for upper and lower class children has been differentiated between academic and practical, vocational mathematics. Some middle class girls were able to obtain an education similar to that provided for boys and to develop independent careers from the late nineteenth century on, but working class girls were restricted in their education to sewing and sums and in their work prospects to the roles of servant, housewife or factory worker. Mathematics education, she argues, has been gendered: learning materials have been focused on men and traditional male activities. When they were represented, women were shown in passive roles. Institutional racism has also been embedded in schools: in school organisation, assessment, the content of the curriculum, learning materials and behaviour of teachers.

Harris produced two packs of learning materials, **Wrap it up** and **Cabbage**, which provide real problems from the packaging industry and from traditional needlework activities that are mathematically challenging (Harris, 1997). She examined the mathematics in needlework from many countries and developed learning materials to re-engage the interest of women in learning mathematics and provide new and rich contexts for mathematical instruction. She suggests that mathematics education would be enriched by discussion of the political and social forces which shape mathematics instruction and affect motivation and achievement through the examination of the mathematics in needlework. Johnston also feels that numeracy learning could be improved by providing opportunities for understanding the complexity of the social practice of numeracy, including considerations of why our society counts and measures the things it does in the ways that it does (Johnston, 2002a).

Harris's work is at the interface, on the one hand, between the traditionally male activity of mathematics and the traditionally female activities of needlework and, on the other hand, between the tradition of mathematics as abstract and new ideas about making mathematics more meaningful, more connected to real life and other subjects, reflecting the language and culture of people using it.

Other work in this vein includes that by Nunes, Schliemann, and Carraher, who found that learners are more successful when the contexts in which the learning is embedded is meaningful to them (Nunes, Schliemann et al. 1993). Abstract learning of mathematical procedures may not be well retained and may not be available for application to practical problems. The mathematics used in working practices may best be learnt within those practices, rather than in the mathematics classroom. Vocational and mathematics teachers could work together, developing activities which make the mathematics in a vocational area visible and accessible.

The Dutch 'Realistic Mathematics' approach developed for schools at the Freudenthal Institute in The Netherlands, has been applied to adult numeracy education by van Groenestijn (van Groenestijn, 2002). She describes a method of assessment in which a structure of mathematical topics at different levels was developed as a framework within which 'realistic' mathematical tasks are used flexibly in interaction between the teacher and the learner. Not only are learners' skills level assessed, but they are asked to explain their methods of calculation. Training tutors to use this framework has resulted in the development of more flexible methods of teaching using more realistic contexts. Adult learners wrote and published their own mathematical problems, using a process of generating ideas, drafting, peer and teacher review and redrafting. It was found that this approach facilitated learners in developing conceptual understandings of mathematical topics as well as their communication skills (van Groenestijn, 2000). Research by Segarra (Segarra, 2002) and Tomlin (Tomlin, 2002b) shows similar findings and Ginsburg and Gal also propose the use of realistic learning contexts in adult numeracy teaching (Ginsburg & Gal, 2000).

The relationship between mathematics and 'real life' and the mathematics which will be needed in future - by the 'educated person', by the employee in an environment of constantly changing technology, and by the scientist - and how this may be achieved, was discussed at an international conference in 1996. The conference was attended by mathematicians, scientists, technologists, policy-makers, and educators coming from research, teaching, administration, industry and commerce. In their account of the conference, Hoyles et al. see a relatively convergent view of a mathematics curriculum emerging from the contributors, based on the construction and interpretation of quantitative models which reflect work practices and motivate learners (Hoyles, Morgan & Woodhouse, 1996; see also Hoyles, Morgan & Woodhouse, 1999).

We turn now to look more closely at mathematics and employment in the context of modern industrialised societies.

Mathematics and employment

Survey evidence in industrialised societies shows that poor numeracy carries a significant disadvantage for the individual in relation to paid work. For example, the IALS results and earlier surveys reviewed by Rivera-Batiz indicate that it has an important impact on earnings, even when language literacy is taken into account (Rivera-Batiz, 1994). Bynner and Parsons found that people without numeracy skills suffered worse disadvantage in employment than those with poor literacy skills alone (Bynner & Parsons, 1997b:27). Literacy and numeracy skills deteriorated when individuals were unemployed; this was especially true for those whose skills had been weakest at age 16. In a further study they concluded that "A basic skill threshold needs to be reached before we can be sure that the skill is going to be retained" (Bynner & Parsons, 1998:12).

So what are the demands of work with respect to mathematics? FitzSimons points out that accounts of workplace mathematical usage tend to undervalue its quantity and quality (FitzSimons, 2002:44), citing Buckingham (Buckingham, 1997) and Noss (Noss, 1997) in support of her argument. Perhaps that argument is now being won. Over twenty years ago the Cockcroft Report aroused interest in mathematics education for work and emphasised the importance of learning on the job and use of out-of-school calculation methods, concluding that "it is possible to summarise a very large part of the mathematical needs of employment as 'a feeling for measurement'" (DES/WO, 1982:24, para 85).

Recent research on mathematics in the workplace reveals a rather more complex picture. In Australia, Buckingham has described what she terms the 'generic numeracies of the shop floor' as: "the capacity to make use of information and mathematical strategies to solve problems" (Buckingham, 1998:89). In the UK, recent research for the UK Science, Technology and Mathematics Council (STM) by a team from the London Institute of Education, has shown that "mathematical skills in the workplace are changing, with increasing numbers of people engaged in mathematics-related work, and with such work involving increasingly sophisticated mathematical activities" (Hoyles et al. 2002:5). The study was undertaken in a diverse range of industries: electronic engineering and optoelectronics; financial services; food processing; health care; packaging; pharmaceuticals; and tourism and based on self-report by the workers taking part in the study. Common trends in all these sectors are identified as follows:

- *team-based working is widespread;*
- *the need for mathematical skills is being progressively extended throughout the workforce as a result of the pressure of business goals and the introduction of IT;*
- *here is a growing need to communicate information effectively, based on mathematical data and inferences and involving colleagues, customers and external inspectors;*
- *there is a need for hybrid skills, e.g., combining technical and analytic knowledge with the ability to communicate analytical information.*
  (Hoyles et al. 2002:12)

As the authors note, this last point has implications for the content and structure of both education and training. In this changing context, they find the following aspects of mathematics to be significant in terms of what they term 'techno-mathematical literacy' (TmL):

- *integrated mathematics and IT skills;*
- *an ability to create a formula (using a spreadsheet if necessary);*
- *calculating and estimating (quickly and mentally);*

- *proportional reasoning;*
- *calculating and understanding percentages correctly;*
- *multi-step problem-solving;*
- *a sense of complex modelling, including understanding thresholds and constraints;*
- *use of extrapolation;*
- *recognising anomalous effects and erroneous answers when monitoring systems;*
- *an ability to perform paper and pencil calculations and mental calculations as well as calculating correctly with a calculator;*
- *communicating mathematics to other users and interpreting the mathematics of other users;*
- *an ability to cope with the unexpected.*
  (Hoyles et al. 2002:4)]

Clearly, this list goes beyond computation (Kanes' 'visible-numeracy' (Kanes, 2002)), and 'numeracy' is relegated to a separate and subsidiary category (Hoyles et al. 2002:11).

The STM study bears out the findings of earlier research with nurses, bankers and pilots (Hoyles, Noss et al. 1999; Noss & Hoyles, 1996a; Noss, Hoyles, & Pozzi, 1998). In that research, which used observation, critical incident analysis and simulations of situations involving mathematics, Hoyles, Noss and Pozzi found that mathematics is bound up with factors specific to workplaces and tasks, that experienced workers exercise their judgement through their knowledge of the context as well as their mathematical skills (Noss et al. 1998). They also note that workers use artifacts in the process of decision-making, although they may be unaware of doing so, a process described as a 'crystallised operation', analogous to Chevellard's 'crystallised mathematics' (Chevellard, 1989). They conclude that the use of mathematics in the workplace depends on whether the activity is routine or non-routine and on the resources available, and that it is essential for researchers to look beyond visible mathematics and beyond the paradigm of 'traditional situated cognition' in order to discern the breadth and richness of mathematical models in use.

Such research may offer ways forward for adult numeracy and mathematics educators who wish to avoid the perceived shortcomings of narrow competence-based training (CBT) approaches. Such approaches are deplored by FitzSimons, in her study of the pharmaceutical industry in Australia, as the failure to address actual workplace needs and to recognise the knowledges workers actually possess, while imposing a regime of pseudo-contextualised skills, many not visited since the early years of school and irrelevant to the contemporary world of work (FitzSimons, 2000a; FitzSimons et al. 2003). She contrasts this approach with that of researchers such as Wedege, and Hoyles, Noss and Pozzi, whom she applauds for their "deeply respectful enquiries into the practices and knowledges of workers on the job" (FitzSimons, 2002:76).

Wedege discusses 'competence' in a more positive light as a construction in adult and mathematics education in her paper presented at the ICME9 conference (Wedege, 2001a). She suggests that numeracy (which, as we have seen in Chapter 1, she defines as "a math-containing everyday competence") is:

- *always linked to a subject (person or institution);*
- *a readiness for action and thought and/or an authorisation for action based on knowledge, know-how and attitudes/feelings (dispositions);*
- *a result of learning or development processes both in everyday practice and education;*

- *always linked to a specific situation context.*
(Wedege, 2001a:27)

Wedege adopted the AAMT technique of 'work-shadowing', outlined above, in her studies in Denmark (Wedege, 2000a, 2000c). She stresses the contextualised nature of mathematical knowledge and the need for so-called unskilled as well as skilled workers to be able to quantify (Wedege, 1999). She contends that mathematical knowledge does not qualify the worker for work unless it is integrated with knowledge, skills and properties that are relevant in relation to technique and organisation in the workplace (Wedege, 2000a).

FitzSimons discusses mathematics in and for the modern complex, multi-layered and dynamic workplace in the context of globalisation, arguing for appropriate mathematics education of the kind described in Chapter 1 as 'mathemacy', after Skovsmose (1998). She points out that most of the literature in this area is premised on the idea of a full-time workforce, although this is clearly not the whole story (FitzSimons, 2002: Chapter 2). Also, not all work is employment, for example, domestic work and hand-crafts traditionally regarded as 'women's work' may be done for love or money (or both - or neither). Harris has blazed a trail here, as we have seen in the discussion of research on the mathematics in everyday life, above. She celebrates the mathematics in women's work, pointing out that its aesthetic as well as its economic value is seldom recognised and its mathematical content commonly ignored (Harris, 1997). Similarly, Llorente describes the mathematics involved in jam-making (Llorente, 1996, 2000) and Black discusses the mathematics in knitting (Black, 1995).

Hutton investigated student nurses' mathematics and nurses' use of calculators on the ward (Hutton, 1998a, 1998b), contributing to a growing literature on mathematics and nursing (Coben & Atere-Roberts, 1996; Hoyles, Noss, & Pozzi, 2001; Noss, Pozzi, & Hoyles, 1999; Pirie, 1981, 1982; Shockley, McGurn, Gunning, Graveley, & Tillotson, 1989). Hoyles, Noss and Pozzi investigated the ways in which expert nurses calculate error-critical drug dosages on the ward, related to the concepts of ratio and proportion, using an ethnographic approach with analysis of episodes of drug administration. They found that experienced nurses use a range of correct proportional-reasoning strategies based on the invariant of drug concentration to calculate dosage on the ward, rather than the single taught method they describe outside of the practice (the formula typically taught in Schools of Nursing: 'what you want over what you've got, times the amount it comes in'). These strategies are tied to individual drugs in specific quantities and volumes, the way they are packaged, and the ways in which clinical work is organised (Hoyles et al. 2001).

A central tenet in this kind of research is "the importance of context and the acknowledgement of (adults') pre-existing strategic knowledges as well as alternative or limited mathematical conceptions (or misconceptions)" (FitzSimons et al. 2003:121). On the basis of studies on the mathematical demands of the modern workplace, Gal recommends an exploration of the curricular and instructional implications of new workplace numeracy requirements, especially those related to: the quality movement in industry; scientific reasoning; group problem solving; and communication skills around mathematical issues (Gal, 1993).

An area that spans adults' lives within and outside employment is what has become known as 'financial literacy'. It is an area where adults' "pre-existing strategic knowledges as well as alternative or limited mathematical conceptions (or misconceptions)" can have a positive or extremely negative effect on their lives, and work in this area is reviewed next.

Financial Literacy

Financial literacy is one aspect of adults' lives about which there is increasing concern on both sides of the Atlantic and in industrialised and impoverished countries.

In England, financial literacy is included in the school Personal Social and Health Education (PHSE) curriculum. The Adult Financial Literacy Group (AdFLAG) was established in 2000 by the Secretary of State for Education and Employment with a remit to make recommendations on ways to improve the financial literacy of the adult population, with a specific emphasis on those who are disadvantaged. The AdFLAG consultation found that:

- *Education for adult financial literacy has never been systematically addressed. There is no defined curriculum or set of learning objectives. Work needs to be done to set out what financial literacy means for adults, especially those at risk of financial exclusion, and progress measured. The Financial Services Authority should be a lead body in the development of financial literacy due to its statutory role to promote public understanding of the financial system.*

- *There has been a limited amount of research carried out specifically to address the financial literacy education needs of consumers as opposed to the need for new products or methods of delivery.*

- *The best way to address financial education within disadvantaged communities is to work through respected and trusted local groups.*

- *There is a vast range of initiatives with either a primary or secondary objective to deliver financial literacy. However, there needs to be a systematic approach to content, delivery, co-ordinating activity and spreading good practice.*

- *There is a close link between levels of basic skills and the use of financial products and services.*
  (AdFLAG, 2000)

Recommendations to a wide range of organizations, including government bodies, are summarised in appendices to the AdFLAG report (AdFLAG, 2000).

Progress on the achievement of the AdFLAG recommendations has been reviewed in a report by PKF commissioned by the government's Adult Basic Skills Strategy Unit. The findings and conclusions of the review are:

- *the current definition of financial literacy is sufficiently broad to encompass all relevant interests; financial literacy is not simply a basic skills issue;*

- *a financial literacy strategy is needed which should set the overall direction and articulate the what, why, how, who and when of the proposed future approach to financial literacy;*

- *ownership, leadership and coordination are essential if the strategy is to be successful;*

- *all stakeholders should be involved in the development of the strategy;*
- *strong programme/project management, adequate funding and effective communications and coordination will all be essential for successful implementation.* (PKF, 2003, paraphrased from pp4-5)

Overall, the report found that significant progress has been made, identifying a range of activity addressing the financial needs of adults across Government, the financial services industry, education and voluntary and community sectors. The report also identified some further areas to address and the need for a co-ordinated strategy for financial literacy across Government.

The DfES has established the Financial Literacy Steering Group, targeting the post-16 age group, and the 'Links with PHSE Curriculum' group, targeting the pre-16 age group. In the latter group, the ABSSU is developing links with the pre-16 curriculum teams leading on PHSE. A wide range of recent initiatives are listed in relation to the AdFLAG recommendations in Appendix 3 of the PKF report (PKF, 2003). These include the Adult Financial Capability Framework, developed by the Financial Services Authority (FSA) with the Basic Skills Agency (BSA) (FSA/BSA, 2003). The Framework covers a broad range of money management and consumer issues. It is intended for all those involved in financial capability education, including money advisers, teachers, trainers, and helpers interested in improving financial capability skills (FSA/BSA, 2003). Also, NIACE (the National Institute for Adult Continuing Education in England and Wales) has undertaken the 'Financial Literacy and Older People' (FLOP) project (NIACE, 2002) and produced a discussion paper, **Old Money. Financial understanding for older adult learners**, on policy and practice in relation to the need for better financial knowledge, understanding and skills, especially for older people (Carlton, Soulsby, & Whitelegg, 2002).

Also post-AdFLAG, the Community Finance and Learning Initiative (CFLI) began in early 2002 and runs until December 2003. It is a partnership, led by the DfES, of HM Treasury, local community-based organisations, including community-based financial institutions, development trusts, credit unions, Citizens Advice Bureaux (CABx), social housing providers and others. The CFLI is targeted around 'basic skills' levels and aims to engage those excluded from mainstream financial services and learning and to encourage take up of learning opportunities to raise skills and employability and the take up of appropriate financial skills. The initiative is being externally evaluated by ECOTECH; no information is yet available.

Meanwhile, a MORI survey was commissioned by the Basic Skills Agency in 2001, which involved the administration of five basic literacy and five basic numeracy tasks, and questions about respondents' ownership of financial products. The research shows that those with poor basic skills do own financial products and may need appropriate help from institutions; it also establishes a link between poor basic skills and financial exclusion (BSA, 2001b).

Earlier, a survey for the National Westminster Bank (NatWest) in the mid-1990s found that 80% of adults felt personal finance and financial understanding should have been taught when they were at school, and 79% of school pupils wanted to receive advice on financial matters (Audience Selection, 1994). Further research for the bank's charitable trust by the National Foundation for Educational Research (NFER) comprised two surveys relating to structured personal money management learning opportunities for adults: a survey of adult learning needs related to financial literacy; and a survey of providers of financial literacy learning resources. In the former category, five groups were surveyed:

- young people in work or training;
- Higher Education students;
- single parents on benefits;
- families in rented accommodation;
- the general public.

The survey report found that many interviewees experienced difficulty with arithmetical calculations. For example, only 52% of single parents were aware that 10% of £300 was worth more than £25.00. A minority in each group understood the meaning of 'gross' and 'net' interest, and a few people failed to recognise that 5.5% was more than 5%. A majority of single parents and families and a large minority of other groups made the wrong choice on a question requiring consideration of information on permitted cash withdrawals. Comparatively few people knew the maximum amount which could be claimed in Housing and Council Tax benefit. Many respondents were found to lack the ability to consider a problem and think of possible solutions; a minority was unable to distinguish between short-term and long-term solutions (Schagen & Lines, 1996).

In response, the bank constituted a working party of teachers, educators and bank staff to develop a national financial literacy programme, 'NatWest Face 2 Face With Finance' (Audience Selection, 1994) and established the NatWest Financial Literacy Centre at the University of Warwick in May 1995. The Centre includes a collection of research and teaching materials. The NFER evaluated the 'Face 2 Face With Finance' programme and found that it was being used successfully in a wide range of schools and colleges. Students and teachers alike found participation valuable and the benefits were shown to be wide-ranging for both. The students were helped to become financially literate, and by participating in real-life activities, they were helped to develop personal money management and enterprise skills, all of which are considered to be valuable preparations for adult and working life (NFER, nd).

In the USA a proliferation of financial literacy programmes has been initiated from the late 1990s on (Vitt et al. 2000). The need for this was established by studies such as Mandell's 'personal financial survey' of US high school seniors, designed to test their knowledge in four categories: income; money management; savings and investment; and spending. The survey found that the level of financial literacy had declined since the "dismal" results of the first such survey in 1997 (Mandell, 2001:6). The weakest areas were money management and savings and investment. An overview of practice, research and policy in the USA with respect to financial literacy has been published by a team from the US Federal Reserve (Braunstein & Welch, 2002).

Britain and the USA are not the only countries where financial literacy is a concern and innovative work has been undertaken in countries where the scale of poverty and the impact of globalisation make issues of financial literacy particularly acute. For example, a report on financial training with poor women in the urban informal sector in Botswana found that the women's knowledge of the effective use of finances was very selective and that many of their business practices were not cost-effective. Furthermore, although training in financial literacy was available in various forms, women were often not able to leave their businesses to attend training. Nevertheless, in spite of these constraints, a number of women had expanded their businesses following training (Kaye, 2001).

Credit Unions have flourished in many countries, with or without an element of formal training. Credit Unions are financial co-operatives that are owned by their members. Members save in a common fund which can then be used to make low interest loans to other members of the credit union. A celebrated example, closely linked to adult education, is the establishment of Credit Unions in Maritime Canada in the early 1930s by Father Jimmy Tompkins of the Extension Department of St Francis Xavier University, Nova Scotia. More recently, the Grameen Bank in Bangladesh (Yunus, 2002) has come to international attention as an example of a practical, grass-roots initiative in non-formal education and poverty alleviation (Wahid, 1994). In the UK the Association of British Credit Unions Limited (ABCUL) is the major trade and training organisation for Credit Unions and has worked with the BSA on their financial literacy programme.

Work on financial literacy seems relatively untouched by debates in situated cognition and ethnomathematics, and the perceived need for it rests on survey evidence that may be open to question, given the problems with surveys outlined above. The mathematics involved in financial operations, such as choosing a pension scheme or a mortgage, or calculating tax or welfare benefits, may be extremely complex. Financial literacy is thus not solely a 'basic skills' issue since the mathematics involved may be anything but basic. Neither is it solely a numeracy issue: being financial literate entails literacy, as well as numeracy skills.

The underlying logic in much of the work on financial literacy appears to be remedial. In this model some adults are seen as unable to manage their finances and education (which may be linked to other initiatives such as credit unions) is seen as being able to assist them in becoming more able, and hence financially stable and solvent. An alternative logic would lead to research into the ways that adults do manage their money, the constraints on them and the artifacts they use to assist themselves in doing so, with a view to learning from people who manage to survive in difficult circumstances and to working with them to devise more effective ways of surviving. It is a measure of the disconnected nature of the field of adult numeracy that this has not been done. Further work is also needed on the part of financial institutions and others on the presentation of financial information to make it more accessible and understandable by non-specialists.

Wider debate and further research on financial literacy at all levels is needed, building on the AdFLAG initiative and drawing on, for example, Hoyles, Noss and Pozzi's research with investment bankers (Hoyles, Noss et al. 1999; Noss & Hoyles, 1996a; Noss et al. 1998) and the work of bodies such as the Financial Services Authority (FSA) and the Citizen's Advice Bureaux (CABx), the latter having considerable experience in debt counselling.

Concluding remarks on context and transfer

The question of the ways in which knowledge, skills and understanding are situated and embedded in contexts and whether or not they are transferable (or translatable) is a key one for all mathematics educators. It is particularly acute for adult numeracy educators because of the expectation that 'numeracy' should be useable, in Kanes' terms (Kanes, 2002) in adult life. Studies are needed of successful transfer/translation by adults between contexts: i.e., between the classroom and beyond and between non-classroom 'real life' contexts.

Research on context and transfer raise important questions also in relation to teaching and learning adult numeracy. In Kanes' and Lave's terms, how can situated numeracy, often 'invisible', as we have seen, become 'constructible' by teachers and learners? This question is explored in the following chapter.

Learning and teaching adult numeracy

Learn. **To teach: from M.E.; S.E. 'till ca 1760, then coll; from 1810, low coll; since ca 1890, sol. Chiefly in *I'll learn you!* (often jocularly allusive). cf. Fr. *Apprendre*, to learn, also to teach.** *Eric Partridge,* **A Dictionary of Historical Slang**. *Penguin, 1961.*

Issues in learning and teaching adult numeracy

This chapter looks at research on, and relevant to, learning and teaching adult numeracy in a range of contexts both within and beyond formal educational provision. The text differentiates between learning and teaching where possible, but it is not always possible to do so, since a distinction between learning and teaching is not always maintained in the literature of education research, any more than it is in colloquial speech. Indeed, arguably it is difficult to design a research project to explore teaching that does not also consider learning. It must also be remembered that the relationship between learning and teaching is asymmetrical: learning takes place both with and without benefit of teaching and even with the best intentions and most careful preparation, teaching does not necessarily result in learning.

A note of caution is necessary at the outset: as will be clear from the discussion in Chapter 1, there is considerable conceptual confusion and contestation around numeracy. As a result, it is all too easy for practitioners, researchers, policy-makers and adult learners themselves to be at cross-purposes in any discussion of what should be taught and learned, how, to whom and by whom, for what purposes and with what outcomes. There is a considerable literature on mathematics teaching and learning in general, but far less specifically relating to adults and hitherto little attempt has been made to make connections and distinctions between the two. Vital questions such as the amount of time and the nature and extent of teaching required for adults to make significant progress cannot be answered with any degree of certainty when we do not yet know how adults learn numeracy (become numerate), nor how best to teach them. This is not to say that nothing is known about learning and teaching adult numeracy but it is to caution that the knowledge-base is as yet insecure and does not support definitive statements on what constitutes good practice in any given situation.

