CRITICAL MOMENTS IN ADULT MATHEMATICS

PROCEEDINGS OF THE 20TH INTERNATIONAL CONFERENCE OF ADULTS LEARNING MATHEMATICS – A RESEARCH FORUM (ALM)

Hosted by
University of South Wales,
Caerleon, Newport
Wales
July 1-4, 2013

Editors: Anestine Hector-Mason, Janette Gibney and Graham Griffiths

Local Organisers

Janette Gibney and Graham Griffiths
Presenters for the ALM 20 conference chose whether or not they wanted to submit their articles for a special edition of the ALM International Journal and go through the formal, blind peer review process. Those papers which went through this process are marked in the table of contents with an asterisk (*) next to the title and are reprinted here by permission of Adults Learning Mathematics – A Research Forum.
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About ALM

Adults Learning Mathematics – A Research Forum (ALM) was formally established in July, 1994 as an international research forum with the following aim:

- To promote the learning of mathematics by adults through an international forum, which brings together those engaged and interested in research and development in the field of mathematics learning and teaching.

Charitable Status

ALM is a Registered Charity (1079462) and a Company Limited by Guarantee (Company Number: 3901346). The company address is: 26 Tennyson Road, London NW6 7SA.

Aims of ALM

ALM’s aims to promote the advancement of education by supporting the establishment and development of an international research forum for adult mathematics and numeracy by:

- Encouraging research into adults learning mathematics at all levels and disseminating the results of this research for the public benefit.

- Promoting and sharing knowledge, awareness and understanding of adults learning mathematics at all levels, to encourage the development of the teaching of mathematics to adults at all levels, for the public benefit.

ALM’s vision is to be a catalyst for the development and dissemination of theory, research, and best practices in the learning of mathematics by adults, providing identity for the profession, and internationally, promoting and sharing knowledge of adults’ mathematics learning for the public benefit.

ALM Activities

ALM members work in a variety of educational settings both as practitioners and research, improving the learning of mathematics at all levels. The ALM annual conference provides an international network which reflects on practice and research, fosters links between teachers and encourages good practice in curriculum design and delivery using teaching and learning strategies from all over the world. ALM does not foster one particular theoretical framework but encourages discussion on research methods and findings.

ALM holds an international conference each year at which members and delegates share their work, meet each other, and network. ALM produces and disseminates Conference Proceedings and a multi-series online Adults learning mathematics – International Journal (ALMJ).

On the ALM website http://www.ALM-online.net, you will also find pages of interest for teachers, experienced researchers, new researchers and PhD students, and policy makers.

<table>
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<tr>
<th>TEACHERS</th>
<th>EXPERIENCED RESEARCHERS</th>
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<td>The work of members includes many ideas for the development of practice, and is documented in the Proceedings of ALM conferences and in other publications.</td>
<td>The organization brings together international academics, allowing the sharing of ideas, publications, and dissemination via the conference and academic refereed journal.</td>
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<th>NEW RESEARCHERS AND PHD STUDENTS</th>
<th>POLICYMAKERS</th>
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<tr>
<td>The conferences and other events allow a friendly, yet challenging environment to test out ideas and develop work.</td>
<td>The work of the individuals in the organization has a history of influencing policies in various countries around the world.</td>
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ALM Members live and work all over the world, and the ALM members’ page will put you in touch with our regional activities and representatives. ALM welcomes new members; please contact the Membership Secretary. Contact details are on the ALM website.
Board of Trustees

ALM is managed by a Board of Trustees elected by the members at the Annual General Meeting (AGM), which is held at the annual international conference.

**ALM Officers and Trustees - 2012–2013**

**Chair:** Dr. Terry Maguire (Dublin, Ireland)

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**How to become a member**

Anyone who is interested in joining ALM should contact the membership secretary. Contact details are on the ALM website: [www.ALM-online.net](http://www.ALM-online.net)

**Membership fees for 2013**

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Preface

The 20th international conference of Adults Learning Mathematics – A Research Forum (ALM 20) was held in Wales, UK. The conference was organised by the University of South Wales, Caerleon Campus, Newport, and was attended by researchers, practitioners and policymakers from many nations. Within the UK, the conference attracted representation from England, Northern Ireland, Scotland and Wales. International attendees travelled from Australia, Ireland, New Zealand, Norway, Senegal, Spain, Sweden, Switzerland and the United States of America.

The theme of the conference was “Critical Moments in Adult Mathematics,” which drew attention to mathematical teaching and learning practices and policies in many countries. Keynote presentations included topics which reflected the varied perceptions and experiences of practitioners and researchers in mathematics, and focused on the challenges and practices of mathematics in and out of the classroom:

- *Engaging critically with powerful numbers in public discourse* by Professor Mary Hamilton, University of Lancaster.
- *More...or less? Developing a critical pedagogy of Adult Numeracy* by Aileen Ackland, University of Aberdeen.
- *Making real-life decisions: does logic help, or is it better to be rational?* by Joan O’Hagan, Independent.
- *Turning Negative to Positive – the challenge of essential numeracy for all* by Lynn Churchman, National Numeracy, England and Wales.

As you, the reader, will see from the submissions, presentations and abstracts in these ALM 20 Conference Proceedings, the strengths and needs of mathematical teaching, learning and policy are, indeed, critical moments.

The conference marked the 20th anniversary of Adults Learning Mathematics – A Research Forum. These Proceedings demonstrate that the organization has established itself on an international basis. This is the 20th volume of proceedings from the international conferences. The International Congress on Mathematical