Perhaps surprisingly, the picture is not a great deal clearer with respect to mathematics education pedagogy generally, which, as we have seen, is dominated by studies of children's learning and teaching. Askew, in his review of studies of mathematics education pedagogy dating from 1968 to 2000, concludes that "detailed comparative studies suggest that differences in pedagogic practices are as much to do with macro influences as variation amongst individual teachers. In terms of implications for practice there is little specific to recommend" (Askew, 2001b:47). He recommends that more research should be done on mathematics pedagogy and practices and the ways in which these are influenced by both the culture of English schooling and teachers' beliefs, a call which could be echoed heartily by adult numeracy educators with respect to their own contexts and beliefs.

Adult numeracy teaching is not alone amongst the so-called 'adult basic skills' in being under-researched. In a review of research for the DfES, Brooks and his colleagues report that little is known about what any area of basic skills teaching is like on the ground (Brooks et al. 2001). They also found little research information on assessment, and noted that criticisms of external awards demonstrate the need for a more rigorous assessment framework. They highlight the absence of intervention studies exploring what factors in teaching basic skills cause progress in learning basic skills and point out that very little is known also about adults with special educational needs in basic skills provision. The team note that evidence on the impact of general adult numeracy tuition is sparse and unreliable.

In the absence of a mature and integrated culture of theory and research in adult numeracy, approaches to teaching and learning are likely to be informed by practitioners' experience and by custom and practice in the settings in which teaching takes place, mediated by any teacher training the practitioner may have undertaken, rather than by research evidence. Adult learners are also likely to be influenced by their previous experiences of learning or attempting to learn mathematics. Experienced practitioners' knowledge is an important resource in any attempt to raise the standing and improve the effectiveness of adult numeracy teaching and learning, but it must be recorded and tested against findings from other settings and interrogated in relation to the wider context. This has yet to happen in England in any systematic way, although some studies are currently underway through the NRDC.

Adult numeracy learning and teaching also take place in a wide range of contexts – the workplace, the classroom, the home, the street and elsewhere, as we have seen in the previous chapter. Mathematics is a 'gatekeeper' subject, with tests and qualifications regulating entry to many jobs and education and training opportunities (Alexander & Pickard, 2002). It is also a service subject for a wide range of other subjects in the social and natural sciences (Elliott & Johnson, 1995; Pickard & Cock, 1997) and, as 'Application of Number' (KS AoN), a key skill for students studying in Further Education (Kaye, 1999). Together with statistics and elementary probability theory, it is seen as essential for scientific literacy and for democratic citizenship (Benn, 1997a) and for the workplace (FitzSimons, 2002; Wedege, 2000a; Hoyles et al. 2002). As a consequence of this diversity, the research literature presents a spectrum of aims and ideals that are sometimes in conflict with each other. These include the issue of whether practitioners have the power to develop their own curriculum, or whether it is mandated, as is increasingly common in the era of economic rationalism and accountability (FitzSimons et al. 2003).

In this chapter we look first at the policy context and provision of adult numeracy in England, before going on to explore relevant research on curriculum development and approaches to teaching and learning, adult numeracy learners, teacher education and the National Numeracy Strategy in Primary Schools.

Policy and provision of adult numeracy in England: *Skills for Life*, Key Skills and the Skills Strategy

In England the provision of adult numeracy education developed in the wake of the adult literacy campaign of the 1970s (BAS, 1972; Coben, 2001a). It remained a relatively marginal backwater of educational provision until the Further and Higher Education Act, 1992, which regulated adult numeracy under Schedule 2 of the Act. Publication of the Moser Report, **A Fresh Start**, in 1999 (DfEE, 1999) heralded a new era for adult numeracy in England. Post-Moser, the government's ***Skills for Life*** strategy for improving adult literacy and numeracy skills in England (DfEE, 2001) has transformed the scene, with adult numeracy seen as an essential element in a range of measures designed to raise the skills levels of the population. In short order, we have seen the introduction of National Standards (QCA, 2000), National Tests (BSA) and the Adult Numeracy Core Curriculum (BSA, 2001a), along with a new regime of teacher qualifications (FENTO) and other developments, including the establishment of the National Research and Development Centre for Adult Literacy and Numeracy (NRDC). The current ***Skills for Life*** target is for one and a half million adults to achieve in the National Tests by 2007 (DfES, 2003b). The ***Skills for Life*** strategy has undoubtedly raised the profile of adult numeracy education in England, just as happened in Australia following the introduction of the Australian Language and Literacy Policy in 1991 (Cumming, 1996). It has also greatly increased the scale of the operation. According to the latest Annual Review of ***Skills for Life***, 300,000 adults improved their literacy and numeracy skills between April 2001 and July 2002, with learning opportunities provided to over 1.5 million learners (DfES, 2003b).

Provision of adult numeracy education in England is located in a range of settings in the new Learning and Skills sector but information on numeracy cannot easily be disaggregated from data on basic skills in general.[2] Colleges of Further Education (FE) are the major providers of adult basic skills education, with 60% of students, followed by Local Education Authorities (LEAs) (20%) and prisons (11%). Provision is of two main types: 'dedicated' basic skills provision; and support for students pursuing another course as their main objective, sometimes called 'embedded' basic skills provision (60% together). There is some evidence that the provision of basic skills support has lowered drop-out and non-completion rates. In their report for the DfES, Brooks and his colleagues consider that there is substantial evidence of other benefits from a range of types of literacy and numeracy provision in both Britain and the United States, including workplace provision. These include: self-reported gains in literacy, numeracy and self-confidence; gains in employment; further study; and (particularly in family learning) gains in parents' ability to help their children and gains for the children. However, the evidence on costs and benefits is small and unreliable (Brooks et al. 2001).

Provision in numeracy and mathematics for students studying vocational subjects encompasses: application of number, one of the key skills specified in the National Qualifications Framework (NQF); 'in-built' mathematics units, geared to particular subjects; GCSE mathematics re-sits, often required by employers and for further study; free-standing mathematics units, available at levels 1-3 (these have been developed to be complementary to the key skill in application of number and can be made vocationally relevant).

Key skills have developed in schools and colleges through work-experience programmes and educational enrichment activities, and elsewhere as part of modern apprenticeships and higher education programmes and in the workplace. Since September 2000, candidate achievement of a key skill in application of number at levels 1-4 has been assessed externally by test and internally by a portfolio of evidence. Key skills application of number (KS AoN) is mapped onto the NQF as follows: GCSE Mathematics graded at D-G gives exemption from the external assessment of Level 1 KS AoN; GCSE grades A*-C in Mathematics give exemption from the external assessment of level 2 KS AoN; and AS/A level GCE in Mathematics gives exemption from the external assessment of Level 3 KS AoN. Further information about key skills is available on the Qualifications and Curriculum Authority's (QCA) website, including

[2] A themed inspectorate report on current practice in literacy, numeracy and English for speakers of other languages, published as this review of research went to press (ALI/OfSTED 2003), exemplifies this point: it largely treats numeracy, literacy and ESOL together. In all three areas, the report found that ***Skills for Life*** has increased the number of learners and raised the profile of adult basic skills but that the proportion of good provision is much lower in literacy, numeracy and ESOL than it is in any other area of learning and there is significantly more satisfactory provision. Specifically on numeracy, the report found that: numeracy is taught less frequently than literacy and there is less demand for numeracy, despite equivalent levels of need; that there is a need for greater expertise in teaching numeracy; and that numeracy is too often taught by rote learning rather than by developing understanding of numerical concepts.

details of reports evaluating the key skills qualification (Warwick, 2001) (QCA, 2001) (Burke, 2001) (Learning for Work, 2001). There is a certain amount of convergence between key skills and basic skills since National Tests for adult numeracy at Levels 1 and 2 draw on the same banks of questions as those for key skills application of number at these levels, i.e., they are effectively the same tests.

A report on the relationship between key skills and basic skills (including numeracy) from a project by the Basic Skills Agency (BSA) and the Learning and Skills Development Agency (LSDA) recommends further research and guidance at a national level on: alignment, overlap and distinctive features across basic skills and key skills standards; effective organisational models for delivering the new curriculum in basic and key skills; support for managers and co-ordinators to identify management issues and share effective practice; initial assessment and diagnostic processes; teaching and learning strategies; parity of esteem and accreditation; exploitation of information learning technologies; and staff development (Perry & Davies, 2001). The comprehensiveness of the 'to do' list indicates just how unresolved the relationship is between key skills and basic skills, a situation exacerbated by complex funding formulae that differentiate between the two areas.

Policy on mathematics education generally also has a bearing on adult numeracy education. This is currently under review by the Government's Post-14 Mathematics Inquiry, announced in October 2002 and due to report in September 2003, chaired by Professor Adrian Smith. The Inquiry was established in the wake of the Green Paper **14-19: Extending opportunities, raising standards** (DfES, 2002a) and other government policy initiatives in education and training.

Most recently, in July 2003 the White Paper, **21st Century Skills: Realising our potential. Individuals, Employers, Nation** (DfES, 2003a) was published, setting out the new national skills strategy. The strategy aims to ensure that employers have the right skills to support the success of their businesses, and that individuals have the skills they need be both employable and personally fulfilled. Numeracy is identified as one of the "skills gaps" in "basic skills for employability"; mathematics is also identified as a "skills gap" (DfES, 2003a:12). Information and communication technology (ICT) is identified as "a third basic skill alongside literacy and numeracy in our ***Skills for Life*** programme" (DfES, 2003a:13). Amongst many points on which the government is inviting comment in the White Paper are: reform of the qualifications framework in order to make it more flexible and responsive to the needs of employers and learners (DfES, 2003a:14); free tuition to enable adults without a good foundation of employability skills to achieve a level 2 qualification (DfES, 2003a:13); piloting of a new form of adult learning grant, providing weekly financial support for adults studying full-time for their first level 2 qualification (DfES, 2003a:13).

Beyond the world of education and training, initiatives to improve public understanding of, and engagement with mathematics, aim to encourage a culture within which mathematics is a positive feature, rather than something to be feared and avoided. Examples include: 'The Production of a Public Understanding of Mathematics', a seminar series sponsored by the UK Economic and Social Research Council (ESRC) in 1998-99; the work of the UK charity **Mathemagic** (www.mathemagic.org); and Hogben's classic book, **Mathematics for the Million**, first published in 1936 (Hogben, 1967) and the work of organisations such as the Centre for Statistical Education of the Royal Statistical Society.

Curriculum development and approaches to teaching and learning adult numeracy

The centrepiece of the ***Skills for Life*** strategy with regard to teaching and learning adult numeracy is the Adult Numeracy Core Curriculum (ANCC) (BSA, 2001a). With the introduction of the ANCC in 2001, for the first time there is a national curriculum for adult numeracy in England. The new curriculum draws on the National Numeracy Strategy in schools (discussed below), key skills units on application of number developed by the QCA (Qualifications and Curriculum Authority), the revised National Curriculum (NC) for mathematics in schools, introduced in September 2000, and numeracy curricula and initiatives from abroad (in particular, the USA, Australia, Canada and France) (BSA, 2001a:1-2).

The Adult Numeracy Core Curriculum covers the ability to: understand and use mathematical information; calculate and manipulate mathematical information; interpret results and communicate mathematical information (BSA, 2001a:3). It follows the model established by the NC for mathematics in schools in covering number, measures, shape and space and handling data (BSA, 2001a:7). The Curriculum is arranged in ascending levels: Entry Level (sub-divided into Entry Level 1; Entry Level 2; Entry Level 3); Level 1; and Level 2 (BSA, 2001a:4). These map onto the National Qualifications Framework (NQF). As stated in ***Skills for Life***, the Levels are "broadly equivalent to the attainment expected of an average seven year-old, an average 11 year-old and GCSE grades A-C respectively and are aligned with NVQ levels and Key Skills at Levels 1 and 2" (DfEE, 2001:13). The Curriculum is deliberately context-free as it is intended that adult learners will 'bring their own contexts' to the pedagogical encounter and teachers will relate the Curriculum to the learner's context.

Against this background, with the child and adult curricula converging, research on approaches to pedagogy and the curriculum developed in children's numeracy/mathematics education may be of particular interest to adult numeracy educators (for example: Askew, 2001a; Grouws & Cebulla, 2000; Nickson, 2000; Pimm & Love, 1992; Selinger, 1994; Shan & Bailey, 1991; Boaler, 1997).

Beyond ***Skills for Life***, in Further and Higher Education in the UK and elsewhere, there has been recognition of the support some students need with mathematics and a corresponding increase in the provision of access programmes and mathematics support services, including mathematics learning centres (Croft, 2000; FitzSimons & Godden, 2000). Curriculum development has been undertaken in this area internationally (Holton, 2000), especially in Australasia (Boondao, 2001; Hartnell, 2000; Yasukawa, 1995), in UK universities (Drake, 1999; Elliott & Johnson, 1995) and in US 2-year colleges (Cohen, 1995).

In some countries (as in England) this has happened in the wake of reforms at national or regional/state levels. For example, a new national Adult Numeracy Curriculum for Denmark has been developed as part of the Preparatory Adult Education (PAE) reform in Denmark, under a law brought in in 2000 (Johansen, 2002). Australia saw considerable curriculum development activity in the 1990s following the introduction of the Australian Language and Literacy Policy in 1991 (Cumming, 1996). In the USA a project funded by the US National Institute for Literacy (NIFL) and run by the Adult Numeracy Practitioners' Network (ANPN; now ANN, the Adult Numeracy Network), aimed to establish a framework for the development of adult numeracy standards, the foundation for curriculum development (Leonelli & Schmitt, 2001). This followed on from adult numeracy reform in Massachusetts (Leonelli & Schwendeman, 1994) and the introduction of the NCTM Standards for mathematics education in schools in 1989 (NCTM, 1989) (NCTM, 2000). ANPN involved hundreds of learners, teachers and other stakeholders, and nearly 300 people were engaged in collecting data from across seven states. The following seven themes emerged, which, it was proposed, should serve as the foundation for the development of adult numeracy standards in the USA:

- *Relevance/Connections*
- *Problem-Solving/Reasoning/Decision-Making*
- *Communication*
- *Number and Number Sense*
- *Data*
- *Geometry: Spatial Sense and Measurement*
- *Algebra: Patterns and Functions*
  (Leonelli & Schmitt, 2001:1)

These themes are discussed in the project report, against the background of the 'four key purposes' for the year 2000 espoused in the US Equipped for the Future (EFF) project. However, the USA's federal system of government means that responsibility for education is held at the State rather than national level, so the pattern on the ground varies greatly between states.

Innovative approaches have also been developed by individual practitioners, where the curriculum is negotiated with adult learners and reflects their agendas for learning. Examples abound in the ALM Proceedings and elsewhere in the adult mathematics education literature, including a report of work in Ireland on evaluating an educational programme for enhancing adults' quantitative problem-solving and decision-making (Colleran, O'Donoghue, & Murphy, 2000; Colleran, O'Donoghue, & Murphy, 2002) and, in the USA, on teaching through real-life mathematics problems (Frankenstein, 1996). For example, nine papers presenting instructional approaches to teaching mathematics to adults were presented at the ALM-7 conference, including a paper on overcoming algebraic and graphic difficulties (Dias, 2001) and a report of a workshop promoting practical activities, informed by research (Marr, 2001a). Other examples include Guedes' and her colleagues' work on mathematics and art with factory workers in Brazil (Guedes, Zandonadi, & Lobão, 1999; Guedes & Zandonani, 1998). In Australia, Marr and Tout have presented a numeracy curriculum and Hogan and Kemp plan for an emphasis on numeracy in the curriculum (Hogan & Kemp, 1999; Marr & Tout, 1997; Tout & Marr, 1999). In The Netherlands van Groenestijn has studied numeracy in the adult basic education classroom from the perspective of Realistic Mathematics Education (RME), inspired by the Dutch educator, Freudenthal (van Groenestijn, 2000; van Groenestijn, 2002). RME "emphasises the use of realistic context problems, representations of reality, and models to relate classroom instruction and learning to the student's real environment and real experience" (van Groenestijn, 2002:336).

Work with parents (termed 'family numeracy' by the Basic Skills Agency when parents and children learn together, and 'keeping up with the children' when designed for adults) in the UK and the USA has been particularly popular (Ashlock, 1990; Brew, 2001; Carmody, 1998; Civil, 2001a, 2001b, 2002; Civil & Andrade, 1999; Merttens, Mayers, Brown, & Vass, 1993; Merttens, Newland, & Webb, 1996; Stein, 2001). While much of the work on family numeracy reported in the literature has not been independently evaluated, Brooks and his colleagues consider that there is suggestive evidence that family numeracy courses benefit parents' numeracy skills (Brooks et al. 2001), a finding confirmed in a later review (Brooks & Hutchison, 2002).

The changing mathematics curriculum is the subject of lively debate in South Africa (Volmink, 1995) where issues of social justice have a particular resonance in the aftermath of Apartheid (Julie, 1996; Kibi, 1996). Social justice is also high on the agenda for Knijnik, who discusses her work with the Landless People's Movement in Brazil (Knijnik, 1997a). Elsewhere in the Hispanic world, the mathematics curriculum in popular education (educación popular) is a matter of lively concern (Gonzales, Montero, Plaza, & Rubio, 1997).

Writing in the USA from a similarly strong commitment to social justice, Frankenstein sets out four goals for what she calls a critical mathematical literacy curriculum: understanding the mathematics; understanding the mathematics of political knowledge; understanding the politics of mathematical knowledge; and understanding the politics of knowledge (Frankenstein, 1998:180). Also writing from an ethnomathematics perspective, Anderson proposes a non-Eurocentric 'worldmath' curriculum (Anderson, 1997).

The 'turn to constructivism' in adult mathematics/numeracy education is evident in vocational education in Ireland (Colleran, O'Donoghue, & Murphy, 2001) and in Higher Education in New Zealand (Miller-Reilly, 2000). Constructivism has arguably had its greatest impact in the USA, where the NCTM Standards for mathematics education in schools (NCTM, 1991, 2000) have been developed since 1989 along constructivist lines (Davis, Maher, & Noddings, 1990). For example, Gal speaks of a "paradigm shift" in K-12 (i.e., school) mathematics education in the wake of the NCTM Standards for teaching mathematics. This paradigm shift has been:

> *influenced by the revolution in cognitive science... and by constructivist ideas in education;... sometimes described by claiming that students should spend more time learning what mathematicians do (e.g., conjecture, experiment, check hypotheses, verify results, explain) rather than what mathematicians know (e.g., number facts, computational rules, formulas, proofs.* (Gal, 2000a:13)

This shift is borne out by the work of Mullen and colleagues (Mullen, Fournier, & Leonelli, 2001), Safford (Safford, 1997) and Gal himself (Gal, 1999).

Writing with Ginsburg, Gal discusses the relative and dynamic nature of numeracy skills, theories of adult learning of mathematics and numeracy, and the goals of adult numeracy teaching, its relationship with adult literacy and the implications for teaching and learning mathematics and numeracy. They propose a set of "instructional principles in adult numeracy education" as follows:

1. *Address and evaluate attitudes and beliefs regarding both learning and using math.*

2. *Determine what students already know about a topic before instruction.*

3. *Develop understanding by providing opportunities to explore mathematical ideas with concrete or visual representations and hands-on activities.*

4. *Encourage the development and practice of estimation skills.*

5. *Emphasize the use of "mental math" as a legitimate alternative computational strategy and encourage development of mental math skill by making connections between different mathematical procedures and concepts.*

6. *View computation as a tool for problem solving, not an end in itself.*
7. *Encourage use of multiple solution strategies.*
8. *Develop students' calculator skills and foster familiarity with computer technology.*
9. *Provide opportunities for group work.*
10. *Link numeracy and literacy instruction by providing opportunities for students to communicate about mathematical issues.*
11. *Situate problem-solving tasks within meaningful, realistic contexts in order to facilitate transfer of learning.*
12. *Develop students' skills in interpreting numerical or graphical information appearing within documents and text.*
13. *Assess a broad range of skills, reasoning processes, and dispositions, using a range of methods.*
    (Ginsburg & Gal, 2000:91)

In England current ideas of good practice in adult numeracy teaching, including the introduction of the Adult Numeracy Core Curriculum, may be seen as constructivist in that they stress the importance of helping the learner to develop understanding, rather than learning by rote. Indeed, this is hardly a new idea: the psychologist, Skemp differentiated between instrumental understanding (blind following of rules) and relational understanding (knowing what to do and why) in the 1970s (Skemp, 1971, 1978), and his ideas have been influential in school mathematics education in the UK. There is probably a fairly widespread belief amongst adult numeracy practitioners that learners construct their knowledge of mathematics in a personalized way through activities which encourage a shared understanding of mathematical concepts.

Benn contrasts a constructivist with a positivist approach, arguing that the former may produce teaching and learning for mathematical, educational and democratic purposes that is more than tokenistic. Zevenbergen, by contrast, criticises constructivism as a liberal bourgeois discourse (Zevenbergen, 1996). Benn probably speaks for many adult numeracy educators who might not call themselves constructivists when she commends a constructivist approach as one that:

> *Assumes that mathematical abilities are multi-dimensional and changeable. Instead of focusing on individualism, it encourages co-operative learning and the social construction of knowledge. This use of mathematics develops an understanding of the world and hence an awareness of inequalities in our society and the underlying assumptions of social organization which cause them. This may lead to the creation of new ideas, perspectives, insights, images and models (Volmink, 1990). It exposes the ideological dimension of mathematics and the relationship between knowledge and power and recognizes that hegemony is not only characterized by what it includes but what it excludes, by what it makes marginal, deems inferior and makes invisible. Mathematics can be used to help develop a wider multi-cultural perspective and enable students to see how powerful the subject can be as a tool for examining society.* (Benn, 1997a:113)

However, Ernest argues persuasively that there is no deterministic relationship between the epistemologies held by mathematics educators and the pedagogical practices they employ (Ernest, 1991). In adult numeracy teaching, as in other aspects of life, there is often a gap between aspiration and achievement and this needs to be borne in mind when reading what are sometimes celebratory, rather than critical, accounts of curriculum development.

Well-meaning policy initiatives may also have unintended effects on adult mathematics/ numeracy curricula. For example, FitzSimons argues that emphasis on human capital development has aligned vocational education provision in Australia with a narrow competence-based training, resulting in an atomisation of curricula (FitzSimons, 2000b).

Coben distinguishes between two discursive domains of adult numeracy which manifest themselves in two different approaches to curricula (Coben, 2002). Domain One is:

> *characterized by formalisation and standardization of the curriculum, and technologisation, unitisation and commodification of learning and learning materials. It is competency-based and outcomes-focussed, with certification being the desired outcome, and explicit equivalence with educational levels in schools. It supports normative claims about the beneficial effects of numeracy for the individual and for society.* (Coben, 2002:27)

She contrasts this with numeracy in Domain Two, which is "about informal and non-standard mathematics practices and processes in adults' lives, which may bear little relation to formal, taught mathematics". Domain One numeracy may have low use value but high exchange value "it is 'hard currency', yielding certificates tradeable on the labour market. Domain Two is the opposite: it has high use value but no exchange value beyond the community of practice in which it occurs...; it is 'soft currency'... (and) situated in Jean Lave's sense (Lave, 1988)" (Coben, 2002:27). She asks whether it might be possible for adult numeracy teachers to reconcile the domains in the design of "the 'acme' of numeracy curricula - one that equips adults to use mathematics appropriately, confidently, meaningfully and effectively" (p29). This is a major challenge, given the situated nature of adults' mathematical knowledge and the mathematical demands of adult life, and the fact that teachers' knowledge of their students' numerate practices and the mathematical demands of their lives may be limited.

There is also the issue of the scope, 'shelf-life' and transferability of qualifications: a qualification that may be 'hard currency' in one context or for a given period, may lack exchange value in another context or time. For example, adults may be assessed in numeracy when applying for jobs or entry to training courses, despite holding a GCSE Mathematics qualification.

More research is needed on learning and teaching numeracy in and for the workplace, including studies of the impact of workplace-related UK government initiatives with respect to adult numeracy, such as Modern Apprenticeships, Key Skills and learning support in adult numeracy for those studying vocational or other subjects, i.e., numeracy in what is often called 'embedded basic skills'. As discussed in Chapter 1, recent research for the UK Science, Technology and Mathematics Council (STM) by a team from the Institute of Education, University of London, has shown that increasing numbers of people are engaged in mathematics-related work, and that such work involves increasingly sophisticated mathematical activities (Hoyles et al. 2002:5). The implications of these changes specifically for adult numeracy teachers and learners are not yet clear, although contributors to the edited collection, Education for Mathematics in the Workplace (Bessot & Ridgway, 2000) have drawn out many issues of interest to teachers at secondary and post-16 levels.

FitzSimons' book, **What Counts as Mathematics? Technologies of power in adult and vocational education** is an excellent example of a research monograph, investigating the implications for teachers and others concerned with adult vocational mathematics, numeracy and workplace competence of policy and technological change in these areas in Australia (FitzSimons, 2002). Also in Australia, in an Australian Association of Mathematics Teachers (AAMT) project, mathematics teachers shadowed paid and unpaid workers for half a day, collecting and analysing their 'work stories' – a useful approach, given that teachers' experience of workplaces beyond the classroom may be limited. The project report summarises the key elements, for teachers, of using mathematics for practical purposes as:

- *clarifying the outcomes of the task and deciding what has to be done to achieve them;*
- *recognizing when and where mathematics could help and then identifying and selecting the mathematical ideas and techniques to be used;*
- *applying the mathematical ideas and techniques, and adapting them if necessary to fit the constraints of the situation;*
- *making decisions about the level of accuracy required;*
- *interpreting the outcome(s) in its context and evaluating the methods used.*
  (DEETYA, 1997:59)

A key issue is the extent to which it is possible to teach for transfer, and if it is possible, how best to do it. This is discussed by Anderson et al. (Anderson et al. 1996) and Masingila et al. present a framework for connecting mathematics learning and practice in and out of school (Masingila, Davidenko, & Prus-Wisniowska, 1996). Evans sets out the process of translation from one set of signifiers and signifieds to another, with careful regard for both similarities and differences (Evans, 2000a). Bessot and Ridgway's edited book, **Education for Mathematics in the Workplace** also contains much of interest in this respect (Bessot & Ridgway, 2000).

All in all, further detailed critical studies of adult numeracy teaching and learning are required before it will be possible to delineate good practice – and good policies - in the light of evidence rather than aspiration, in the workplace and elsewhere. In the meantime, the adult numeracy/mathematics curriculum must meet the needs of students with diverse goals. This means it must be 'vertically progressive' in terms of development of content, as well as 'horizontally supportive' with respect to the mathematical aspects of other subjects and other contexts. Limited number skills are not enough and if adult numeracy education is to be conducted in a democratic way, the scope, content and mode of learning must be negotiated with adult learners rather than imposed on them. As we have seen, the Adult Numeracy Core Curriculum is deliberately context-free, thus giving an opportunity for negotiation and contextualisation. However, while experienced numeracy teachers may have no difficulty in relating the Curriculum to the learner's context, this may pose a challenge for less experienced teachers, or teachers experienced in a limited range of contexts, especially given the issues around transfer outlined in Chapter 2.

Elements of mathematics

There have been many studies of teaching and learning particular elements of mathematics, mostly based on research with children but which may nonetheless be relevant to adult educators, given that yesterday's children are today's adults. It is likely that errors and misconceptions (as well as attitudes, discussed in the next chapter) established in childhood may persist into adult life, indeed become more and more entrenched through repetition. Instead of 'practice makes perfect', the risk is that practice may make permanent (a point made by Professor Alison Wolf in a seminar in the MA in Adult Basic Skills at the Institute of Education, University of London, November 2002). A selection of studies is reviewed here, including studies with adults, focusing especially on elements of mathematics covered in the Adult Numeracy Core Curriculum.

Valuable information about children's errors and strategies is contained in the reports of successive national surveys of school children aged 11 and 15, undertaken in the 1980s for the Assessment of Performance Unit (APU) (APU, 1980a, 1980b, 1981, 1985, 1988; Ruddock, 1987). These have been summarized by Foxman et al. (Foxman, Ruddock, McCallum, & Schagen, 1991), who found a significant decline between 1982 and 1987 in the performance of 11-year olds on questions about fractions, computation, applications, rate and ratio. Also, the 1987 APU data have recently been re-analysed with respect to mental calculation methods used by 11-year-olds in different attainment bands (Foxman & Beishuizen, 2002). At around the same time, a group from Chelsea College, University of London, undertook the Concepts of Secondary Mathematics and Science (CSME) survey, testing 10-15 year-olds in each year group and a group at the Shell Centre, University of Nottingham, developed a teaching programme designed to remedy children's mathematical errors (Shell Centre, 1987).

Some elements of mathematics are considered to be intrinsically "hard to teach and hard to learn", for example, fractions, decimals, ratios and percentages (Barnett, Goldenstein, & Jackson, 1994). Several researchers have investigated these areas, including Lamon, who discusses essential content knowledge and instructional strategies for teachers in teaching fractions and ratios for understanding (Lamon, 1999) and Kerslake, who investigated children's strategies and errors when working with fractions (Kerslake, 1986). Steinke investigated adults' understanding of the 'part-whole' concept (Steinke, 2001) and Brover et al. (Brover, Deagan, & Farina, 2001) use fractions as an example of the need for adult numeracy teachers to understand the mathematics they teach. Piel and Green argue for de-mystifying the division of fractions (Piel & Green, 1994) and Streefland considers the place of fractions in Realistic Mathematics Education (Streefland, 1991).

In a study of the process of learning fractions, Mack found that in the initial stages of learning, students' informal knowledge is disconnected from their symbolic knowledge (Mack, 1990). They tend to use their informal knowledge to solve problems related to real life, and their formal knowledge for problems regarding concrete or symbolic representations. Teaching rote procedures before acknowledging the nature of the concepts on which these build causes students to apply procedures blindly. It also interferes with their use of potentially helpful informal knowledge. Many students have misconceptions about fractions because they attempt to apply the rules for whole number arithmetic to their work with fractions. Students can build successfully on their informal knowledge to construct meaning from formal representations, although a clear relation must exist between the two for this to happen. Building on informal knowledge often results in a developmental progression that differs from the traditional sequence for teaching the concepts involved. For example, more complex topics, such as problems involving the regrouping or conversion of fractions, are generally taught at the end of a teaching unit. Mack's research indicates that students can and possibly should handle these concepts much sooner.

Hart studied the understanding of ratio demonstrated by children between the ages of 11 and 16 (Hart, 1981) and in later work investigated children's strategies and errors in ratio calculations (Hart, 1984). Ginsburg et al. explore adult learners' informal knowledge of percentages (Ginsburg, Gal, & Schuh, 1995). Capon and Kuhn investigated women's use of a proportional reasoning strategy in an everyday context: the supermarket (Capon & Kuhn, 1979); as discussed in Chapter 2, Lave investigated adults' 'best buys' in the supermarket (Lave, 1988). Also, Stacey investigated shoppers' "error detecting and error correcting codes" (Stacey, 1998). Hoyles, Noss and Pozzi investigated the ways in which expert nurses calculate error-critical drug dosages on the ward, related to the concepts of ratio and proportion (this work is also discussed in Chapter 2, above) (Hoyles et al. 2001). Their findings support those of Vergnaud on what people actually do when calculating, which shows that they work with quantities and relationships rather than numbers per se (Vergnaud, 1988).

Adults' understanding of number has been investigated by Steinke (Steinke, 1999) and Simpson describes approaches geared to building mathematical memory with rapid reconstruction (Simpson, 1998). Gal has worked on developing adults' statistical literacy (Gal, 1997, 2000b), as has Evans (Evans & Rappaport, 1998).

Anghileri investigated intuitive approaches, mental strategies and standard algorithms (Anghileri, 2000), an investigation that may be particularly relevant to adult numeracy teachers, given the inclusion of mental methods in the ***Skills for Life*** Adult Numeracy Core Curriculum. She argues for a re-assessment of the Primary curriculum, so that

> *By focusing on the development of number sense through encouraging mental methods and informal written strategies, children will develop confidence in their own approaches to problem solving and maintain an inclination and enthusiasm for mathematics.* (Anghileri, 2001:25)

With Beishuizen, she compared British and Dutch views of which mental strategies were most effective in the early number curriculum (Beishuizen & Anghileri, 1998).

Anghileri also reviewed research on mental and written calculation methods for multiplication and division (Anghileri, 2001), a topic explored with respect to adult numeracy students by Polkinghorne (Polkinghorne, 1999) and with respect to student teachers by Graeber and Tirosh (Graeber & Tirosh, 1988; Graeber, Tirosh, & Glover, 1989; Tirosh & Graeber, 1989; Tirosh & Graeber, 1990). British research on mental and written calculation methods for addition and subtraction have been reviewed by Thompson (Thompson, 2001) and Matthijsse has investigated addition and subtraction up to 100 in adult numeracy (Matthijsse, 2000). The use of calculators by adults in the ABE classroom is investigated by Manly (Manly, 1997) and in nursing by several researchers (Hutton, 1998a; Murphy & Graveley, 1990; Shockley et al. 1989).

Researchers have identified a cognitive gap between arithmetic and algebra (Herscovics & Linchevski, 1994) and Steen asks "Does everybody need to study algebra?" (Steen, 1992). In the UK, the existence of an 'algebra gap' between GCSE and A-level has been identified and it is argued that this gap is bigger than that in other subjects (Wiliam, Brown, Kerslake, Martin, & Neill, 1999).

Studies have also been done with adults returning to study algebra, including Safford's investigation of her students' learning of algebra (Safford, 1995, 2000a) and Dias' work on overcoming adults' algebraic and graphic difficulties (Dias, 2001). Elliott and Johnson describe their 'Relearning Algebra' project (Elliott & Johnson, 1997; Johnson & Elliott, 1995), while Bednarz et al. offer perspectives for research and teaching algebra (Bednarz, Kieran, & Lee, 1996). Marr and Helme have produced a resource book for teachers of algebra to adults (Marr & Helme, 1995). Sutherland integrates situation-based and algebraic approaches through the use of spreadsheets (Sutherland, 1994).

Nunes et al. studied measurement of length and area designed to test the socio-cultural (Piagetian) theory of development in children. They conclude that

> *Simple measurement systems involve three basic operations. First, a unit which is conserved across time and space must be found. Second, it must be applied successively to the object when it is larger than the unit. Third, it must be systematically subdivided when there is no whole number that can fully cover the object. These basic operations are involved in both the measurement of length and area.* (Nunes, Light, & Mason, 1993:53)

In designing instruction, they advise teachers to introduce cultural practices that support children's intuitive approaches to measurement (Nunes, Light et al. 1993).

A large scale experimental project in the UK with young unemployed people on Youth Training Schemes compared different methods of teaching numeracy and problem solving. The study showed that using a range of contexts for teaching was most effective in improving trainees' abilities to generalise their numeracy skills to new problems and situations (Wolf, Silver, & Kelson, 1990). Research on measurement with other young unemployed people in Australia is reported by Johnston (Johnston, Baynham et al. 1997), who draws on notions of social practice. She argues that it enriches our understanding of measurement "to conceive of it not only as the logical development of a measuring tool, but also as a process growing out of the complexities of social conditions" (Johnston, Baynham et al. 1997:118). She concludes with the useful reminder that:

> *In our irredeemably quantified society, a lack of facility with numbers puts us at the mercy of those who are at home with numbers and use them to describe and prescribe our world. One use of numeracy is to be able to engage with such arguments in their own terms. To remain within the discourse of number however is to risk blindness to the limits of its use. Learning a craft involves not only skill with the tools, but knowledge of when to use them. Yes, let's teach people how to measure (and to count and to calculate), but let us ask also about the appropriateness of the measure, let us ask why, who and what we are measuring.* (Johnston, Baynham et al. 1997:118)

Such judgments are ultimately an expression of the values of the teacher and the quality of the relationship both sought and achieved between the teacher and adult learner.

Assessment

Assessment may be regarded as the sharp end of curriculum development: the point at which teachers endeavour to establish what an intending learner already knows (diagnostic assessment), devise or adjust programmes of study according to the progress the learner is making (formative assessment) or find out whether what has been taught has been learned (summative assessment). More research is needed at each stage with respect to adult learners.

This is not to say that no relevant research has been done. Wolf's report of a project for the Manpower Services Commission (MSC) which aimed to develop a new form of mathematics assessment suited to post-school, on-the-job training and a study of the best conditions under which such assessment may best be incorporated into an effective and efficient training programme in the UK government's erstwhile Youth Training Scheme (YTS) is a case in point (Wolf, 1984). The project derives from three propositions:

> 1) *The use of mathematics is best taught by emphasising understanding, and the practical application of techniques, rather than rote learning.*
>
> 2) *Effective teaching and learning derive from an organised system of preliminary assessment/diagnosis; appropriate training (where necessary); re-assessment and further training as required.*
>
> 3) *Effective programmes cannot simply be established by decree, but must involve and incorporate the ideas of the people responsible for administering them.* (Wolf, 1984:7)

The project report presents principles of good practice, including diagnostic assessment, well-structured objectives, contextualised teaching materials and staff training.

> *The diagnostic assessment exercises are built around actual tasks performed in a job. The mathematics used is inherent in the tasks, and the methods are those of the trade in question. However, the tasks are structured in such a way that the trainee's progress and approach are monitored in detail, and detailed diagnostic information obtained whenever the trainee has any problems.* (Wolf, 1984:6)

Supervisors found the assessment instruments easy to use and to incorporate into their current training programmes and the results illuminating. However, they tended to underestimate the seriousness of trainees' difficulties with number and the need for repetition in training and the importance of understanding rather than rote learning.

Other reports of work on assessment include that by van Groenestijn (van Groenestijn, 2000; van Groenestijn, 2001) in The Netherlands and, in Ireland, Ward's review of alternative assessment methods in the National Training and Development Institute (Ward, 1998) and O'Donoghue's presentation of 'An assessment-driven open learning system for adults learning mathematics' (O'Donoghue, 1997).

Cumming and Gal draw out a number of implications for future assessment practice in adult numeracy from their international review of 'Assessment in adult numeracy education: Issues and principles for good practice' (Cumming & Gal, 2000). These are:

> 1. *Both instruction and assessment of adult numeracy skills should be informed by broad definitions of numeracy to encompass the work and life mathematical experiences and strategies adults already have.*
>
> 2. *Ideally, assessment should address reasoning processes and (mathematical)*

problem solving, conceptual knowledge and computation, and the ability to interpret and critically react to quantitative and statistical information embedded in print or media messages, as well as examine transfer of mathematical problem solving across life and work contexts.

3. *Assessment should be directed by the instructional focus and goals of the program, not vice versa.*

4. *One type of assessment alone (e.g., use of standardized tests) will not be sufficient to inform all assessment or evaluation requirements of learners or a program.*

5. *Convenient and apparently simple assessments such as standardized tests may not be appropriate and informative and may do a disservice to students, teachers, and a program.*

6. *Adult numeracy assessment should encompass the range of assessment forms being used in other educational settings and may include oral reports, group activities, portfolios, and so forth.*

7. *Adult numeracy assessment should recognise that adult learners may perform at quite different levels in oral mathematical discussions than on written tasks.*

8. *Assessment indicators for workplace programs are most appropriately drawn from a task analysis of work.*

9. *Assessment should inform students in a systematic way of their progress in, and achievement from, a program.*

10. *Only appropriate interpretation and use should be made of assessment information; adult numeracy practitioners need to be aware of cultural difficulties in planning and interpreting assessment.*
    (Cumming & Gal, 2000:328-9)

Literacy, language and ICT in relation to numeracy

Considering that much adult numeracy work takes place alongside literacy and ESOL provision and often involves some of the same learners, it is surprising that there is not more research on the inter-relationships between adult literacy, language and numeracy. Similarly, relationships with information and communication technoplogy (ICT) have been little explored (Mellar et al. 2001). A recent review of research for the DfES notes that numeracy skills for speakers of other languages seem to be almost entirely overlooked (Brooks et al. 2001).

Some work has been done, however. For example, Gal discusses the links between literacy, language and numeracy under three headings: mathematics as language, in which mathematics is viewed as a separate language system; language factors in learning mathematics, referring to the role of written and oral language in communicating mathematics; and language-mathematics links in real-world contexts, referring to the varying degrees of involvement of language in the different 'numeracy situations' he identifies:

> *Effectively, management of 'pure' interpretive skills involves reading, writing, language comprehension, and other literacy skills to a much greater degree (than generative skills); it also requires solid familiarity with the content of the task, conceptual understanding, and a critical stance, rather than only computational prowess.* (Gal, 2000a:22)

Other writers have explored different aspects of the relationship between literacy and numeracy. For example, Lee and her colleagues explored the 'pedagogical relationships between adult literacy and numeracy' in their study investigating the question: "what are adult educators to do with the mathematics that occurs in the social tasks and texts encountered by adult learners across an increasingly diverse range of educational contexts and programs?" (Lee et al. 1996:iv-v). Their study included detailed case study analysis of two classrooms in Western Australia and New South Wales. In addition to calling for teacher education in adult numeracy (discussed below), they identify the need for curriculum resources for literacy pedagogy which will develop teacher expertise in numeracy (Lee et al. 1996:92) and for appropriate research into the teaching of mathematics to adults. They argue that "research needs to be directed towards the rethinking of mathematics pedagogy consequent upon the changing environments of instruction" (Lee et al. 1996:93).

Zevenbergen investigates the literacy demands of adult numeracy (Zevenbergen, 2000), while Durgunoglu and Öney discuss the numeracy needs of adult literacy participants (Durgunoglu & Öney, 2000). Coben explores the possibilities of 'a literacy way of working' in the adult numeracy classroom in her analysis of an attempt to teach fractions to a literacy organizer, cast in the role of a student for the exercise, but genuinely ignorant about fractions (Coben, nd (1985)). Stoudt sees challenges and new directions in the process of enhancing numeracy skills in adult literacy programmes (Stoudt, 1994). With respect to children's numeracy education, Hill asks: what do we know and what can we learn from the literacy experience? (Hill, 2000). Bickmore-Brand and her colleagues in New Zealand discuss literacy and learning support in the mathematics curriculum (Bickmore-Brand, Chapman, Kiddey, & King, 1996).

Tomlin discusses approaches to student writing developed in adult literacy work in her attempts to create a more democratic environment in the adult numeracy classroom (Tomlin, 1995, 2002a). She also discusses methodological issues arising from the adoption of concepts from the 'New Literacy Studies' in numeracy research (Tomlin, with Baker, & Street, 2002); these are discussed in Chapter 5. Colwell describes the publication of a magazine written and produced by adult numeracy students in London, the **Take Away Times** (Colwell, 1998). A seam of work on journal-writing in the mathematics classroom is mined by educators working with adults (Beveridge, 1995; Curry, 2000; Dziedzic, 1997) and children (Borasi & Rose, 1989; Williams & Wynne, 2000). Other work on student writing in adult numeracy classes has been reported on both sides of the Atlantic and in both hemispheres (Benn, 1997b; Kerner, 2001; McCormick & Wadlington, 2000).

Issues in numeracy learning of adults learning English as an additional language have also been addressed by researchers, including Marr, who asks: 'How can they belong if they cannot speak the language?' and discusses ways of enhancing students' language use in the adult mathematics classroom (Marr, 2001b). Southwell also discusses language in mathematics for adult second language learners (Southwell, 2001) and ter Heege writes on the development of activities for adults using a second language in their numeracy learning (ter Heege, 1997). Colwell considers adults' experiences of learning and using mathematics in a second language (Colwell, 1997) and, in Canada, Ciancone and Jay discuss planning numeracy lessons for an ESL literacy classroom (Ciancone & Jay, 1991). Other work in this area is reported by Falk (Falk, 1998), Boomer (Boomer, 1994) and MacGregor (MacGregor, 1993). Contributors to Durkin and Shire's edited book, **Language in Mathematical Education: Research and practice**, cover a range of issues in mathematics education in relation to language (Durkin & Shire, 1991). While their focus is on children's education, the book includes useful sections on learning and disability and on cross-linguistic and other issues which should be of interest to adult numeracy educators, as also should be Morgan's book, **Writing Mathematically: The discourse of investigation** (Morgan, 1998).

Recent research on the effectiveness of information and communication technology (ICT) in teaching adult basic skills has found that:

- *ICT use in basic skills provision is at an early stage of development;*

- *ICT attracts learners but care must be taken that vocational promises are not oversold and the correct balance is struck between ICT learning and the needs of learners;*

- *ICT may be a barrier to learning for some people, however, this probably applies to a small number of people and it is likely that training can improve their confidence;*

- *the perception of ICT is changing - the web is a source of information for older learners and a source of entertainment for younger learners - learning materials need to take these changing perceptions into account;*

- *the greatest impact of ICT was found for literacy learners at Entry Level 2/3, probably because of the nature of the learning materials available and targetting by tutors;*

- *materials and approaches needed with very low levels of literacy skills and for supporting numeracy need to be developed;*

- *care must be taken to match delivery with preferred learning styles, the teacher remains very important for most learners but a significant number of learners like to work in a more autonomous ways;*

- *on-line learning for learners with literacy and numeracy needs is still at a very early stage of development, if it is to develop further tutors will require training in on-line mentoring techniques;*

- *tutor-training is a priority in: basic ICT skills; specific pedagogic approaches to integrating ICT into literacy and numeracy provision; on-line mentoring; the impact of ICT on the nature of learning;*

- *studies of developing ICT expertise in teachers, in particular the importance of an institutional approach to training.*
  (Mellar et al. 2001)

A randomised controlled trial (RCT) of the use of computer assisted instruction (CAI) in literacy and numeracy instruction with male inmates of a maximum security prison in the

USA shows a positive (but not statistically significant) effect for both literacy and numeracy (Batchelder & Rachal, 2000). Nicol and Anderson compare computer-assisted and teacher-directed teaching of numeracy to adults (Nicol & Anderson, 2000) and Pickard describes computer-aided learning and teaching in her classroom (Pickard, 1997).

Research on mathematics learning and computers in general, including in the school sector, includes studies by Noss (Noss, 1991) and by contributors to Keitel and Ruthven's edited book (Keitel & Ruthven, 1993). Ruthven's review of British research on developing numeracy with technology covers findings of research on calculator and computer use in teaching and learning numeracy and reveals an important difference between school and adult 'real life' cultures, since in the latter technology has become commonplace. Ruthven concludes that, by contrast,

> *present uses of technology do not greatly enhance a schooled numeracy which continues to prize independence from technology; and this culture acts as a critical barrier to the development of forms of technology integration within schools which mirror those emerging in the workplace.* (Ruthven, 2001:31)

In New Zealand, Bickmore-Brand has derived seven principles of teaching and learning for on-line teaching of numeracy and/or mathematics in her application of language-learning principles to mathematics teaching:

> ***CONTEXT****: creating a meaningful and relevant context for the construction of knowledge, skills and values*
>
> ***INTEREST****: realising the starting point for learning must be from the knowledge, skills and or values base of the learner*
>
> ***MODELLING****: providing opportunities to see the knowledge, skills and or values in operation by a 'significant' person*
>
> ***SCAFFOLDING****: challenging learners to go beyond their current thinking, continually increasing their capacities*
>
> ***METACOGNITION****: making explicit the learning processes which are occurring in the learning environment*
>
> ***RESPONSIBILITY****: developing in the learners the capacity to accept increasingly more responsibility for their learning*
>
> ***COMMUNITY****: creating a supportive learning environment where learners feel free to take risks and be part of a shared context.*
> (Bickmore-Brand, 2001:252)

She concludes that while improved instructional design of on-line and multi-media materials can support teaching and learning approaches such as modelling, scaffolding, reciprocal teaching and collaborative problem-solving, "the real challenge lies in the area of developing critical reflective learners" (Bickmore-Brand, 2001:258).

Explorations of the relationships between numeracy and literacy, language and ICT have clearly opened up some lively and fruitful areas of research and discussion and suggest scope for further research and development. This may be especially significant for those who are not fluent readers and who are presented with 'wordy' problems, whether in 'real life' or in the classroom. IT is also vitally important, given its increasing penetration of the workplace, as we saw in Chapter 2 (Hoyles et al. 2002). One way forward, which would also bring the voice of adult learners to the fore, might be the development of a web-based adult numeracy student magazine, a successor to the **Take Away Times**. This could provide a forum for adult numeracy students to communicate with each other and exchange ideas, experiences and learning materials.

Multiple intelligences

Gardner's theory of 'multiple intelligences' (MI) (Gardner, 1993) has been influential in the USA amongst researchers concerned with children's learning and the NCSALL 'Adult Multiple Intelligences study' has explored its relevance to adult learners, including adult learners of mathematics in adult basic education (ABE), as it is known in the USA (Kallenbach & Viens, 2001). Costanzo (Costanzo, 2001) and Fortini (Fortini, 2001) were both teacher-participants in the AMI study. Costanzo summarises the findings arising from the Adult Multiple Intelligences (AMI) study and gives her own reflections in relation to mathematics in her ABE classes, including:

- *Using MI theory leads teachers to offer a greater variety of learning activities - AMI teachers found themselves using more open-ended assignments as part of their teaching repertoire;*

- *The most engaging MI-based lessons use content and approaches that are meaningful to students - the author describes working on team-building exercises with students that allowed them to display their strengths through project work based on real-life problems, including a project to encourage more students to come to the learning centre.* (Costanzo, 2001:107)

Costanzo notes that her students became co-researchers with her in the AMI study. When she asked them what advice they would want to give teachers to help them to plan effective ABE lessons they recommended emphasising all the intelligences and in particular the personal intelligences (Costanzo, 2001). This approach would seem to warrant further investigation.

Critical pedagogies

Discussions about the purposes of adult numeracy/mathematics learning and teaching have drawn on the ideas of the Brazilian educator, Paulo Freire and others to develop critical pedagogies in adult numeracy/mathematics education. For example Frankenstein describes her 'critical mathematics education' approach as an application of Freire's epistemology (Frankenstein, 1987). Her approach is demonstrated in her 'textbook' for adults: **Relearning Mathematics: A Different Third R - Radical Maths** (Frankenstein, 1989) and discussed in her articles with Powell and others (Frankenstein & Powell, 1994; Frankenstein, Powell, & Volmink, 1994). Benn also writes from a Freirean perspective, while drawing on other thinkers, including Foucault, Lyotard and Gramsci (Benn, 1997a). She argues that Freire's emphasis on the need to start where people are, using their knowledge and culture to make them critically aware and to 'refocus' what to them may be 'alien knowledge', is appropriate for adults learning mathematics (p145). Harris also writes approvingly of a Freirean approach (Harris, 1997:143) and identifies the Mozambican ethnomathematics educator, Gerdes, as working in an explicitly Freirean framework (Gerdes, 1997a).

Coben (Coben, 2000c) considers Freire's legacy for adults learning mathematics and reviews Frankenstein's approach and the place of numeracy in the Freirean development education programme, REFLECT (Regenerated Freirean Literacy Through Empowering Community Techniques) promoted by the British NGO, ACTIONAID (Archer & Cottingham, 1996; Newman, 1998). She notes Freire's huge symbolic importance as a 'radical hero' - a beacon for oppositional practitioners and theoreticians, and analyses Knijnik's ethnomathematical approach to educational work with the Landless People's Movement in Brazil in terms of Freire's and Gramsci's ideas (Coben, 1998b). She notes that the syncretic and eclectic nature of Freire's vision has inspired very different approaches (including Frankenstein's and REFLECT) and allowed his followers to 'cherry-pick' from his ideas those that suit their purposes. She concludes that

> *Ultimately, Freire's legacy will be judged by the use that is made of his ideas by those inspired by his vision and by the extent that his ideas contribute to, rather than inhibit, the development of theory and practice in adult education, including adult mathematics education. The jury is out.* (Coben, 2000c:339)

While critical pedagogies probably represent a small part of adult numeracy/mathematics education practice, their emphasis on learner empowerment has struck a chord with many practitioners and researchers and they are an important counterbalance to what some see as hegemonic but dangerously limited competence-based agendas for adult basic skills (FitzSimons, 2002).

Adult numeracy learners

Experience tells anyone who has ever worked with adults that there is no such thing as a generic adult learner of numeracy. The picture presented in the Moser Report (DfEE, 1999) of adults with 'spiky profiles' (different levels of skill in different areas) strikes a chord with many practitioners but it is only part of the story. To understand adult numeracy learners better we need to consider the different forms in which they manifest themselves, mindful of the fact that the definition of adulthood varies across different societies and for different purposes within societies (Safford, 1999). Here we encounter a problem, because no reliable data exists on learners of adult numeracy in England, since surveys by the BSA ceased in 1997/98. In 2001, research for the DfES on adult basic skills learners (i.e., those attending adult basic skills provision) found that: a high proportion are white, monolingual English-speaking, unwaged or unemployed, and poorly qualified; their major motive for attending provision appears to be a desire for self-development, and the major barrier appears to be the fear of stigma; course completion rates are high (75-80%) for students who stay on a course beyond the first few weeks, and about half achieve their goals; those who drop out mainly do so because they are dissatisfied with provision; data on progression are lacking for general basic skills provision; the major motive for parents attending family learning is to help their children and these adults have higher attendance, retention and completion rates than adults in general provision, and their progression to further study and/or employment is high (Brooks et al. 2001). We do not know how closely adult numeracy students align with this general pattern. In order to gather more data on adult basic skills learners in England, a longitudinal panel survey has been commissioned by the Adult Basic Skills Strategy Unit; this is scheduled to report in late 2005.

Meanwhile, we know that difficulties with numeracy are an obstacle to participating in learning of any subject for 6% of adults, according to the latest National Adult Learning Survey, **NALS 2001** (La Valle & Blake, 2001) and although nearly 350,000 people were attending basic skills provision in 1996/97, this represented less than 5% of those estimated to be in need (Brooks et al. 2001).

Research on different groups of adults with respect to numeracy/mathematics education is extremely patchy. Three general areas are selected for further discussion here: adults with learning difficulties and disabilities, gender and age, before turning to look at issues in adult numeracy teacher education.

Adults with learning difficulties and disabilities

In the USA, techniques for collaborative work with adults with what are termed 'specific learning difficulties' have been presented by Sacks and Cebula (Sacks & Cebula, 2000). The term 'specific learning difficulties' is used in their paper to "describe particular barriers to learning and areas that remain problematic to a learner to a severe degree beyond what could usually be anticipated for similarly instructed, motivated peers of average cognitive aptitude" (Sacks & Cebula, 2000:180). The discussion on dyscalculia, below, is relevant here. As is clear from Magne's bibliography (Magne, 2001), there has been very little research on numeracy education with adults with learning difficulties and disabilities (termed SLDD in the UK, a term which covers a heterogeneous group of adults encompassing the full range of cognitive abilities, focussing especially on the least able). Exceptions to this rule include Kenyon, who has looked at some common profiles of learning disabled adult learners and presents strategies for use in the mathematics class to meet their needs (Kenyon, 2000) and Zawaisa and Gerber who researched the effects of explicit instruction on mathematics problem-solving by community college students with learning difficulties (Zawaiza & Gerber, 1993). There is little research on mathematics in what is usually termed Special Educational Needs (SEN) teaching in primary or secondary schools, apart from Daniels and Anghileri's book focusing on SEN in the secondary school sector (Daniels & Anghileri, 1995). Clearly, more research is required in this area.

Gender

A considerable amount of work has been done on gender issues in learning mathematics, especially in North America and also in the UK and Australia (Fennema & Hart, 1994; Hyde, Fennema, & Lamon, 1990). Surveys of adults' mathematical abilities and their effects now routinely differentiate between men and women, so that there is an increasing amount of data available, for example, from UK studies drawing on data from the National Child Development Survey (NCDS) of people born in 1958 and the Birth Cohort Survey of those born in 1970 (BCS70). One such survey found that numeracy skills deteriorate the longer people are out of paid employment, especially for men who had poor mathematics scores at age 16 (Parsons & Bynner, 1999). Another study found a strong relationship between poor numeracy skills and the number of times 30 year old women in BCS70 reported having been arrested (Parsons, 2002).

Research on gender has tended to focus on women and girls, encouraged by organizations such as the International Organisation of Women in Mathematics Education (IOWME) and in the UK by GAMMA, the Gender (formerly Girls) and Mathematics Association. Publications by Benn (Benn, 1997a), Boaler (Boaler, 1994), Burton (Burton, 1986), Fennema (Fennema, 1995), Harris (Harris, 1997), Johnston (Johnston, 1998), Jones and Smart (Jones & Smart, 1995), Walkerdine (Walkerdine, 1989), Hanna (Hanna, 1996) and Willis (Willis, 1996), amongst others, have all contributed to the development of ideas about women's and/or girls' mathematical learning and practice. Burton offers an international perspective on gender and mathematics in her edited collection (Burton, 1990). Rogers and Kaiser look at the influences of feminism and culture on issues of equity in mathematics education in their edited book (Rogers & Kaiser, 1995). Smart and Isaacson celebrate women's collaborative learning of mathematics (Smart & Isaacson, 1989). Some of the research on gender focuses on attitudes to mathematics and on mathematics anxiety; that work is reviewed in Chapter 4, below.

Another strand is research with women who are mothers, including a series of papers by Civil, describing her work with a group of Hispanic women in Arizona, USA, in which the group develops 'confianza' (trust) and dialogue through learning mathematics (Civil, 2000, 2001a, 2001b, 2002; Civil & Andrade, 1999). She quotes the 15 year-old son of one member of the group, talking about his mother who is attending Civil's workshops:

> *Now... she is learning in a different way, understanding the why of the formulas and where they come from and how they can be applied in her life; she shares it with the entire family and we all get involved in a mathematical reunion that is fun. We are all teachers and students at the same time, there is no difference and that there be much respect and confianza is most important.* (Civil, 2001b:177)

Carmody has also looked at 'maths and mothers' (Carmody, 1998) and Brew has looked at the implications for women and children of mothers returning to study mathematics (Brew, 2001). She finds that there are benefits for such women of having older children at home, in terms of the encouragement it gives them to verbalise their mathematical knowledge. She also finds dramatic and positive changes in children's attitudes to mathematics and their achievements in mathematics.

Such research has arisen as a response to the perceived invisibility of women and girls in mathematics and mathematics education and the downplaying or outright dismissal of women's mathematical abilities, informed by a feminist epistemology of mathematics education (see Chapter 1). For example, spatiality is one area where female mathematical skills have been deemed to be deficient, despite evidence that is equivocal at best (Benn, 1997a; Walkerdine, 1989; Fennema, 1995). Harris, in her book, **Common Threads: Women, mathematics and work** (Harris, 1997) puts this view to shame by counterposing some of the geometrically-rich creative work traditionally done by women to traditionally 'male' activities involving similar mathematics (for example, bending a pipe and turning the heel of a sock in knitting).

Johnston notes that the general consensus on mathematics and gender now strongly rejects biological explanations of difference or at least rejects their usefulness in constructing interventions. Using the methodology of 'memory work', she suggests that it can be a useful tool for understanding mathematics as practice and the gendered experience of the use and abuse of mathematical power (Johnston, 1998). Henningsen also explores issues of gender in relation to women and men learning mathematics. She points out that there is "considerable literature on what makes women feel *bad* about mathematics. There is some research on what makes women feel *better* about mathematics but very little about what makes women feel good about mathematics" (Henningsen, 2002).

Leder documents changing perspectives on mathematics and gender in her contribution to the **Handbook of Research on Mathematics Teaching and Learning** (Leder, 1992). Kaiser, cited in Benn (Benn, 1997a:136-7) identifies five phases of mathematics in relation to gender:

(1) *womenless mathematics* - common until the 1970s; then (2) *women in mathematics* - with women entering mathematics, but on men's terms; in the 1980s came (3) *women as a problem in mathematics*, with the emphasis on intervention projects; next (4) (a phase towards which Benn contends we may be heading) sees *women as central to mathematics*; while (5), as yet ill-defined, "might be *mathematics for all*, a reconstruction of mathematics as a connected and constructivist discipline" (Benn, 1997a:137, emphasis in the original).

Age

Age as a factor in adult numeracy/mathematics learning has been rather less explored than gender, although many surveys use age as an ancillary dimension. There is evidence that the numeracy skills of older adults are poorer than those of younger adults, though whether that is due to skills or memory deteriorating with age, or to lower standards set - or achieved - by those adults in initial education in years gone by, or changes in mathematics or mathematics education over time, is not clear. Also, the picture is not one of younger adults consistently out-performing older adults at all levels of numeracy, as a UK survey of 3001 people aged between 22 and 74 in 1994 found:

- *the oldest age group assessed in the survey - 72-74 year olds - did much worse than any other age group;*
- *on average, 62-64 year olds and 52-54 year olds did about the same, although significantly worse than younger people;*
- *those aged 42-44 and 32-34, on average, performed consistently better in numeracy than older people;*
- *the 22-24 year olds in the survey performed worse, on average, in the numeracy assessment tasks at the higher levels than 32-34 year olds and 42-44 year olds.* (BSA, 1995:29)

Where research on age as a factor in mathematics or numeracy learning has been done it has tended to focus on older adults. For example, Withnall has reported on her research on older adults' needs and usage of numerical skills in everyday life. She explored the numerical skills that older adults use most commonly in their everyday lives and identified whether different periods of retirement demand the acquisition of new skills to deal with areas of difficulty. She recommends ways in which the provision of adult education could facilitate learning opportunities in numeracy for older adults (Withnall, 1995a). Also, recently, work on financial literacy and older people has been undertaken by NIACE in the 'Financial Literacy and Older People' project (NIACE, 2002) following the publication of the Adult Financial Literacy Advisory Group report (AdFLAG, 2000), discussed in Chapter 2, and the establishment of a UK government Cabinet Sub-Committee on Older People.

If we are to move towards the goal of mathematics for all, it is surely imperative that issues of learner identity and social and economic location are considered and data collected and analysed with respect to gender, class, age, ethnicity, disability, culture, language, environment (rural, urban, inner city, suburban, etc.) and labour markets at local, regional and national levels.

Teacher education for adult numeracy

As has been noted above, in Chapter 1, teacher education is currently undergoing a major transformation, with the introduction of Subject Specifications at National Qualification Framework (NQF) levels 3 and 4 (the equivalent of GCE A level and undergraduate levels respectively) for adult numeracy teacher education (but interestingly not for those teaching Key Skills) in England. The Subject Specifications cover both subject and pedagogical knowledge (DfES/FENTO, 2002). For the first time, teachers will be expected to achieve a subject qualification at NQF level 4, the same level as their colleagues teaching in secondary schools, while those in the post-16 sector who are supporting numeracy learning as teaching assistants, or teaching other subjects in which numeracy features, will be expected to achieve NQF level 3. At the same time, 3-day teacher training courses have been run to support the introduction of the Adult Numeracy Core Curriculum. Postgraduate programmes in adult basic skills, including numeracy, are being developed, and there is a small but growing number of students pursuing doctoral studies in aspects of adult numeracy.

Research on the subject of adult numeracy teacher education and continuing professional development (CPD) is extremely rare. Little is known about those teaching adult numeracy. Brooks and his colleagues found that basic skills tutors are mainly female, part-time and well-qualified, but that professional development for them seems patchy (Brooks et al. 2001). We do not know how many of these tutors teach adult numeracy, or what their qualifications are, although a NRDC study of basic skills tutors, currently underway, should provide useful data.

The most recent review of research on teacher education in adult mathematics education was not able to identify any researchers who review the situation comprehensively from an international perspective; such data as exists is based on the work of a small number of researchers and inferences made from the general body of research in the field. On this basis, the authors group those teaching mathematics to adults into three categories: (a) tutors who have no particular background in mathematics; (b) trained mathematics teachers; and (c) academic mathematicians. They contend that teacher preparation is problematic in all three categories (FitzSimons et al. 2003). It is not known how adult numeracy teachers in England are distributed across these categories but it is probable that the majority is in categories (a) and (b). Many of those in category (a) may be literacy or ESOL teachers, or teachers of vocational or other subjects, who are also teaching numeracy.

One outcome of the current reforms underway in adult numeracy teacher education in England is that tutors with no particular background in mathematics may in future be fewer in number, since, as noted above, the requirement is that incoming teachers must successfully complete training at NQF level 4 (undergraduate level) in both mathematical subject competence and adult numeracy pedagogy (DfES/FENTO, 2002). A parallel situation to that pertaining in adult numeracy before the current reform, with non-mathematics specialists teaching mathematics or numeracy, still exists in the school sector amongst teachers of 11 year olds, many years after the introduction of Qualified Teacher Status (QTS) for those teaching in schools (Coben, 2001b) and there is continuing concern about the shortage of qualified mathematics teachers (Open University, National Association of Mathematics Advisers, & King's College London, 2003). However, studies by Begle in the 1970s and 1980s found that higher mathematics qualifications were not correlated with more effective teaching (Begle, 1968, 1979). Anecdotally, it appears that many teachers of vocational or other subjects, and of literacy and ESOL do not feel competent or confident including numeracy in their teaching.

Teachers in category (b): trained mathematics teachers from the school sector, should represent an asset rather than a problem, although these teachers are unlikely to have been trained in teaching adults. There is therefore a danger that they may inadvertently reinforce any feelings of inadequacy their adult students feel by triggering memories of failing at mathematics as children. Also, while many school teachers value children's skills and knowledge, children necessarily have less life-experience than adults on which to draw in their mathematics learning. Tout and Marr discuss similar issues in their paper on adult numeracy professional development in Australia (Tout & Marr, 1997) while Ma argues that undergraduate-level mathematics is not necessary in order to teach the subject at elementary levels (Ma, 1999).

There has been a handful of studies of adult numeracy teacher education in England. Chanda has reported on initial teacher education for teaching and assessing Numeracy across the 14-19 years curriculum (with specific reference to GNVQ Application of Number) (Chanda, 1997). Joseph undertook a survey of adult numeracy tutors who were members of ALM and found many of them to be dissatisfied with the courses and qualifications then available to them (Joseph, 1997). Coben and Chanda reviewed developments in adult numeracy teacher development in England in the period immediately before the current reforms, comparing the situation unfavourably with that in Australia (Coben & Chanda, 2000) and Coben and Joseph look at the past, present and future of adult numeracy tutor training in England (Coben & Joseph, 2000).

Elsewhere, in Ireland, Maguire and O'Donoghue report on their national survey of practitioners involved in teaching mathematics to adults, which they conducted from February to May 2001; a survey that could usefully be replicated in England. They found a paucity of training: 82% of those surveyed indicated that they had had none, or insufficient training specifically in teaching adults mathematics. This, coupled with an exam-orientated education system at second level, means that Irish practitioners' experience of mathematics teaching is very limited and focused on getting the right answer rather than on generating an understanding of mathematics (Maguire & O'Donoghue, 2002:129). In the USA in the mid-1990s fewer than 5% of adult education teachers were certificated to teach mathematics (Gal & Schuh, 1994); many of those teaching mathematics to adults came to be doing so "by accident" or because it was a condition of their employment (Mullinix, 1994). Llorente and colleagues from Argentina have reported on in-service workshops in that country bringing together trained teachers and those without formal training teaching in vocational education to work on adult mathematics education, an approach that they advocate (Llorente, Porras, & Martinez, 2001).

In Australia teacher education for adult numeracy certainly received more attention during the 1990s (Marr & Helme, 1991) than was the case in the UK. Lack of available teacher expertise was identified as the most urgent and obvious consideration in Lee, Chapman and Roe's study in the mid-1990s. They considered that in the first instance this is a question of mathematics expertise:

> *Since the majority of those who are currently addressing in their curriculum and their pedagogy the question of 'integrating' or otherwise relating literacy and numeracy instruction are literacy teachers, there is a strong sense of anxiety concerning expertise and familiarity with mathematics. The causes of this are complex and relate to teachers' own experience and success within their own schooling history. There is, however, a perceived urgent need for teacher education and professional development in mathematics.* (Lee et al. 1996:91-92)

This perceived urgent need culminated in the publication of **Adult Numeracy Teaching – Making Meaning in Mathematics** (ANT), an impressive pack supporting an 84-hour (voluntary) training course, using a critical constructivist approach. The pack is described by its authors as

> *designed to provide teachers with a broad understanding of the content and structure of mathematics and how it is applied to modern life, and to develop their confidence in their own use of mathematics and in theories, methodologies and communications processes appropriate for teaching numeracy in adult basic education. The programme aims to blend theory and practice about teaching and learning adult numeracy within a context of doing and investigating some mathematics, whilst developing a critical appreciation of the place of mathematics in society.* (Tout & Johnston, 1995)

The Australian experience seems particularly relevant to that in England, given widespread current concern about the lack of available teacher expertise.

There may also be lessons to be learned from studies of teacher education and continuing professional development in mathematics education in schools, an area recently reviewed with respect to primary mathematics education by Brown and McNamara (Brown & McNamara, 2001). Even more recent is a report by the Advisory Committee on Mathematics Education which makes a series of eight recommendations, all of which would probably be echoed by most adult numeracy teachers:

1. *We recommend that the Government should initiate urgently the process of developing and funding a long-term programme of CPD for teachers of mathematics that can meet their needs at various stages of their careers. To help launch this initiative, the Government should first: obtain relevant data on both the number of teachers of mathematics needed over the next 10 years and the qualifications of existing teachers; commission a survey of current CPD providers in mathematics; and convene a series of seminars to examine international best practice in CPD for teachers of mathematics.*

2. *We recommend that CPD for teachers of mathematics should contain an element of broadening and deepening of mathematical knowledge. This should complement an appreciation of how pupils learn, and a comparison of varied methods of teaching, mathematics. The weighting of each of these components will vary from course to course according to teachers' and schools' needs and goals. A survey of teachers of mathematics to elicit their views on CPD would help to determine these needs fully.*

3. *We recommend that part of any CPD programme should be structured so as to allow opportunities to relate theory to practice in the classroom, and to provide time for informed and collaborative reflection with peers and with those with appropriate expertise.*

4. *We recommend that teachers of mathematics should be expected to engage in CPD throughout their working careers. This implies an entitlement to time and funds, alongside a system of accountability and rewards.*

5. *We recommend that teachers of mathematics must be given an allocation of time and resources to enable coherent planning and development to take place at an*

institutional level. There is currently a crisis in mathematics teaching, and some funding tied to CPD for teachers of mathematics must be provided directly to schools and colleges. The Government should commission a study to quantify both teacher in- and out-of-school training entitlement and the resource implications for schools of making such an allocation.

6. *We recommend that a network of Local Mathematics Centres (LMCs) should be developed to encourage the growth of a community of teachers of mathematics across all phases and to provide a source of expert advice, resources and information. The Government should commission a feasibility study of how LMCs might function and then set up a pilot centre involving teachers, Local Education Authority staff and academics from mathematics and education departments.*

7. *We recommend that a National Academy for Teachers of Mathematics should be established to have a strategic overview of CPD at a national level and to coordinate its operation locally. The Government should commission a feasibility study to set out a range of options with costings and then seek private sponsors for funding.*

8. *We recommend that some CPD funding should be made available directly to teachers of mathematics to enable them to undertake substantial professional development according to their individual needs and goals.*(ACME, 2002)

A recent report produced by contributors from The Open University, the National Association of Mathematics Advisers (NAMA) and King's College London raises similar concerns about the state of mathematics education in schools. The report found that:

- *The figures show a decline in the proportion of teachers of mathematics with mathematics qualifications since the 1996 DfES Curriculum and Staffing Survey.*

- *24% of the teachers had 'weak' or 'nil' mathematics qualifications.*

- *14.6% of secondary pupils are taught mathematics by teachers with 'weak' or 'nil' mathematics qualifications.*

- *England is short of over 3500 qualified mathematics teachers.*

- *Only 37% of appointments made in the academic year 2001-2002 were perceived by schools to be 'good appointments'; 20% of posts advertised went unfilled.*

- *The requirement for teachers of mathematics has increased by 10% since 1996 as the secondary school cohort has increased from 3m to 3.3m.*
(Open University et al. 2003:1)

In answer to Coben and Chanda's question: "what are the skills, knowledge and understanding required by those who undertake adult numeracy teaching?" (Coben & Chanda, 2000:317), the authors of the chapter on adult lifelong mathematics education in the **Second International Handbook of Mathematics Education Research** are unequivocal:

The direct and indirect evidence points to one conclusion: teachers of mathematics at all levels need to know mathematics, know their students, have knowledge of the 'pedagogy'

> *of mathematics (Cooney, 1999), and have a commitment to their own lifelong learning.* (FitzSimons et al. 2003:124)

But do they all need to know mathematics to the same level? Interesting work has been done on teacher knowledge for adult numeracy by researchers from the New York City Math Exchange Group (MEG), drawing on international comparative research in the school sector. MEG is a voluntary collaborative group of Adult Basic Education teachers which "bases its work on the idea that teachers can learn the way we expect our students to learn – by constructing mathematical knowledge and understanding socially" (Brover et al. 2001:248).

In a paper presented at the ALM-7 conference, the MEG team draw on an international comparative study of US and Chinese elementary school teachers by Ma (Ma, 1999), and Stigler and Hiebert's analysis of the TIMSS data (Stigler & Hiebert, 1999). The team agree with Ma that elementary mathematics is emphatically not "'basic', superficial, and commonly understood" (Ma, 1999:146). They also concur with Cooney's observation that the level of difficulty is often conflated with the level of understanding (Cooney, 1994:11). They point out that "The question most often asked of teachers' math knowledge is: How far? But we should ask: How deep?" (Brover et al. 2001:247). They argue that ABE teachers need to develop what Ma calls PUFM:

> *Profound understanding of fundamental mathematics (PUFM) is more than a sound conceptual understanding of elementary mathematics - it is the awareness of the conceptual structure and basic attitudes of mathematics inherent in elementary mathematics and the ability to provide a foundation for that conceptual understanding and instil those basic attitudes in students.* (Ma, 1999:124)

The MEG team assert that students who apply comparable intellectual rigour to so-called 'elementary' strands of mathematics such as fractions as to later 'advanced' mathematics "are able to build on strong foundations and make connections in mathematics throughout their lives". They go on to state that

> *This works not only in support of professional development for teachers, but in support of adult and elementary school learners, who too often get the message that they are incapable of understanding even "easy" mathematics, and who are not provided with the appropriately trained teachers necessary to explore and construct knowledge of complex subjects such as fractions and other "elementary" mathematics.* (Brover et al. 2001:250)

In order to test their view, the MEG team set groups of adult mathematics/ numeracy educators tasks originally set by Ma (Ma, 1999). The educators were a self-selected group of delegates to the ALM-7 conference and experienced and new MEG teachers. The tasks were: "Divide $1\frac{3}{4}$ by $\frac{1}{2}$" and "Write an appropriate story problem". They found that both the ALM attendees and experienced MEG members were able to compute the division of fractions problem, create story problems related to it, and reason mathematically and abstractly to a greater extent than either Ma's sample of US teachers or the sample of new MEG teachers. They note with interest Ma's point that Asian teachers have more opportunity than US teachers for collaborative working with peers and that:

> *The key period during which Chinese teachers develop a teacher's subject matter knowledge of school mathematics is when they teach it - given that they have the motivation to improve their teaching and opportunity to do so.* (Ma, 1999:147)

The MEG team find this encouraging, since, while "many ABE teachers do not have sophisticated academic math experience, they may become better math teachers while teaching". They argue for comprehensive and ongoing staff development, through teacher-researcher and collaborative models with long-term institutional support, to enable all teachers to develop their PUFM and hence be better able to understand, apply, and teach mathematics to their students (Brover et al. 2001:250).

Other work with children may also hold lessons for adult numeracy teacher education. For example, the **Successful Interventions Numeracy Research Project**: 5-9 (Stage 2), which ran from 1999-2000 in Victoria, Australia. The outcomes of the project, which may be relevant to work with adults, may be summarised as follows:

- *Teachers make a difference. "That is, opportunity to learn is as much a factor in explaining differences in performance as so-called ability. Providing relevant professional support and differentiating teaching to ensure all students have relatively equal opportunity to learn would appear to offer a better chance of maximising success for all" (p7).*

- *Improvements were achieved as a result of concentrating on recognised good practice but 'good' mathematics teaching, although necessary, is not sufficient. The way in which learning is supported and organised is also important, as is the way in which expectations of numeracy-related learning in schools and students is represented.*

- *Significant numbers of students appear to be experiencing difficulty in relation to some aspects of numeracy. The most common areas of difficulty were: fractions, decimals and multiplicative thinking, and the ability to interpret apply and communicate what was known in context.*

- *Early diagnosis and intervention are critical. Key numeracy-related 'growth points' and the scaffolding needed to help students to make progress need to be identified as soon as possible. Teachers need to be supported to identify poor learning behaviours and replace them with more effective learning strategies.*

- *Student success is an important factor in students' readiness to engage with mathematics in the middle years of schooling. Flexible group work in mixed ability classes seems to be a useful approach but further work is needed to work out how might be done effectively and efficiently in practice.*

- *Speaking and listening are key to the construction of shared meaning for mathematical ideas and texts. However, this only works when there is sufficient trust, knowledge and confidence to share and work on what is known and how it is known - and that requires sufficient time to focus on meaning, rather than just 'doing'. Learning from experience depends on having access to a network of related ideas which inform and are shaped by doing. Without these, the 'doing' becomes boring and repetitive. This implies a shift in expectations and targets away from a large number of relatively disconnected ideas to a very much smaller, more connected set of 'big ideas' supported by descriptions of the sort of conversations that teachers might be expected to have with students if they understood those ideas.*

- *Attempting to meet unrealistic curriculum expectations places teachers and students at odds with each other. The 'crowded curriculum' syndrome provides little space for connecting, generalising and conjecturing, and the primary focus on 'doing', as opposed to enquiry tends to generate passive learning and poor learning habits. A strong implication of this research is that serious consideration needs to be given both to the nature and degree of content specificity that is provided in mathematics curriculum framework documents. A focus on the 'big ideas' and the scaffolding needed to acquire and use those ideas with confidence is needed as a matter of urgency. Consideration also needs to be given to how the curriculum in general is framed at this level with particular focus on the relationships and possibilities for learning that exist in cross-curriculum approaches to teaching and learning.*(Siemon et al. 2001)

Experience from the schools sector in England may also be relevant, given the convergence of the adult and child curricula. Accordingly, the next section reviews an English study of 'Effective Teachers of Numeracy'.

Effective Teachers of Numeracy project
by Sheila Macrae

This project was carried out by a team at King's College London between 1995 and 1996 for the Teacher Training Agency (TTA) (Askew, Brown et al. 1997). The main aim of the study was to identify the key factors that enable teachers to put effective teaching of numeracy into practice in the primary sector. In order to realise this aim, three initial questions had to be answered:

- What is meant by numeracy?
- How could the team identify effective teaching of numeracy?
- How could they find effective teachers of numeracy?

It was decided to adopt a broad definition of the term 'numeracy' to encompass the ability to calculate accurately but also to go beyond that to include a 'feel for number' and the ability to apply arithmetic.

Effective teaching of numeracy was defined as teaching that helped children to:

(i) acquire knowledge of and facility with numbers, number relations and number operations based on an integrated network of understanding techniques, strategies and application skills;
(ii) learn how to apply this knowledge of and facility with numbers, number relations and number operations in a variety of contexts.

Data sources
In order to develop some understanding of teachers' beliefs and practices, four data sources were used: questionnaire data from all 90 teachers who took part in the study; observations of 84 mathematics lessons; three interviews with each of 18 teachers; two interviews with each of 15 teachers.

Some findings from the project

The team was surprised at some of the findings about what makes a teacher effective. For example, organisational style for mathematics teaching was not a predictor of how effective teachers were. Whole-class question and answer teaching styles were used by both highly effective and less effective teachers. Similarly, individualised and small group work were used by teachers across the range of effectiveness. Within schools, setting across an age group was used by highly effective teachers. The same published mathematics schemes were used by highly effective and much less effective teachers.

The findings also raised questions about the sort of mathematical knowledge needed by teachers in order to be effective. Contrary perhaps to expectations, being a highly effective teacher was not positively correlated with high levels of mathematical qualifications, a finding supported, as noted above, by Begle's research in the USA (Begle, 1979). Instead, the amount of continuing professional development in mathematics education undertaken by teachers was a better predictor of their effectiveness.

From the team's data analysis what seemed to distinguish some highly effective teachers from the others was a consistent and coherent set of beliefs about how best to teach mathematics whilst taking into account children's learning. In particular, the theme of 'connections' was one that particularly struck the team. Several of the highly effective teachers seemed to pay attention to:

(i) connections between different aspect of mathematics, for example, addition and subtraction, or fractions, decimals and percentages;
(ii) connections between different representations of mathematics, including moving between symbols, words, diagrams and objects;
(iii) connections with children's methods, including valuing these methods and being interested in children's thinking and sharing the children's methods.

The team came to refer to such teachers as having a 'connectionist' orientation to teaching and learning numeracy. Such an orientation included the belief that being numerate involved being both efficient and effective. Being numerate for these teachers required an awareness of different methods of calculation and the ability to choose an appropriate strategy.

Associated with the connectionist orientation was the belief that most children can learn mathematics given appropriate teaching. In this orientation, teaching needed to be introduced in a clear manner and the links between different aspects of mathematics made explicit.

Two other orientations were also identified. In the first, the teacher's beliefs were more focused on the role of the teacher (a transmission orientation) and in the second, their beliefs focused on the children as independent learners of mathematics (discovery orientation).

In the transmission orientation the teacher placed more emphasis on teaching than learning. This orientation involved a belief in the importance of a collection of procedures or routines, particularly regarding paper and pencil methods. This involved one method for doing each particular type of calculation, regardless of whether or not a different method would be more efficient in a particular case. This emphasis on a set of routines and methods that need to be learned, leads to the presentation of mathematics in discrete packages. An example of this would be fractions taught separately from division.

In the discovery orientation learning takes precedence over teaching and the pace of learning is largely determined by the children. Children's own strategies are most important and their understanding is based on working things out for themselves. Children are seen as needing to be 'ready' before they can learn certain mathematical ideas. This results in a view that children vary in their ability to become numerate.

Askew argues that the orientations connectionist, transmission and discovery are ideal types; no single teacher in the project held a set of beliefs that precisely matched those within each orientation. Nevertheless, teachers who were identified as having a transmission or a discovery orientation were shown to be less effective in their teaching than those identified as connectionist (Askew & Brown, 2001). It would be interesting to investigate whether these findings also held true for adult numeracy teachers.

The National Numeracy Strategy in Primary Schools
by Sheila Macrae

The government's National Numeracy Strategy (NNS) in primary schools predates and in some ways prefigures aspects of the ***Skills for Life*** strategy, in particular with regard to the Adult Numeracy Core Curriculum, making the NNS of potential interest for adult numeracy educators.

The NNS initiative was launched in 1998, nine years after the introduction of the first National Curriculum (NC) for state schools in England and Wales, itself an attempt to "raise standards consistently, and at least as quickly as they are rising in competitor countries" (DES/WO, 1987:2-3). Mathematics was seen as a key subject area and the ways in which numeracy/mathematics was taught in primary schools in England and Wales underwent enormous changes during the 1990s, with the launch of various initiatives.

One such initiative, the National Numeracy Project (NNP), was introduced by the Conservative Government in 1996 in response to children's poor results in international comparative surveys. While the NNP was developed in only 13 local education authorities (LEAs), many of its recommendations were taken up by other schools well in advance of the national extension of the NNP into the National Numeracy Strategy (NNS). The NNS was implemented in English primary schools by the Labour Government in 1999. The main aim of the NNS was to raise achievement levels and in particular to fulfil targets set by David Blunkett, the then Secretary of State for Education. The target for mathematics was to raise the percentage of 11 year olds reaching Level 4 (the expected median level) from 59% in 1998 to 75% by 2002. While the NNS (unlike the NC) was not mandatory, early evidence suggested that most schools were trying to put the Strategy's recommendations into place (OFSTED, 2000).

However, Brown points out that for both political and educational reasons the National Numeracy Strategy takes a rather narrow view of numeracy, focusing on "proficiency, regarding numeracy as a culturally neutral and value-free set of autonomous skills, underpinned by visual models such as the number line" (Brown, 2002:3).

The NNS also does not differentiate between mathematics and numeracy. For example, in government recommendations for a NNS, it is stated that there should be a "daily mathematics lesson (which) will allow pupils to reach a high standard of numeracy (with) a high proportion of these lessons spent on numeracy" (Reynolds, 1998:2). As Askew (Askew, 2001b:107) points out, "the statutory content of the Mathematics National Curriculum could not be set aside with the introduction of the National Numeracy Strategy, and there is now a blurring of the distinction between numeracy and mathematics". Noss (Noss, 1997), however, cautions against equating mathematics with numeracy as this can result in reducing the mathematics curriculum to those aspects that can most easily be learned and Askew (Askew, 2001b) argues that the curriculum risks being reduced to those elements that can most easily be taught. This is a risk that Kanes also warns of in his discussion of "constructible numeracy", as we have seen (Kanes, 2002).

Within the NNS, there was an increased emphasis on number and calculation, particularly mental tasks, including estimation and selection from a range of strategies. It was also stipulated that there should be a "structured daily mathematics lesson of 45 minutes to one hour for all pupils of primary age" (DfEE, 1999:2). The first part of each lesson was to be an oral/mental starter, for approximately 10 minutes, followed by a main teaching session for around 30-40 minutes and finally a plenary phase of about 10 minutes. In addition, there was to be detailed planning using a suggested week-by-week framework of objectives, specified for each year group. As a result, many skills were introduced at an earlier stage than previously, and areas of mathematics other than number were covered. To help with all these detailed requirements, there was a systematic, standardised national training programme run by consultants locally and by school mathematics co-ordinators in all schools, using videos to demonstrate 'best practice', with in-school support for low-performing schools. **The Framework for Teaching Mathematics from Reception to Year 6** (DfEE, 1999) provided further guidance on 'good direct teaching', pupil groupings, class organisation, differentiation and setting. In this way, the pedagogical aspects of teaching were clearly set out.

In line with the shift away from a focus on the individual child to a focus on the whole class, the reports of the Numeracy Task Force (the group that formulated the plans for the NNS to develop out of the NNP) recommended corresponding styles of teaching with a subtle but important shift of emphasis between the preliminary and final reports. For example, in the preliminary report one of the recommendations was that more time should be spent in mathematics lessons with the teacher involved in "direct communication with pupils". It was suggested that this could be achieved "particularly by teaching the whole class together using good questioning techniques" (DfEE, 1998b). In the final Task Force report this means had become an end in itself. The first recommendation was for a daily mathematics lesson in which "Teachers should teach the whole class together for high proportion of the lesson" (DfEE, 1998a:2). Such recommendations have become crystallised in what is known as the 'three-part numeracy lesson'.

The three-part lesson

We now look at each of the three parts of the daily mathematics/numeracy lesson.

Oral/mental starter The first part of the lesson is designated as the oral/mental starter, as Anita Straker, architect of the NNP, contended:

> *The ability to calculate mentally lies at the heart of numeracy. Mental methods should be emphasized from an early age with regular opportunities to develop the different skills involved.* (Straker, 1999:43)

It is interesting to note that the term 'mental arithmetic' was dropped in the 1990s because of its negative connotations, as described by Buxton (Buxton, 1981), with 'mental calculation' replacing the term 'mental arithmetic'. As Thompson explained,

> *the negative emotions that this phrase conjured up in many people's minds - reminding them of stressful times when they were unable to recall a number bond or tables quickly enough to avoid the wrath of their maths teachers - persuaded some educators that a different more positive-sounding phrase was needed.* (Thompson, 1999:147)

Four main reasons are given in the literature for teaching mental calculations. Firstly, in everyday life most mathematical calculations are done mentally rather than written down (Wandt & Brown, 1957). Secondly, McIntosh argued that mental calculations encourage the user to find shortcuts which develop better understanding of the number system (McIntosh, 1990). Thirdly, problem-solving can be improved by regular practice of mental calculations as this necessitates the selection of appropriate strategies to carry out the calculation (Driscoll, 1981). Finally, written mathematics has been found to improve through the practice of mental calculations (DES/WO, 1982).

Askew explains that the relationship between mental and written methods has, traditionally, been determined by the size of the numbers used. That is, small numbers could be worked with mentally, while larger numbers were written down (Askew, 2001a).

An important but often neglected aspect of mental calculations is the self-confidence of the user. While children may have a range of facts and skills at their disposal, if they lack the confidence to take risks and 'have a go', they are unlikely to use these skills to develop appropriate strategies. To build the confidence of such children, teachers need to create a positive atmosphere in the classroom and deploy positive teaching tactics that encourage children to have a go. According to Thompson there are minimum requirements for children to be able to carry out successful mental calculations (Thompson, 1999). These include, a sound knowledge of number facts; a secure understanding of the number system and the various operations; the skill to put into practice the facts underpinned by these understandings; and the confidence to use their knowledge in their own way to find answers.

Main teaching session The second, and main, part of the NNS numeracy lesson is specified as the main teaching session, comprising whole class teaching; this should encompass "a high-proportion of the time" (DfEE, 1999:2).

The research evidence for whole class teaching is mixed. Peterson and Janicki found in a review of mathematical learning studies, that with the more direct approaches of traditional, whole class teaching, pupils tended to perform slightly better on achievement tests (Peterson & Janicki, 1979). However, they performed worse on tests of more abstract thinking, such as creativity and problem solving. In an examination of Dutch studies, the proportion of whole class teaching appeared to have a significant positive association with attainment in only three out of 29 studies (Creemers, 1997). In two other large-scale statistical studies there has been a positive correlation between whole class teaching and attainment (Galton & Simon, 1980; Galton, Simon, & Croll, 1980; Good, Grouws, & Ebmeier, 1983). Croll (Croll, 1996) noted that teachers whom Galton et al. (Galton et al. 1980) had referred to as 'class enquirers' were more successful than those termed 'individual monitors' and used four times as much time in whole-class teaching. However, a third group, who achieved only marginally less well than the 'class enquirers', used little whole class teaching. In work by Creemers it was found that children learn more in class when taught or supervised by the teacher, than when working on their own (Creemers, 1994). This was accounted for by teachers providing good, well thought-through presentations, enhancing children's time on task, making more contact with the children and spending less time on classroom management.

Straker argues that whole class teaching should have certain components: "It is an essential craft which involves balancing different elements: demonstration, explanation, questioning, discussion and evaluation of pupils' responses and direction" (Straker, 1999:42). However, noting that in individual cases particularly poor results have also been associated with whole class styles, investigators have cited evidence for the quality of teacher-pupil interaction being a much more important factor than class organisation (Galton, 1995; Good & Biddle, 1988; Good & Grouws, 1979). These studies suggest that a whole class format may make better use of high quality teaching but may equally increase the negative effects of lower quality interaction, a finding supported by Brown in her evaluation of evidence on the NNS from the Leverhulme Numeracy Research Programme and other studies at King's College London, discussed below (Brown, 2002).

Plenary phase In this final short phase the teacher recaps on the work covered during the hour and demonstrates to the class the ways in which the ideas and concepts explored fit into the larger picture of mathematics/numeracy. The time may also be used to talk to the children about where the work will lead in the following lesson(s). In this phase also, children's mathematical thinking may be examined and new ways of dealing with mathematical tasks shared with the rest of the class. The plenary phase also provides an opportunity for the teacher to finish the session on a positive note in order to leave the children feeling positive about their efforts and looking forward to the next lesson.

Evaluation of the National Numeracy Strategy

External evaluation of the National Literacy and Numeracy Strategies in England has been carried out by a team from the Ontario Institute for Studies in Education (OISE), University of Toronto (Earl et al. 2000; Earl et al. 2001, Earl et al. 2003). The OISE/UT team concluded that the NNS has been generally well-supported by schools and that although the 2002 targets were not reached, there have been improvements in teaching practice and pupil learning and a substantial narrowing of the gap between the most and least successful schools and LEAs. While virtually all classrooms were found to be using elements of the strategies, there was considerable disparity across teachers in subject knowledge, pedagogical skill and knowledge of the Strategies and intended changes in teaching and learning have not yet been fully realised. Many see the NNS as needing to be re-energised. The commitment to collective capacity-building is identified as the most promising direction for addressing future challenges (Earl et al. 2003).

The Office for Standards in Education (OFSTED) has also evaluated the National Numeracy Strategy. Its survey of 300 schools found key weaknesses with both written and mental calculation, particularly in children in Years 3 and 5 (OFSTED, 2000).

The Leverhulme Numeracy Research programme conducted by Brown and colleagues at King's College London (Brown, 2002) found an overall average gain in Year 4 students' results, across the implementation of the NNS, of about 3%, i.e., the equivalent of just over two months' development. While this is statistically significant, the authors concede that it may be disappointing to some who expected that the National Numeracy Strategy would cause a large increase in attainment (Brown, 2002:2).

The biggest improvements were recorded in the middle 50%, then in the top group, with a slight deterioration found in the lowest attaining children. i.e., attainment was further polarised, as they state:

> *Both observation of lessons, especially as part of the case study work, and interviews with children suggest that this slight deterioration is partly due to the fact that low attaining pupils derive little benefit from the whole class teaching episodes, and the topic of the lesson does not always correspond to their areas of greatest need.* (Brown, 2002:7).

The effect of the National Numeracy Strategy on teaching was found to be mixed. Teachers welcomed the NNS (as many adult numeracy teachers seem, on anecdotal evidence, to be welcoming the adult curriculum and associated 3-day training); complaints were about inflexibility, and lack of time to concentrate on some topics when children had not grasped them.

The report points out that the increase in frequency of whole class teaching predated the NNS; mathematics is now often more challenging; lessons are more lively, pacy and interactive (Brown, 2002:9). "However it was difficult in classroom observation to be sure that the new teaching styles were actually producing better learning" (Brown, 2002:9). "Teachers were clearly working hard but not all children were, with frequently changing activities providing opportunities for distraction" (Brown, 2002:10). The team state "We investigated the mean class gains made by different classes in the first two years of this study (Y4 and Y5) and found no detectable difference in gains achieved over a year by teachers who use a high proportion of whole class teaching as against those who use very little" (Brown, 2002:10). Whole class teaching was therefore not a source of great improvement, a finding consistent with an earlier study for the Teacher Training Agency (TTA), **Effective Teachers of Numeracy** (Askew, Brown et al. 1997).

The team's analysis of teaching found that "it is difficult to detect the effect on attainment of high quality teaching" (p12); literature suggests teachers affect at most about 10% of variance after pupil effects have been removed. No effect on pupil gains was found from the 5-day training course; teachers valued improvement in their own knowledge and confidence and attributed greater effects on practice to in-school INSET and working with the framework document.

The team concluded that:

> *This evidence thus suggests that assessment change and curriculum change is more effective than changing teaching style in producing learning gains, but that changes are unlikely to be very dramatic (and if they are, may well be superficial).*
>
> *Some further changes which seem likely to be beneficial:*
>
> - *More work on applied problem-solving (not just contrived word problems) – already under way;*
> - *More formative assessment, more differentiation and more teaching assistants to assist teachers in adapting the Framework to the needs of their pupils, especially to addressing the specific problems of lower attainers, and to a lesser extent, higher attainers;*

- *Longer timespans on some single difficult topics, both within lessons and across groups of lessons;*

- *More sustained teacher professional development; for some teachers, especially mathematics co-ordinators, outside the school and for others within the school using release time of the mathematics co-ordinator.*(Brown, 2002:12-13)

Leverhulme Numeracy Research Programme
by Sheila Macrae

This major programme was conducted by researchers at King's College London between 1997 and 2002 (Brown, 1997-2002). It comprises a core study which focused on tracking numeracy in order to provide information about pupils' progression in the subject during the primary phase and to assess relative contributions to gains in numeracy. In addition, there were five focus projects examining various aspects of numeracy. The main aim of the study was to "Take forward understanding of the nature and causes of low achievement in numeracy and provide insight into effective strategies for remedying the situation" (Brown, 2002:1).

While there has been a small number of longitudinal intervention studies (see for example, Steffe, Cobb, & von Glasersfeld, 1988; and Maher & Martino, 1996), the researchers recognized that there was a great need for more longitudinal studies that examine the ways in which children develop their mathematical thinking. Accordingly, this programme provided a much-needed analysis of children's progress in learning mathematics in the primary sector.

The study's findings have been published in a series of papers and articles listed on the project's website (Brown, 1997-2002). These studies provide a generic model of children's progression in their learning of numeracy and information about "how and why both individual test items and individual children depart from the generic model". Overall, the team highlight the "complex yet weak relationships between teaching and learning" and note that the National Numeracy Strategy, although undoubtedly "a major attempt at systemic change, has had at most a small effect in most areas of numeracy" (Brown et al. 2003:22). A similarly ambitious longitudinal project would be required to determine whether this outcome can be avoided with respect to adult numeracy in the wake of ***Skills for Life***.

Conclusion

So where does this leave us? In their study of 'literacy and learning in mathematics', Bickmore-Brand makes a series of recommendations that may be taken to relate to adult numeracy teaching and learning generally:

1. *Academic positions for adult numeracy should be established at universities concerned with adult teacher education, to provide an infrastructure for future research and development as well as for effective teacher education for teachers of adults.*

2. *Broad ranging, adequately funded research should be carried out collaboratively between teachers and researchers. Specific areas of research need identified include:*

i) systematic investigation and development of innovative pedagogical strategies in different adult programs, e.g., the pedagogical 'integration' of literacy and numeracy;
ii) the investigation of how adults learn within different pedagogies;
iii) the investigation of gender issues in adult literacy and numeracy pedagogies;
iv) investigation of the relationship between traditional notions of 'literacy' and 'numeracy' and new forms of textualisation such as computers.

She also recommends a substantial increase in teacher education and professional development, together with adequate funding for the development of curriculum resources appropriate to the changing conceptions of adult numeracy (Bickmore-Brand, 2001). Her recommendations resonate with the findings of many of the studies of adults' and children's numeracy and mathematics teaching and learning reviewed in this chapter.

Factors affecting learning

...but still
Learning is labour, call it what you will.
George Crabbe, 1810, 'Letter XXIV: Schools', 19, in The Borough

Nearly 30 years ago, White pointed out that while to be 'illiterate' is shameful, to be 'unnumbered' carries less stigma, since numeracy is regarded as a special gift (White, 1974). Whether this is still the case is a moot point but there is considerable evidence to support the idea that learners' attitudes, beliefs and feelings about mathematics and their confidence (or lack of it) in their own mathematical abilities have an effect on their learning. There is also growing interest in dyscalculia and the workings of the brain in mathematical activity. This chapter considers all of these as factors affecting learning.

Affective factors - attitudes, beliefs and feelings

McLeod gives a useful schematic review of research on affect and mathematics learning in general in the **Journal for Research in Mathematics Education** (JRME) from 1970 to the mid-1990s, taking in research on attitudes (see the section below by researchers from King's College University of London), student beliefs, emotional responses to mathematics and new approaches, including anthropological approaches which are beginning to have an impact on research related to affect (McLeod, 1994) (see also McLeod, 1992). Other studies include Mandler's 'Affect and learning: Causes and consequences of emotional interactions' (Mandler, 1989) and McLeod and Adams' edited collection, **Affect and Mathematical Problem Solving: A new perspective** (McLeod & Adams, 1989). Such approaches suggest that research should focus on the social organisation of the site of learning and the specifics of mathematics learning in the classroom or other setting.

The role of emotions in adult mathematics learning is explored by Evans in his book, **Adults' Mathematical Thinking and Emotions** (Evans, 2000b). He maintains that thinking and emotion are inseparable, so that human mathematical activity is always also emotional, rather than only cognitive. He explores complex issues of mathematics anxiety (an issue discussed below by Sheila Macrae) and looks at social differences in adults' mathematics performance, anxiety and confidence. In a later article he discusses the process of developing research conceptions of emotion among adult mathematics learners (Evans, 2002).

Singh's report on the available research and the results of a mini-survey into the attitudes of adults to mathematics found that:

1. *Abstraction and lack of relevance in mathematics is a common cause cited by students for their dislike of and failure in mathematics.*

2. *The fear of failure induced by testing and the nature of mathematics pedagogy may be one of the causes of anxiety in adults.*

3. *Teachers have significant influence in motivating or disaffecting students of mathematics.*

4. *Women may be more prone to develop negative attitudes to mathematics both through socialization processes and the content and pedagogy of mathematics.*

5. *Adults may develop a Eurocentric view of the history of mathematics through their experience of school mathematics.* (Singh, 1993:335)

The next section reviews research on attitudes towards mathematics generally, mainly focusing on studies undertaken in the schools sector, extracted from a review undertaken at King's College London in 1997. This is followed by a review of research on mathematics anxiety and of studies of the working of the brain, including dyscalculia.

Attitudes towards mathematics by Jo Boaler, Margaret Brown, and Valerie Rhodes

This section comprises a review of research on attitudes to mathematics extracted from a report by a group from King's College, London (Osborne et al. 1997:40-48). The section begins with a discussion of factors influencing pupils' attitudes to mathematics, including: gender; teaching, learning and the curriculum; and confidence. It then goes on to discuss: choice of mathematics post-16; changes in attitude effected by special initiatives; the influence of societal attitudes to mathematics; and the relationship between participation in science and mathematics and improved national economic performance.

A. Factors influencing pupils' attitudes to mathematics

Introduction

There is some confusion over what is meant by 'attitude'. A definition used by McLeod, in a major survey article of research on attitudes to mathematics in the US, will be adopted (McLeod, 1992). He splits *affect* into three components, *beliefs*, *attitudes* and *emotions*. *Beliefs* are cognitive and relatively stable, *emotions* are short-lived, strong and non-cognitive, and *attitudes* are in between. Attitudes are thus longer-term, 'cooler' and more cognitive versions of emotions, so that preference for one aspect of mathematics rather than another, or more general feelings of enjoyment in solving mathematical problems, are categorised as attitudes.

There have been several large-scale attitude surveys which inquire into students' attitudes in a general way, normally under the headings of:

- importance/usefulness of mathematics;
- liking/enjoyment of mathematics.

The results of such surveys will be summarised briefly before leading into the headings dealing with more specific factors relating to subject choice.

In all countries mathematics is almost universally regarded by pupils, parents and teachers as both important and useful, and the UK is no exception. In the TIMSS international comparison more than 90% of pupils from each country thought it important to do well in mathematics, echoing strong home support shown in previous international studies. The importance is seen in terms of entry to higher education and jobs (Beaton et al. 1996).

A smaller proportion, 75%, of both 11 and 15 year-olds in the APU surveys in the 1980s had agreed that mathematics was useful, usefulness again being perceived partly in relation to job qualifications. Nevertheless 30% to 40% of 15-year-olds were more sceptical about the usefulness for everyday life of some specific topics in the curriculum, for example, solving equations and trigonometry. Mathematics is also held in high esteem by parents who recognise that the subject is used as the primary screening device for entry to many professions (APU, 1988).

Although in international surveys England is usually placed well up on the 'liking' scale (top in 1991 with 80% approval) enjoyment of mathematics decreases with age. For example 75% of 11 year olds agreed that they enjoyed most things in mathematics and half said it was their favourite subject, but only 47% of 15 year-olds admitted to enjoying mathematics problems (APU, 1988; Lapointe, Mead, & Phillips, 1989). Nevertheless there is still evidence that some pupils harbour fear of the subject (Hendley, Parkinson, Stables, & Tanner, 1995).

There have been very few attempts to monitor changes of attitudes to mathematics over time. The data from international surveys do not relate to the same items, but nevertheless the fact that British 13 year-olds had the second most positive composite attitudes, behind only Canada, out of 20 countries in 1991, is consistent with a high position (3rd out of a different 20, behind only Nigeria and Israel) in 1981 (Lapointe, Mead, & Askew, 1992; Robitaille & Garden, 1988). In the TIMSS survey England was 6th out of 39 countries for overall composite attitude, but only just behind the leaders. In terms of self-concept in mathematics, England was first out of the 39 (Beaton et al. 1996). Hence there is little evidence of movement either way in attitude to mathematics.

1. Gender

The achievement of girls in mathematics has been increasing steadily over recent years and in 1995 equal numbers of girls and boys attained GCSE grades A - C. However the under-representation of girls at higher levels of mathematics remains a cause for concern. In 1995 girls made up only 35% of A-level mathematics candidates. There is also evidence that girls are under-represented at the highest levels of mathematics. In 1995, 5 boys to every 4 girls attained grades A and A* at GCSE.

In spite of similar levels of attainment, boys are still more likely to rate themselves as more confident and able mathematically (APU, 1988; Elwood & Comber, 1995; Woodrow, 1996). Other sex-stereotyped attitudes, such as the idea that 'mathematics is for boys', seem to have largely disappeared in UK schools.

The research into gender differences in attitude and attainment is extensive. Fortunately the messages that emerge from this research are also very consistent, with the strongest messages being the following:

- *The attitude and attainment of girls is improved by mathematical environments that are based upon problem-solving and that include group work in non competitive settings (Becker, 1995; Boaler, 1997; Morrow & Morrow, 1995; Thompson, 1995). Such approaches are termed 'girl-friendly' because of the positive impact they have upon girls, but they are also known to raise the attitude and achievement of boys.*

- *Girls often do not choose mathematics because they cannot see its relevance to their lives and the social world (Kaiser-Messmer, 1993; Reyes, 1984). 'Connected teaching' approaches (that are more experiential & link mathematics with other* *subjects and with realistic problems, as described in Becker (Becker, 1995)) counter this perception and increase participation amongst girls.*

- *Teachers' acceptance that girls have a lower level of confidence than boys, can strengthen girls' feelings of helplessness, thus reinforcing lower expectations of their abilities (Head, 1995). More than a quarter of girls surveyed in three schools said teachers' beliefs that boys were 'smarter' than girls resulted in differential treatment in the classroom (Gwizdala & Steinbeck, 1990). Jones and Smart describe three intervention strategies specifically designed to encourage girls to gain confidence in their mathematical abilities (Jones & Smart, 1995). It was hoped that confronting girls with their feelings of inadequacy and helping them understand that these were not unique to them but common to girls generally, would help to allay some of their fears.*

- *Lack of confidence and self-esteem is also known to reduce participation amongst girls (Armstrong, 1985). Various intervention programmes have been used in the past to increase the confidence of girls, but research shows that efforts to change the way mathematics is presented is preferable and more successful than changing the responses of girls to fixed models of mathematics. When mathematics is taught in a non-confrontational environment, with time and space for discussion and thought girls become more positive and confident (Boaler, 1997; Morrow & Morrow, 1995).*

- *An in-depth study of a setted mathematics department in the UK showed that many high ability girls were disadvantaged because of their placement in the top set (Boaler, 1997). This supported earlier results from several UK schools (Landau, 1994). Girls responded badly to the high pressure, competition and fast paced lessons that were features of a top set environment and these caused them to reject mathematics. As approximately 94% of mathematics classes are setted in the UK, this may be one of the reasons that girls are under represented at the highest levels of mathematics GCSE and many do not pursue mathematics beyond compulsory levels. Other studies have shown that placement in high sets or fast tracks has a negative effect upon the attitudes of students (Swiatek & Benbow, 1991), and research suggests that fast paced lessons may be a particular deterrent for high ability girls (Head, 1995).*

- *Some single-sex groupings have been shown to improve the attitudes of girls (Colley, Comber, & Hargreaves, 1994; Gwizdala & Steinbeck, 1990) particularly when these have been implemented as part of general initiatives to improve the experiences of girls (Morrow & Morrow, 1995; Smith, 1986).*

2. Teaching, Learning and the Curriculum

Various research projects have monitored the influence of teaching methods upon students' beliefs about and attitudes towards mathematics. In the UK in the mid-1990s the predominant method of teaching in the upper secondary years was reported by OFSTED to be 'listening to the teacher and then working through exercises' in setted classes (OFSTED, 1994), a situation which may have changed since the implementation nationally of the government's Key Stage 3 strategy in 2001 (Furlong, Venkatakrishnan, & Brown, 2001). The beliefs that students generally form in response to this exposition and practice method of teaching may be summarised as:

- *mathematics is mostly memorising;*
- *mathematics requires lots of practice in following rules;*
- *mathematics questions must be solved quickly (generally in less than 2 minutes);*
- *the mathematics learned in school has little or nothing to do with the real world.*

(Becker, 1995; Boaler, 1997; Cobb et al. 1991; English, O'Donoghue, & Bajpai, 1992; Schoenfeld, 1989).

Many of these beliefs are known to deter students from choosing mathematics for further study (Landau, 1994; Quilter & Harper, 1988).

The positive response of students to the more unusual, open mathematics teaching approaches in which students are given extended mathematics problems to solve and environments are less competitive and more discussion based, is well documented. Numerous research projects have shown that such environments both raise the attainment of students and improve their attitudes to mathematics dramatically (see for example, Athappilly, Smidchens, & Kofel, 1983; Boaler, 1997; Charles & Lester, 1984; Cobb et al. 1991; Pyne, Bates, & Turner, 1995; Sander, 1996; Winograd, 1991). OFSTED also report that classrooms that embody a range of teaching styles, rather than extensive textbook work, increase pupil interest, motivation and achievement (OFSTED, 1994).

Clute suggested that, while pupils with low levels of anxiety benefit from a more interactive discovery approach, pupils with a high level of mathematics anxiety and low confidence in their abilities may achieve more in a structured learning environment (Clute, 1984). However the research referred to in the previous paragraph suggests that the structured environments in turn tend to breed low confidence and dependency, and are the result of a 'didactic contract' (Brousseau, 1997) in which teachers and pupils connive in low levels of intellectual challenge.

There is also evidence that open, discussion-based mathematics lessons cause more students, especially girls, to choose mathematics at higher levels (Morrow & Morrow, 1995; Thompson, 1995).

The use of calculators (Hembree & Dessart, 1992) and computers in mathematics teaching (Watson, 1993) is also known to produce improvements in both motivation and attitudes towards mathematics amongst students.

Thus, although many students are reported to hold views in this country that are likely to inhibit their choice of mathematics, the research suggests that these attitudes can be improved with a move away from the prevalent model of exposition teaching, towards more varied, open, problem solving teaching methods (see Chapter 3, above).

3. Confidence

English pupils tend to have a high self-concept in regard to their success in mathematics compared to pupils from other countries, although they do not score particularly well on tests. Thus in the TIMSS survey (Beaton et al. 1996) England had the highest proportion of pupils who thought they were doing well or very well in mathematics (93%). This is much higher than the 47% in an international survey in 1988 (Lapointe et al. 1989), although there are some difficulties in comparing across different questionnaires. Thus there is some evidence that confidence has increased over time.

B. Choice of mathematics post-16

When choices are made about the further study of mathematics, students consistently cite usefulness and enjoyment as the major factors that influence their decisions (Armstrong, 1985; Bland, 1994; DFE, 1994; Landau, 1994; Sharp, Hutchinson, Davis, & Keys, 1996). Quilter & Harper in the UK found that the most important reasons given by students for not taking mathematics were its irrelevance to the 'real world' and teachers' inability to present the subject in a meaningful way (Quilter & Harper, 1988). Landau showed that such negative attitudes were particularly expressed by high attaining girls who had elected not to continue with mathematics, but were also cited by high-attaining boys (Landau, 1994). As noted in previous sections, there is also evidence that open, discussion-based mathematics lessons cause more students, especially girls, to choose mathematics at higher levels (Morrow & Morrow, 1995; Thompson, 1995). Tebbutt found that sixth-formers in the UK believed mathematics A-level GCE to be more traditional, narrow, less interesting and less useful for their careers than other subjects (Tebbutt, 1993). Taverner and Wright showed that most modular A-level syllabuses lead to traditional didactic teaching methods, with the exception of the SMP syllabus which has encouraged more discussion, IT use, and reading of articles about mathematics (Taverner & Wright, 1997). This syllabus is also the only one which does not appear to disadvantage girls, in that the relationship between GCSE and A-level grades is uniquely the same for both sexes.

While examination results indicate that there is little difference in the mathematical abilities of girls and boys, the fact that boys have been found to enjoy the subject more may be a major determinant in their choosing to study it at higher levels (Jones & Young, 1995). Other important factors include career aspirations and differential GCSE entry patterns. Murphy and Elwood show that girls' access to A level mathematics is frequently limited because disproportionate numbers of girls are entered for the intermediate GCSE tier (Murphy & Elwood, 1996). In 1994 this amounted to almost 59% of the female entry compared with 54% of the male entry. They suggest that this is caused by teachers' perceptions about lack of confidence amongst girls and their desire to provide girls with a 'safety net'. However, the over-representation of girls in the intermediate tier precludes them from gaining A* and A grades and many schools do not allow students who attain a B on the intermediate tier to take A-level. Many able girls are therefore automatically prevented from studying mathematics at a higher level.

Heads of mathematics departments have reported that good female role models have a positive effect on girls' uptake of mathematics at A level (Sharp et al. 1996). It has also been shown that female role models can reinforce boys' more positive attitudes. For instance, Evans et al. found that a team of all female researchers were successful in changing the attitudes of girls to mathematics and science, and that boys also became more positive (Evans, Whigham, & Wang, 1995). There is however a lack of same-sex role models for girls in mathematics departments, where the Heads of Department are predominantly men, as are almost 60% of mathematics teaching staff (Elwood & Comber, 1996). Colleges with a higher proportion of female mathematics teachers have a higher take-up of A level mathematics among girls (Sharp et al. 1996); international evidence corroborates the fact that a higher proportion of women teachers is positively correlated with a greater participation rate for girls (Robitaille & Garden, 1988).

A level mathematics is perceived to be more difficult than many other subjects (DFE, 1994; Landau, 1994; OFSTED, 1994; Sharp et al. 1996). Using data on the 1993 A level results, FitzGibbon and Vincent found that mathematics and the sciences were indeed more difficult than other A level subjects (FitzGibbon & Vincent, 1994), although Taverner and Wright show that modular syllabuses in general lead to higher results (Taverner & Wright, 1997). Students who study mathematics at A level but do not wish to study it further find the subject considerably harder than their experiences at GCSE had indicated (Bland, 1994; Sharp et al. 1996). There is evidence that pupils who are encouraged in their mathematical studies are more interested in the subject and that this is particularly true for girls (Thomas, 1986). It has been suggested that fear of the subject and a lack of belief in their own abilities, can account for a paucity of girls choosing either to study the subject at A level, or to pursue a career which requires a strong mathematical background (Armstrong, 1985; Cheng, Payne, & Witherspoon, 1995; Elwood & Comber, 1995; Landau, 1994).

Pupils who choose to study mathematics at a higher level are generally more able than pupils who choose not to study the subject. Evidence has shown that pupils who obtain good results at GCSE are more likely to study mathematics and science at A level (Cheng et al. 1995; FitzGibbon & Vincent, 1994). Pupils achieving three or more A level passes in mathematics and the sciences obtained 0.3 GCSE points more than pupils with mixed A levels, and 3 points more than pupils specialising in the arts and social sciences (DFE, 1994).

Boys are more likely to make stereotyped choices than girls with 63% of their A level choices being in stereotypically male subjects. Whitehead thus suggests that the imbalance at A-level is caused by over-representation of boys, rather than under-representation of girls (Whitehead, 1996).

Research has shown that differences in attitude are apparent not only between the sexes, but also between different ethnic and racial groups. Woodrow draws attention to the significantly greater likelihood of students of Asian and Chinese origin in the UK, and slightly greater likelihood of Afro-Caribbean students, specialising in mathematical subjects, in comparison to white students (Woodrow, 1996). This seems likely to be partly due to cultural factors, with Asian and Chinese families giving a higher status to mathematics.

In the US in contrast, female Latino students in particular have been shown to lack confidence in their mathematical abilities, whereas African Americans have a positive image of their performance, despite low test scores (Catsambis, 1994).

C. Changes in attitude effected by special initiatives

All of the intervention studies that have been reported in the literature show important gains in students' attitudes and achievement in mathematics. These studies may be divided into two main types, according to their aim. A number of intervention projects have been devised with the specific aim of improving girls' attitudes towards mathematics and increasing their achievement and take-up of advanced courses, (see, for example, Thompson, 1995; Evans et al. 1995; Morrow & Morrow, 1995; Smith, 1986). These projects have used a combination of single-sex grouping and more open, collaborative teaching approaches which relate mathematics to 'real world' problems. All of these approaches have been shown to improve attitude and encourage take-up of advanced levels of mathematics amongst girls.
The second type of project has not been concerned with gender in particular, but in improving the experiences of all students. However, such projects have also tended to change the way mathematics is taught, making it more experiential and less rule-bound, with more problem-

solving experiences and employing constructivist theories of learning (Charles & Lester, 1984; Cobb et al. 1991; Pyne et al. 1995). Such approaches have uniformly demonstrated improvements in attitude amongst students, both boys and girls, matched by improvements in attainment.

D. Influence of societal attitudes to mathematics

Very little research has been undertaken into public attitudes to mathematics in Britain, an issue explored in an ESRC Seminar Series coordinated by Professor Leone Burton in 1998-99, referred to in Chapter 3, above. The public image of mathematics and mathematicians is generally regarded as negative. A recent study supports this notion: it found that schoolchildren regarded mathematicians as distinctly strange (Berry & Picker, 2000). A recent study by Lim of public images of mathematics identified three widely claimed myths in the literature:

1. *Mathematics is a difficult subject*

2. *Mathematics is only for the clever ones*

3. *Mathematics as a male domain*
   (Lim, 2002)

Lim argues that these myths may contribute to students' images of mathematics and that the public view of mathematics might play an important role in shaping the image of mathematics of our future generation.

In the early 1980's Sewell obtained results which suggested that at least half the population, including many with high mathematical qualifications, had negative attitudes to mathematics, ranging from lack of confidence to anxiety and even fear, and that these attitudes inhibited them from applying mathematics (Sewell, 1981). Buxton achieved success in working with a small group of adults (mainly women) with 'mathphobia', manifesting itself by feelings of panic when faced with mathematical tasks, which rendered thought impossible (Buxton, 1981). Traumatic experiences at primary school were found by Relich to have a life-long effect on some Australian primary teachers, although again in some cases this was shown to be redeemable (Relich, 1996). In general, mathematical self-concept was found to be strongly influenced by primary school experiences and parental attitudes. Half the teachers with very high mathematical self-concepts remembered a teacher who had been a role model.

The only reference found to a large-scale survey of public attitudes to mathematics teaching was also carried out in Australia (Galbraith & Chant, 1990). Those with positive attitudes to mathematics themselves supported progressive changes in the curriculum, whereas those who had negative views of the subject gave substantial support for a 'back to basics' agenda. Neither gender supported the view that mathematics was mainly a male preserve, but females were more fatalistic about the innate nature of mathematical talent, and thus more alienated. Mathematics was uniformly regarded as important and mathematical prowess was generally accepted as a proxy for general intelligence.

In relation to parental attitudes, 13-year-old students reported internationally high levels of parental support, but rather lower levels of parents being knowledgeable enough to help with mathematics (about 50% of fathers, but less than 40% of mothers), and lower levels still of parents appearing to enjoy the subject (Robitaille & Garden, 1988). English pupils reported the second highest level of parental support on this group of items out of 20 countries.

E. Relationship between participation in science and mathematics and improved national economic performance

Correlations between mathematical performance and *per capita* GNP in different studies have generally been at best positive but very small, and at worst strongly negative. However a correlation between rate of increase of *per capita* GNP and mathematical performance seems likely, given the strong performance in these comparisons of the erstwhile fast-growing Pacific Rim countries, like Japan, Korea, Taiwan, Singapore. The correlation between attitudes to mathematics and per capita GNP are also consistently strongly negative (Beaton et al. 1996; Husen, 1967a, 1967b; Lapointe et al. 1992; Robitaille & Garden, 1988).
There are no clear results relating economic performance to attitude, participation or attainment in mathematics, despite the influential writings of authors such as Prais (Bierhoff & Prais, 1995; Prais & Wagner, 1985).

Nor is there any clear relation between the proportions of the population specialising in mathematics at age 18 and economic performance as measured by *per capita* GNP. However the effects are difficult to identify because of different traditions as to what proportion of students remain at school, whether mathematics is compulsory for all and if so to what level, what degrees of specilisation occur, and so on.

International studies (Beaton et al. 1996; Husen, 1967a, 1967b; Lapointe et al. 1992; Lapointe et al. 1989; Robitaille & Garden, 1988) also consistently show strong negative correlations between attainment and attitude (confidence and liking). High attaining countries are generally those where students show the most closed, rule-based views of mathematics, and think that mathematics is boring, difficult and elitist. High attaining countries at age 13, in particular Japan, have the lowest proportions of girls later specialising in mathematics. Teachers in such countries also tend to have negative attitudes and dislike teaching mathematics significantly more than in lower-attaining countries.

In one study (Beaton et al. 1996) Singapore is an exception, with positive attitudes accompanying high attainment, although the reason for this is unclear. In previous comparisons Hungary was unusual in demonstrating high attitude, attainment and participation; significantly Hungarian teachers believed the subject to be more open, creative and important than teachers in other countries, and enjoyed teaching it more.

We turn now to look at a particular aspect of attitude to mathematics, often associated with poor performance, that of mathematics anxiety.

Mathematics Anxiety
by Sheila Macrae

A great deal has been written about mathematics anxiety, including feelings of fear and an attitude of dislike of mathematics. In some studies, mathematics anxiety is seen to be related to low performance, while in others the relation with attainment is considered to be more complex and more directly concerned with fear of failure and perceived, rather than actual, lack of ability. Anxiety, stress, lack of confidence, mathphobia when faced with mathematical problems is apparent across most cultures, as evidenced by literature on the subject emanating from, for example, the UK, America, Europe and Asia.

A wide range of methods has been employed to try to understand mathematics anxiety and its effect on individual performance. Popular tools used by several researchers (see, among others, Ashcraft & Faust, 1994; Pajares & Urdan, 1996) have been the Mathematics Anxiety Rating Scale (MARS) and the Mathematics Anxiety Scale (MAS). Some controversy, however, surrounds the use of these scales. In work undertaken by Rounds and Hendel it was suggested that the MARS and MAS did not measure the same construct (Rounds & Hendel, 1980). Mathematics anxiety, they concluded, was a unique affective variable, quite different from other affective variables, and not amenable (in their study) to these research tools. Another study by White set up to investigate and lessen mathematics anxiety, found that using the MARS had no effect on its reduction (White, 1997).

Mathematics anxiety can be partly understood by looking at people's understanding of the subject. In a study by Wiliam et al. many undergraduate students reported that they had chosen to study mathematics at university because of its precision, its neatness, its exactness (Wiliam, Brown, & Macrae, 2000-03). The 'black and whiteness' of mathematics attracted many students because they understood where they were with it: they knew when they were right and when they were wrong. While this can draw some people, it can also repel others and create cycles of anxiety among those who experience more wrong than right answers. A downward spiral can then result as people's confidence is shaken and their expectations of success diminish. Not surprisingly then, many people see mathematics as a subject they can, or (perhaps more frequently) cannot, do and many shy away from it.

Mathematics anxiety in the primary school

The seeds of much mathematics anxiety are sown in primary school and can be exacerbated by both teachers and parents. Traumatic experiences at primary school were found by Relich to have a lifelong effect on some Australian primary teachers (Relich, 1996). Among those with high mathematical self-concepts, half could recall a teacher who had been a good role model. Green also highlighted the role of the teacher in reducing mathematics anxiety and the importance of ensuring that comments on students' work are both constructive and positive (Green & Ollerton, 1999).

Burnett and Wichman found that teachers' and parents' own anxiety about mathematics can be passed onto students. They recommended that anxiety can be reduced by including literature in the teaching of mathematics as well as real-life problem solving (Burnett & Wichman, 1997). A study by Stix also found that using literature in the form of keeping pictorial journals helped to reduce mathematics anxiety and boost students' confidence (Stix, 1996). Stix contended that there is a strong relationship between mathematical problem-solving and visualisation. Pugalee also found the use of writing, in both the teaching and learning of mathematics, to be effective in student learning and anxiety reduction (Pugalee, 1998). Burns reported that story problems involving, for example, animals, had a beneficial effect on young students' numerical reasoning and that their problem-solving abilities improved through the use of stories (Burns, 1998).

The use of games to reduce mathematics anxiety is examined by Hatch (Hatch, 1998). She describes how students, using games, can practise mental mathematics in ways that can reduce their anxiety and can, therefore, be more effective than mental tests, which many students find stressful. Caldwell also demonstrates the benefits of board games to help students learn mathematics and build their confidence (Caldwell, 1998). She advocates their use with parents and children. As can be seen from the above examples, the ways in which teachers approach the teaching of mathematics can do much to alleviate or increase mathematics anxiety; as can teachers and parents' own attitudes and feelings about it. As we have seen, Osborne et al. in their review of attitudes to mathematics, extracted above, found that, while parents regard mathematics as very important, they rarely perceived themselves as being very proficient (Osborne et al. 1997).

In a large scale study by Brown et al. primary teachers frequently described those students who easily grasped mathematical concepts and found right answers as quickly as possible to be the best at the subject (Brown et al. 2001). It was as if mathematics should involve little or no struggle. Many of those students who had to work harder to understand mathematical ideas soon came to see themselves as being not very good at it and these views were often endorsed by their teachers' attitudes. Yet these same students who struggled over, for example, written work, did not necessarily regard themselves as being poor at, for example, English or History.

Mathematics anxiety in the secondary school

In a study by Biller, it was found that students who had high levels of mathematics anxiety also had negative attitudes towards their potential success in the subject. In order to overcome this, the author emphasises the importance of students working in accordance with their preferred learning styles (Biller, 1996). Teachers, therefore, need to set up the mathematics classroom in such a way as to provide opportunities that take account of these different learning styles. As well as being aware of different learning styles, teachers also need to be concerned about the sorts of learning environments they create. Clute suggested that, while students with low levels of anxiety benefit from a more interactive discovery approach, those with a high level of mathematics anxiety and low confidence in their abilities may achieve more in a structured learning environment (Clute, 1984). However these structured environments can tend to breed low confidence and dependency, and are seen by Brousseau to be the result of a 'didactic contract' in which teachers and students connive in low levels of intellectual challenge (Brousseau, 1997). A study conducted by Mitchell and Gilson examined classroom environments and their effects on students' anxiety levels about mathematics. It was found that where there was high situational interest in the subject this had a positive effect on individual interest, with reduced anxiety levels. The authors suggest that teachers may need to pay as much attention to the motivational aspects of mathematics as they do to the learning aspects (Mitchell & Gilson, 1997). Stipek et al. review the value (and convergence) of practices suggested by motivational research and promoted by mathematics education reformers (Stipek et al. 1998). According to Middleton, the literature on motivation treats it as given and unchanging and there is very little on how students might be motivated (Middleton & Spanias, 1999). This accords with McLeod's view in his reconceptualisation of research on affect in mathematics education (McLeod, 1992).

According to Reyes, there are connections between mathematics anxiety and general anxiety, along with a consistent negative relationship between mathematics anxiety and achievement. Self-concept, Reyes argues, has a consistent positive relationship with general academic achievement and with achievement in mathematics (Reyes, 1984). Mathematics anxiety can be reduced through systematic desensitisation, according to McLeod (McLeod, 1994).

In a study set up to determine which factors were most important in reducing student anxiety about statistics, Wilson reported that statistically significant predictors on anxiety included students' mathematical preparation, perceptions of their own ability, how confident they were in using a calculator, and gender, with males, generally, being more confident than females (Wilson, 1996). Work undertaken by Mitchell into students' performance in statistics also indicated some gender differences in performance (Mitchell, 1993). Conners et al. emphasise the need, in learning statistics, to make learning memorable in a positive way (Conners, McCown, & Roskos-Ewoldsen, 1998).

Mathematics anxiety has been found to be more closely associated with females studying mathematics than males. In the work of Osborne et al. teachers expected females to be less confident than males and this attitude often resulted in differential treatment in the classroom (Osborne et al. 1997). Hodgson found that more able females performed better when the work they were asked to complete was described as 'problem solving' rather than 'mathematics' (Hodgson, 2003). In Head's study, he reported that there was no innate evidence for fewer females choosing to specialise in mathematics, and this is argued to be related to affective rather than cognitive factors, particularly a lack of suitable role models (Head, 1981). Head also suggested that much mathematics anxiety stems from feelings of inadequacy in the learning and memorisation of mathematics, and to boredom associated with so much repetition.

Shashaani also found gender differences in her research into attitudes to mathematics and computers. She found that males had more positive attitudes than females to both subjects (Shashaani, 1995). The use of computers to reduce mathematics anxiety is examined by Wiegel and Bell (Wiegel & Bell, 1996). They describe a study in which it was shown that pre-service teachers who used computers as part of their mathematics course developed better attendance, less anxiety and more positive attitudes to the subject. Another study which pointed out the benefits of computers in helping to reduce mathematics anxiety was reported by Zimmer and Fuller (Zimmer & Fuller, 1996). They found that while computer use reduced the anxiety and improved the attitudes of some students, it was important that the computer use was positive.

Mathematics anxiety in adults

As stated above, much mathematics anxiety would appear to have its origins in early schooling but its effects can still be acutely felt in adulthood. The shame that many adults (including teachers) feel at their perceived lack of ability and about which Bibby (Bibby, 2002) has written, can exacerbate their mathematics anxiety and prevent them from seeking help. She argues that viewing the issue simply as mathematics anxiety is unhelpful; we should not get rid of emotion, rather we should transform it into something positive. Hodgen has argued in a similar vein and found that there appeared to be scope for generating positive emotions for mathematics with primary teachers (Hodgen, 2003).

In a study carried out by Sewell for the Cockcroft Inquiry, it was shown that at least 50% of the adult population, including many with high mathematical qualifications, had negative feelings about the subject (Sewell, 1981). These ranged from a lack of confidence to anxiety and even fear, which discouraged them from using mathematics. These findings were particularly interesting because there was little evidence that employers were dissatisfied with the mathematical skills of their workforce. However, the results of Sewell's study were considered so important that the Cockcroft Committee (DES/WO, 1982) framed their recommendations largely to address adults' negative attitudes to mathematics.

Another study by Quilter and Harper also reported mathematics anxiety among 147 adults with university degrees in subjects other than mathematics. This anxiety arose largely from feelings that mathematics were irrelevant to real-world experiences and of little interest to them (Quilter & Harper, 1988). Osborne et al. also highlighted the fact that many adults, including those who are highly qualified, display a lack of confidence in their mathematical ability, sometimes verging on mathphobia (Osborne et al. 1997), and impeding their capacity for rational thought (Buxton, 1981). This inability to think calmly and confidently when faced with mathematical tasks was also investigated by Ashcraft and Kirk who found that anxiety interfered with people's working memory, rendering it difficult to work in a logical, step-by-step way (Ashcraft & Kirk, 2001). Jones et al. discussed the importance of mathematical skills in the workplace and the relationship between mathematics anxiety and course completion rates. It was found that those students who were the most anxious about their ability to cope with course mathematics were more likely to drop out, regardless of their actual ability (Jones, 1996). Work undertaken by Tobias showed that a large number of people regard mathematics negatively and with anxiety because the subject is shrouded in myth, misunderstanding and intimidation (Tobias, 1978). She urges people to see that their fear of mathematics is the result and not the cause of their negative feelings.

In a meta-analysis of randomized controlled trials, a 'modified numeracy' approach involving relaxation training and other psychological techniques, plus self-directed mastery learning, was found to have positive effects on arithmetic and regular attendance was associated with greater progress. Few other factors thought to influence progress are supported by quantitative, empirical evidence; this is especially true of ICT, workplace provision, numeracy, and writing (Torgerson, Brooks, Porthouse, & Burton, 2003).

We turn now to look at dyscalculia against the background of studies of the functioning of the brain in mathematical activity.

Dyscalculia and the functioning of the brain in mathematical activity by Dhamma Colwell

The functioning of the brain in mathematical activity

Neurologists and psychologists are making progress in mapping areas of the brain which are associated with various mathematical activities. Studies have been carried out using functional magnetic resonance imaging (fMRI), cathode ray tube (CRT) scanning, positron emission tomography (PET), and by giving mathematical tasks to patients with identifiable damage to the brain through stroke or injury and to patients with Alzheimer's or other forms of dementia.

Many of these investigations are case studies of individuals with idiosyncratic problems. The authors report the effects on function and behaviour of damage to particular parts of the brain and therefore reveal the necessity of those parts to normal cognitive processing. This does not, however, imply that particular functions are carried out in particular parts of the brain, only that those parts are involved in the functions. Theories of how the brain functions now tend towards cerebral circuits, sometimes on one side of the brain, and sometimes using both sides (Burbaud, Camus, Caille, Biolac, & Allard, 1999; Gruber, Indefrey, Steinmetz, & Kleinschmidt, 2001).

One theory proposes the existence of a 'number module' in the brain, a series of 'hard-wired' circuits which is thought to be able to subitise from birth: to recognise the 'numerosity' or quantity of collections of up to four or five objects without counting them (Butterworth, 1999).

From this develops the individual's knowledge of mathematics through the use of cultural resources: counting body parts to represent other objects (counting on the fingers, in British society), and using specialised counting words, symbols and external representations like tallies and calculators. Individuals have been identified who are unable to subitise and have been unable to learn to calculate.

One region of the brain is identified in many studies as being particularly involved in understanding numbers: the parietal lobes (Alonso & Fuentes, 2001). These are the areas of the brain in each hemisphere which are associated with the perception and interpretation of muscular movements as well as touch, temperature and taste.

These studies come from a different professional culture from that of education: neurologists and clinical psychologists are often dealing with loss or absence of function. Some studies involve attempts to 'train' the patients to perform certain mathematical tasks, but in general the focus is on diagnosis and the development of models of the brain's functions, rather than treatment, or improvement in functionality. These ways of thinking may sound alien to educationalists. However, the knowledge of cognition being developed should have important implications for the improvement of teaching and learning, both for students with learning difficulties and disabilities and more generally.

The mathematics that is used in these studies tends to be de-contextualised number recognition and memory, comparison of number size, and the addition, subtraction, multiplication and division of whole numbers. Problem-solving, measurement, spatial relationships, ratio or algebra appear to be rarely investigated. Assessment of the mathematics used in everyday life is not reported.

Many studies show that what might appear to a mathematics or numeracy teacher as closely related ideas, produce activity in separate parts of the brain. For example, the recognition of Arabic numerals is dissociable from the recognition of alphabetically written numbers, i.e., some patients are able to recognise numbers in one format and not the other. This suggests that the storage of numerals and number words are on separate neural networks (Cipolotti, 1995; Macoir, Audet, & Breton, 1999).

Patients have presented difficulties with reading and writing number words while their literacy with other kinds of words was unimpaired, suggesting that number words are not treated like ordinary words by the brain, but have their own neural circuits (Basso & Beschin, 2000). Some patients who had difficulty reading or writing number words were still able to calculate (Markowitsch et al. 1999). The time taken to read numbers has been measured and found to depend on their magnitude, their syllable length and their proximity to previously read numbers, so that both semantic and phonological processes seem to be at work (Brysbaert, 1995). The ability to use ordinal numbers appears to be separate from the ability to use cardinal numbers (Ta'ir, Brezner, & Ariel, 1997). Response times are different for calculating with numbers presented as Arabic digits and as words, suggesting that memory processes for arithmetic are not notation-independent (Campbell, 1994).

There is also evidence of separate neural networks for the storage and retrieval of arithmetic facts, on the one hand, and the manipulation of numerical quantities on the other (Dehaene & Cohen, 1997). Arithmetic facts all appear to have separate storage areas (Hittmairdelazer, Sailer, & Benke, 1995). Conceptual knowledge of arithmetic seems to be separately processed (Hittmairdelazer et al. 1995).

Even simple addition tasks involve several processes in the brain: number recognition; comparison of number size; addition fact retrieval; and pronunciation (even if the calculation is done silently) (Butterworth et al. 2001; Campbell, 1994). Short-term memory may also be involved (Noel & Fias, 1998). Calculation with small numbers appears to use different parts of the brain from calculation with large numbers and estimation, possibly because the small-scale number facts may be stored as verbal knowledge (Stanescu-Cosson et al. 2000). Visual and verbal strategies for performing mental calculations activate different areas of the brain (Burbaud et al. 1999).

It has been found that the time taken to identify the larger of two numbers increases in normal individuals as the numbers get closer together, suggesting not that calculation or counting are involved, but rather the recognition of the quantities concerned (Butterworth, 1999). But individuals have been found for whom the reverse is true: they take longer to identify the larger number, the further apart the numbers are. This is attributed to them being unable to connect the number symbols with quantities and having to count to identify the larger number.

When a different task is given and the subjects are asked to choose the number written in larger type but this represents a smaller quantity, this property interferes with the task so that it takes longer to choose the correct number. This suggests that normal individuals automatically interpret the symbol as the value of the number, even when they have been asked to identify something different.

Dyscalculia

Dyscalculia: Incidence

Dyscalculia, sometimes referred to as 'acalculia' or 'anarithmetica', is not a well-defined syndrome. It can be demonstrated that people with brain damage or disease have exhibited a wide range of different problems with number recognition and calculation. But developmental dyscalculia, i.e., dyscalculia which has not manifested after injury or disease of the brain, is much more difficult to define. Some researchers have found the prevalence of developmental dyscalculia to be between 3% and 6% of the population, which is at a similar level to that of developmental dyslexia and attention deficit hyperactivity disorder (ADHD) (Butterworth, 1999; Gross-Tsur, Manor, & Shalev, 1996; Neumarker, 2000; Shalev, Auerbach, Manor, & Gross-Tsur, 2000). The different percentages reflect the different ages at which people are tested as well as diverse definitions and different instruments used for measurement.

Dyscalculia: Assessment

Studies of dyscalculia have used a range of different tests:

- the ICD-10 Specific Disorder of Arithmetic Skills (Neumarker, 2000);
- the DSM-IV Mathematics Disorder tests, (Neumarker, 2000);
- the Wide Range Achievement Test – Revised Sub-tests (Barwick & Siegel, 1996; Levin et al. 1996);
- the NUCALC Battery (Bzufka, Hein, & Neumarker, 2000);
- the Graded Difficulty Arithmetic Test (Crutch & Warrington, 2001);
- the Wechsler Digit span test (del Piccolo, Borgatti, & Gruppo, 1996);
- the Wechsler Adult Intelligence Scale – revised (Hirono et al. 1998);
- the Wechsler Intelligence Scale for Children, third Edition, with the Block Design and Judgement of Line Orientation Sub-tests (Levin et al. 1996);

- the Peabody Individual Achievement Test (Levin et al. 1996);
- the Sao Paulo MAT Test (dos Santos, Nakamura, & Rosa, 1996);
- the EC 301-R Battery (Carlomagno et al. 1999).

The Dyslexia Institute recommend two tests of number skills that can be administered by teachers: the Cilham and Hesse Basic Number Screening Test; and the numeracy section of the WRAT-3. Other tests are only licensed for use by chartered psychologists.

Crutch and Warrington have recently developed and standardized three new tests of mathematical knowledge, focusing on quantity facts, number operations and multiplication facts (Crutch & Warrington, 2001). Another new test is being developed and standardised by NFER-Nelson (Butterworth, Zorzi, Girelli, & Jonckheere, 2001), which aims to be able to test the 'numerical potentiality' of people of all age groups, 'independently of their abilities and opportunities in other competencies' (like language and literacy). The time taken to perform the various tasks will be considered alongside accuracy.

Different tests stem from different viewpoints, so that comparison of data from different studies is difficult (Neumarker, 2000). Some studies define participants as having dyscalculia if their mathematical performance is significantly below the rest of the population, but their performance is normal in other subject areas, or on verbal IQ tests. But this definition breaks down where participants also have dyslexia or other specific functional problems. It is thought that 40% of dyslexics have significant problems with mathematics (Butterworth et al. 2001). It is unclear whether this is caused by the dyslexia making the linguistic aspects of mathematics difficult, or whether it is a separate condition. A correlation has been found between difficulties with reading speed and arithmetic fact retrieval, particularly with multiplication tasks (Rasanen & Ahonen, 1995).

Dyscalculia: Symptoms

Symptoms of dyscalculia include difficulties with ideas of number size, which make it problematic to estimate and compare numbers, or navigate up and down a scale, or count in twos and threes (Butterworth et al. 2001). Dyscalculics may have problems with translating between number words and numerals and lack an understanding of the place value system. They may find it extremely difficult to memorise number facts, but also be unable to deduce one fact from another because of their lack of understanding of the number system. Measurement, especially proportions, can be difficult, as can spatial relationships. They may have great difficulty in understanding word problems and deciding which operation is required. A lack of recognition of dyscalculic symptoms coupled with failure in learning can lead to mathematics anxiety and avoidance of mathematics.

Dyscalculia appears to be an inherited condition and as many females as males are affected, unlike dyslexia, which is more prevalent in males (Shalev et al. 2000). Developmental dyscalculia can occur alone or in association with diverse neurological conditions: developmental language disorder, epilepsy, treated phenylketonuria, Fragile X syndrome, Turner's syndrome and ADHD. Dyscalculia can be a symptom associated with hemiplegic migraine (Marchioni et al. 1995). Dyscalculia can also occur as a result of pre-natal alcohol exposure (Kopera Frye, Dehaene, & Streissguth, 1996).

A particular condition, Gerstmann's Syndrome, associates four symptoms: finger agnosia, agraphia, right-left disorientation and dyscalculia. Gerstmann attributed their association to dysfunction of the body schema. However, some evidence suggests that the impairment is in the inability to manipulate mental images, rather than in the body schema (Mayer et al. 1999) and that this is crucial to progressing beyond counting on the fingers to mental calculation (Butterworth, 1999).

Aphasic patients very often also present dyscalculia. Not only are those abilities affected which rely on linguistic ability, counting, reading numerals aloud, or writing them to dictation, but they also tend to have difficulty with calculation. Multiplication appears to be more affected than the other basic operations of arithmetic (Delazer & Bartha, 2001).

About half of a group of children with dyscalculia exhibited signs of left hemisphere dysfunction (Shalev, Manor, Amir, Wertmanelad, & Gross-Tsur, 1995): their performance on basic calculation and visual-spatial tasks was severely affected. The other half of the group showed other signs of right hemisphere dysfunction, but their mathematical performance was not so severely affected as the left hemisphere half of the group.

Of young children with dyscalculia, about half continue to exhibit severe problems by the age of 13-14. The other half do improve up to this age, but continue to function at a below average level (Shalev, Manor, Auerbach, & Gross-Tsur, 1998). Educational interventions may be a factor in improvement.

Acquired dyscalculia has been found to be an early symptom of dementia, some authors suggesting that it should be used as an indicator for that disease (Carlomagno et al. 1999; Girelli & Delazer, 2001; Hein, Bzufka, & Neumarker, 2000; Hirono et al. 1998). It correlates with the severity of the dementia (Kalbe & Kessler, 2002). But some patients can lose other functions while their number knowledge is unaffected (Cappelletti, Butterworth, & Kopelman, 2001). Post-stroke, dyscalculia is associated with the loss of auditory comprehension (Caporali, Burgio, & Basso, 2000). Both may be recovered.

Implications for adult numeracy teaching and learning

Findings about the functionality of the brain while performing mathematical tasks suggest the learning and using of mathematics is extremely complex in terms of neural circuits: many different processes are involved, even in what might appear to be very simple mathematical tasks. There is potential for minor abnormality or loss of function to have far-reaching consequences for the individual's capacity to perform mathematical tasks.

If the frequency of developmental dyscalculia in the general population is as high as some researchers have found, then there could be a significant proportion of learners in adult basic education with genetic impairments that affect their abilities to learn mathematics. In addition, some learners with brain injury or disease (possibly undiagnosed) may wish to improve their mathematics and may experience difficulties with particular tasks.

The research suggests that care should be exercised that assumptions are not made about adult learners' abilities in one area of mathematics from the assessment of other areas. For example, the fact that a learner cannot calculate or solve a problem expressed in number words does not imply that they do not hold concepts of numbers or that they cannot calculate at all. Tests and examinations which focus on prescriptive tasks, which are timed and do not allow the use of calculators, and which are marked mechanically, may disadvantage people with dyscalculia.

Further research is needed in both defining and diagnosing dyscalculia. Diagnosis of adults will be particularly difficult because many adults have bad relationships with mathematics, ranging from mild anxiety to total avoidance. Some adults have not had access to much schooling for various reasons. Mathematics tests may reveal what adults have and have not been able to learn, but not necessarily whether they have specific learning difficulties. Diagnosis of the patterns of errors is needed.

It has been found that in the teaching situation, some learners will respond more successfully to visual representations by using visual strategies and some to verbal representations using verbal strategies (Burbaud et al. 1999). Some learners may be unable to learn some aspects of mathematics at all, e.g., the multiplication tables, but may be able to master other strategies for calculation, like using successive doubling for doing multiplication (Butterworth et al. 2001). Using a calculator may not present any problems if the learner understands the nature of the operations required. More research is needed to establish effective methods for dyscalculics to learn the different topics in mathematics.

The British Dyslexia Association (BDA) sees a structured, sequential, multisensory teaching approach as necessary for the successful learning of mathematics by dyslexic children. Their guidelines do not mention making the connections explicit between different areas of mathematics (BDA, 2001) although this has been found to be an important factor in the effective teaching of numeracy to children (Askew & Brown, 1997). Whether the BDA's recommended teaching approach is appropriate for adults with dyscalculic problems has not been established.

Methodological issues

"I have no data. It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts." Sherlock Holmes, in **A Scandal in Bohemia**, by Conan Doyle.

As will be clear from the review so far, it is not – quite - the case that we have no data about adult numeracy, rather that we have too little, and that what we have is distributed in a fairly arbitrary fashion across issues and topics. In the absence of data on adults we may draw on data on children's mathematics education but we need to remember that the differences and similarities between adults' and children's learning and teaching are as yet imperfectly understood. In the UK, at least, cultures of teaching adults have developed in rather different contexts from cultures of school teaching, and within adult education and training there are many diverse settings, each with their own professional (or amateur) culture and values. This review attempts to synthesize the main points for further research and development and to draw out some implications for practice, mindful of the fact that adult numeracy practice and the settings for practice vary greatly, as do adult learners themselves.

That said, this chapter draws together key features from the foregoing chapters, beginning with an outline of methodological issues in research on adult numeracy, then summarises the findings of this review in answer to the question: what do we know and what do we need to know about adult numeracy – and what should we do about it?

Methodological issues in research on adult numeracy

Most research on adult numeracy is interpretive and uses qualitative methods. This may reflect the fact that up to now much of the relatively small amount of research on adult numeracy worldwide has been unfunded and consequently small in scale, often undertaken by researchers who are also practitioners, investigating their own practice. It also reflects a general bias in educational research towards qualitative methodologies.

It would be interesting to compare the situation with respect to adult numeracy research methodologies with that in mathematics education research generally, where different approaches to research have been analysed by Wiliam. He views knowledge-building in mathematics education as

> *a dual process of establishing warrants for particular beliefs, and eliminating plausible rival hypotheses, where 'plausibility' is established either by explicit reference to a theoretical frame, or implicitly within a discourse.* (Wiliam, 1999:1)

He develops a classification based on whether the primary source of evidence is reason, observation, representation, dialectic or ethical values, and argues that the consequences of educational research must be subjected to the ethical judgements of the community.

A major challenge for adult numeracy researchers is that explicit reference to a theoretical frame is constrained by the under-theorised state of the field and that professional and academic discourses are only now beginning to emerge. That said, as this review testifies, a healthy range of research methodologies in adult numeracy/mathematics education is emerging.

Despite the preponderance of qualitative studies, quantitative studies are not entirely lacking, as the large scale surveys, reviewed in Chapter 1, attest. These have been extremely influential in putting adult numeracy 'on the map' for policy-makers, for example, the UK's poor showing in the IALS led, via the Moser Report, to the establishment of ***Skills for Life***. Quantitative studies on a smaller scale by, for example, Steinke in the USA and Pickard and Alexander in the UK, also exist. Steinke uses statistical analysis to correlate data on adults' understanding of the 'part-whole' concept with their success in basic mathematics classes in the USA (Steinke, 2001) and Pickard and Alexander investigate the effects of digital measuring equipment on the concept of number of students in UK higher education (many of them adult returners), using quantitative techniques (Pickard & Alexander, 2001).

Research designs and tools for investigation vary widely, including, for example, developmental research (van Groenestijn, 1997), Piagetian clinical exploration (Llorente, 1997), biographical approaches (Coben & Thumpston, 1994; Johnston, 1998) and action research (Colleran et al. 2002). Techniques used to gather data include questionnaires, observations, interviews, photographs, and audio and video recordings. Theoretical frameworks are similarly diverse, including, for example: critical constructivism (Yasukawa et al. 1995); post-structuralism, linguistics and semiotics (Evans, 2000b); Bourdieuian theory (Zevenbergen, 1998); and political theory (Coben, 1998a). Tools used for analysis of data include statistical analysis (Steinke, 2001) and Discourse Analysis (Morgan, 2000; Tomlin, 2001).

Mixed methods

Some studies encompass both quantitative and qualitative techniques and indeed the use of multiple methods (whether quantitative or qualitative, or a mixture of the two) allows for triangulation of data. For example, Lee, Chapman and Roe, in their study of 'Pedagogical Relationships Between Adult Literacy and Numeracy' used four methods of research and analysis:

i) historical review of the development of the concept of 'numeracy' to inform debates within contemporary adult education;

ii) semi-structured interviews and discussions with teacher-practitioners and curriculum theorists, planners and developers;

iii) the collection and critical review of selected curriculum documents and resource materials;

iv) detailed case study analysis of two classrooms in Western Australia and New South Wales.

(Lee et al. 1996)

Another example in the adult field is given by Evans, who discusses the use of multiple methodologies in his study of cognition and affect in the context of numerate activity among adult students. He outlines the relative strengths of three research strategies for critically considering claims about gender differences in mathematical performance: quantitative; qualitative cross-sectional; and qualitative case study (Evans, 1995). He concludes that

> *Rather than polarizing the discussion by asking which method is "best", we can note the relative strengths of each, and attempt to combine the different approaches in a way that is effective for the problem at hand. The **quantitative** approach is useful when we wish to make comparisons across subjects, or groups of subjects, and we aim for some degree of generality. ... The **qualitative case study** approach is useful when we wish to explore the richness, coherence (i.e., not being separated into variables) and process of development of a limited number of cases. ... The **qualitative cross-subject** approach provides an intermediate approach, for cases where it may be challenging to produce comparability across subjects ... but where some generality in findings is sought. (Evans, 1995:8; emphasis in the original)*

Some further examples of studies of adult numeracy utilising different research designs are outlined below.

Experimental/intervention studies including randomised controlled trials
Experimental or intervention studies generally are rare in adult numeracy. One such was a large scale experimental project in the UK with trainees on Youth Training Schemes, which compared different methods of teaching numeracy and problem solving (Wolf et al. 1990).

A recent systematic review and meta-analysis of randomised controlled trials (RCTs) evaluating interventions in adult literacy and numeracy undertaken for the NRDC (Project B1.1) found only one such trial in adult numeracy. This investigated the use of computer assisted instruction (CAI) in literacy and numeracy instruction with male inmates of a maximum security prison in the USA (Batchelder & Rachal, 2000).

As the authors of a recent review of assessment instruments for the NRDC found (Project B1.2), intervention studies in adult numeracy teaching are currently hampered by the lack of linguistically- and culturally-sensitive and adult-friendly assessment instruments to measure the effect of interventions; they urge the creation of such an instrument in order to rectify this situation.

Ethnographic approaches
Ethnographic approaches in mathematics education generally have been reviewed by Eisenhart (Eisenhart, 1988) but of the explicitly ethnographic studies reviewed here (Askew, 2001a; English et al. 1992; Hoyles et al. 2001; Masingila et al. 1996; Scribner, 1984), only two (Hoyles et al. 2001; Masingila et al. 1996) involve adults. However, while full-blown ethnography may be rare in the adult numeracy/mathematics literature, the use of ethnographic tools is more common. For example, studies involving ethnographic observation include Noss, Hoyles and Pozzi's study of adults 'mathematising' in three work contexts: investment banking; aviation (pilots) and pediatric nursing. They used a combination of methods, including observation in the workplace (Noss, Hoyles, & Pozzi, 2000). Hind's report of an investigation of the numeracy aspects of the implementation of the Council Tax in Southend included observations of Council meetings (Hind, 1993). Studies involving participant observation are also fairly well established amongst researchers investigating their own practice, or their students' learning, e.g., (Civil, 2000; Duffin & Simpson, 1995).

A problem for ethnographic researchers hoping to observe numeracy practices in situ is discussed by Tomlin (Tomlin, et al. 2002): this is the invisibility of many such practices in adults' lives (see also Coben, 2000a; Kanes, 2002; Noss, 1997). As she points out,

> *Numeracy includes literacy, visual, gestural, and oral communicative practices, and additionally mental imaging and calculation. People 'solve numerical problems' without necessarily leaving any clearly identifiable trace that they have done so.* (Tomlin, et al. 2002)

She illustrates her point with reference to adults' decisions, in which numeracy is involved, concerning jobs and household budgeting. She suspects that the mathematics in these decisions is hidden, for most people, in past experiences, constraints and choices, so that "for most people they probably do not feel like 'numerical problems'". Even where people are consciously using numbers and problem-solving, the numeracy involved may still be invisible. This is because:

> *Firstly much numeracy goes on in the head, leaving no visible evidence. Secondly, people may count as maths only what they find difficult – if they can do it, it's common sense rather than maths (Coben, 1997a) so they don't tell us about it.* (Tomlin, et al. 2002:481-2)

Tomlin does not offer a solution to this problem; instead, she hopes her paper will contribute to a productive discussion (Tomlin, et al. 2002:487).

Practitioner research

Many studies reported in the adult numeracy/mathematics education literature have been undertaken by practitioner-researchers or teacher-researchers. The need to build capacity and expertise in this area is recognised and a programme aiming to develop the expertise of teacher-researchers working in adult numeracy (as well as adult literacy and language) education is currently underway in the NRDC. Earlier, in the USA, a project on the implementation of the NCTM-based Massachusetts Adult Basic Education Mathematics Standards in a range of communities and programme contexts used teacher-researchers (Leonelli, Merson, & Schmitt, 1994). These teacher-researchers used a wide range of interpretive strategies for data collection, including observations, field notes, interviews, audiotape recording and think-aloud protocols. The accounts reveal "the profound diversity of adult students' needs and interests, the salience of context to teaching method and outcome, and the critical need for educators to interrogate and find alternatives to conventional modes of curriculum and testing" (from Foreword). The teacher-researchers also said how much they learned from the process.

An example of a study described as a teaching experiment and having a strong developmental aspect is given by Marr (Marr, 2000). Her study, with an Australian adult mathematics class, addressed a problem identified by Pimm: the fact that those who most need to speak the language of mathematics usually have the least opportunity to speak it (Pimm, 1987:55). Audio and videotapes were used to record students' talk as they participated in a range of mathematical activities, including group and pair tasks designed to encourage meaning-making talk and to enhance their use of mathematical language. The study demonstrates that aspects of language acquisition will develop when supplemented with conceptual tasks and activities that focus on the written and oral use of mathematical understandings. Marr accordingly recommends that curriculum planning in adult numeracy/mathematics classes should pay attention to strategies to increase students' communicative competence.

As FitzSimons et al. point out, the fact that researchers use a variety of perspectives and frameworks to examine issues in the field is hardly surprising given the applied nature of the research domain and its interdependence on neighbouring disciplines (FitzSimons et al. 2003:118).

The key issues, as with all education research, are whether the research design is ethical, practicable and fit for purpose (i.e., is it appropriate for the question or hypothesis that is under investigation? is the evidence produced pertinent?) and whether the findings are valid and reliable, and analysed in a rigorous and appropriate way.

Practicability is to some extent dependent on the availability of funding for implementation of research and development and it is to be welcomed that funded studies of adult numeracy are now underway in NRDC, with further studies planned. Heterogeneity in research design in studies of adult numeracy is healthy and should be encouraged, given the diversity and under-researched nature of the field – or moorland – of adult numeracy, and the myriad issues worthy of investigation.

Gal's remark, in a work published in 1994, still holds true: "It is surprising that no attempts have been made so far to synthesise, interpret, replicate, or extend research of relevance to adult numeracy education that has been published by workers in other disciplines" (Gal, 1994:15). This review attempts to lay the foundation for such work.

What do we know and what do we need to know about adult numeracy – and what should we do about it?

Conceptualising numeracy

- Numeracy is a deeply contested concept. It may be considered as mathematical (rather than solely numerical) activity rooted (situated) in its social, economic, cultural and historical context.
- Numeracy is not 'simple' or 'basic', neither, for many people, is it 'easy'; rather it is fundamental to mathematical understanding and mathematical activity.
- Not all mathematical activity is visible, either to the observer or the protagonist, a fact that raises problems for teachers and researchers, as well as for learners, who may dismiss the mathematics they can do as 'just common sense'.

Surveying numeracy

- Surveys of numeracy reveal high levels of poor numeracy in the adult population in England, with a deleterious effect on the lives of the adults concerned. However, the measurement of adult numeracy remains problematic, especially at the lower ability levels and with those with reading or language difficulties.
- Research on adults' use of mathematics (their 'numerate practices') has focused especially on everyday and work contexts. These studies suggest that mathematical activity is deeply embedded in the contexts in which it takes place.
- Researchers differ on the extent to which it may be possible to 'transfer' learning between contexts, with some taking a pessimistic view; the alternative concept of 'translation' may be helpful in enabling us to see this as a process which does not happen automatically but which can be supported by appropriate teaching.

Designing and implementing policies for adult numeracy

- The UK government's ***Skills for Life*** strategy has transformed the landscape of adult basic skills in England and significantly raised the profile of adult numeracy.
- There is scope for international comparative policy studies in adult numeracy/mathematics education.

Teaching and learning adult numeracy

- The Adult Numeracy Core Curriculum is deliberately context-free. While most experienced numeracy teachers may have no difficulty in relating the Curriculum to the learner's context, this may pose a challenge for less experienced teachers, especially given the issues around transfer outlined above.
- Curriculum development in adult numeracy has taken different forms in different countries and settings. Innovative approaches have been developed where the curriculum is negotiated with adult learners and reflects their agendas for learning.
- The adult numeracy/mathematics curriculum must meet the needs of students with diverse goals. This means it must be 'vertically progressive' in terms of development of content as well as 'horizontally supportive' with respect to the mathematical aspects of other subjects. Limited number skills are not enough.

- Projects in the school sector making mathematics more experiential and less rule-bound, with more problem-solving experiences and employing constructivist theories of learning, have uniformly demonstrated improvements in attitude amongst both boys and girls, matched by improvements in attainment.
- Evidence on the impact of adult numeracy tuition is sparse and unreliable. Detailed critical studies of adult numeracy teaching and learning are required, including intervention studies, before it will be possible to delineate good practice in the light of evidence rather than aspiration.
- Studies investigating teaching and learning of particular elements of mathematics suggest that some (e.g., fractions, decimals, ratio and proportion) are likely to prove more difficult than others for some students.
- Errors and misconceptions learned in childhood are likely to persist into adulthood, adult numeracy teachers should therefore be aware of research in this area.
- Curriculum resources appropriate to changing conceptions of adult numeracy need to be developed.
- Assessment methods developed within the Realistic Mathematics approach in The Netherlands may be useful in England. Adult learners write and publish their own mathematical problems, using a process of generating ideas, drafting, peer and teacher review and redrafting. This approach has been found to facilitate learners in developing conceptual understandings of mathematical topics as well as their communication skills.
- Research on adult numeracy teaching and learning in relation to literacy, language (ESOL) and ICT is bearing fruit, however, much more remains to be done, especially with respect to speakers of English as an additional language.
- There is some evidence that aspects of language acquisition will develop when supplemented with conceptual tasks and activities that focus on the written and oral use of mathematical understandings.
- Research suggests that students can build successfully on their informal knowledge to construct meaning from formal representations, although a clear relation must exist between the two for this to happen.
- Small scale teacher-researcher studies in the USA on adults' Multiple Intelligences with respect to adult numeracy suggest that this approach may be worth pursuing, amongst others.
- The emphasis in critical pedagogies on learner empowerment and the social purposes of numeracy has struck a chord with many practitioners and researchers; these are an important counterbalance to 'limited proficiency' agendas in adult numeracy.
- Evaluation of the National Numeracy Strategy (NNS) and research on effective teachers of numeracy in the NNS context, should be read with interest by those implementing the Adult Numeracy Core Curriculum, given the strong links between the two.

Seeing the wood for the trees: numeracy *in situ*

- Research is needed on the changing numeracy demands of society and the ways in which adults can develop numerate (or mathemate) thinking to meet those demands.
- Research and development work on financial literacy has developed apace since the 1990s in response to changing demands on adults; these pressures are unlikely to diminish.
- The need for mathematical skills, including the ability to communicate information based on mathematical data, is being progressively extended throughout the workforce as a result of the pressure of business goals and the introduction of IT. Employees increasingly need not only to be proficient in the basic mathematical operations, but also to have broader general problem-solving skills, interrelating IT with mathematics.

Researching adult numeracy

- The research domain of adult numeracy is fast-developing but still under-researched and under-theorised. It may be understood in relation to mathematics education, as well as to adult literacy and language, and to lifelong learning generally.
- Most research on adult numeracy is interpretive and uses qualitative methods, although quantitative studies do exist, most notably in the form of large-scale surveys. Research designs vary widely, including mixed methods, experimental studies, ethnographic studies and practitioner research.
- Heterogeneity in research design in studies of adult numeracy is healthy and should be encouraged, given the diversity and under-researched nature of the field – or moorland – of adult numeracy and the myriad issues worthy of investigation, provided that the methods used are ethical and fit for purpose.
- Practitioners and researchers need opportunities to learn from each other – practitioner/researcher fora and networks such as ALM, ANN and ALNARC have a key role to play; international perspectives are important here.

Developing teachers of adult numeracy

- Teacher education in England is currently undergoing major transformation, with the introduction of Subject Specifications at Levels 3 and 4 for adult numeracy teacher education and the development of postgraduate courses in adult literacy, numeracy and ESOL. The 1990s Australian experience seems particularly relevant to that in England, given widespread current concern about the lack of available teacher expertise (a problem also identified in Australia).
- Data on those currently teaching adult numeracy is needed, with changes in the workforce mapped as current reforms become established. This will become available through the NRDC longitudinal panel study of adult literacy, numeracy and ESOL teachers.
- Some adult numeracy teachers' lack of subject knowledge is a continuing concern. However, studies in mathematics education with children suggest that, rather than high levels of mathematical qualifications, it is teachers' engagement in continuing professional development in mathematics education that correlates with effective teaching. International comparative studies suggest that rather than asking how far a teacher's knowledge of mathematics extends, we should also ask how deep it goes - teachers need to develop a profound understanding of fundamental mathematics (PUFM); they also suggest that teachers can develop their subject knowledge when they teach it.
- Effective initial teacher education is needed, linked to comprehensive and ongoing continuing professional development (CPD), using teacher-researcher and collaborative models with long-term institutional support. Practitioners need time and support to work collaboratively, to train, study and reflect on their work and to undertake research, including at postgraduate level.
- Academic positions for adult numeracy should be established at universities concerned with adult teacher education, to provide an infrastructure for future research and development as well as for effective teacher education for teachers of adults.
- Studies of effective teachers of numeracy/mathematics in the schools sector suggest that strategies that encourage a 'connectionist' orientation to teaching and learning numeracy with active learner engagement: connecting; generalising; conjecturing; and enquiring are the most effective. It includes the belief that being numerate involves being both efficient and effective and that most people can learn mathematics given appropriate teaching. For teachers it means being aware of different methods of calculation and able to choose an

appropriate strategy. Teaching needs to be introduced in a clear manner and the links between different aspects of mathematics made explicit.

Learning adult numeracy

- Factors affecting learning - attitudes, beliefs and feelings about mathematics, including mathematics anxiety - should be of vital concern to adult numeracy educators and information and opportunities for reflection on these factors should be included in teacher education and CPD.
- The ways in which teachers approach the teaching of mathematics can do much to alleviate or increase mathematics anxiety, as can teachers and parents' own attitudes and feelings about it.
- Evidence on dyscalculia is mixed. Nevertheless, adult numeracy educators need to be aware of current research on dyscalculia and on the functioning of the brain in mathematical activity. More research is needed to try to establish effective methods for dyscalculics to learn the different topics in mathematics.
- Research on different groups of adults with respect to numeracy/mathematics education is extremely patchy. If we are to move towards the goal of mathematics for all, it is imperative that issues of learner identity and social and economic location are considered and data collected and analysed with respect to gender, class, age, ethnicity, disability, culture, language, environment (rural, urban, inner city, suburban, etc.) and local labour markets.
- Very little is known about adults with special educational needs in basic skills provision; research is needed in this area.
- Very little is known about learning and teaching adult numeracy with adults who speak languages other than English; research is needed in this area.
- Practitioners, policy-makers and researchers need to learn from and listen to adults learning - and doing – mathematics. Practical ways of doing this need to be developed. One way forward might be the development of a web-based student magazine, a successor to the 'Take Away Times', using techniques developed in Dutch 'Realistic Mathematics Education' (RME) studies. This could provide a forum for adult numeracy students to communicate with each other and exchange ideas, experiences and learning materials, while developing or building on literacy, language and numeracy skills. It would also enable teachers, researchers and policy makers to hear the 'voices' of some adult learners.

Building capacity in adult numeracy

- There is an urgent need to build capacity in all aspects of adult numeracy: theory; research; teaching; teacher education and communication with and between learners.
- Adult numeracy specialists need to engage with policy-makers (in the basic skills area and in mathematics education generally, e.g., the Government's Post-14 Mathematics Inquiry), and to providers of mathematics education to children and adults, employers, trades unions and others with a wider interest in adults learning mathematics.
- Initiatives to improve public understanding of, and engagement with mathematics should be encouraged.

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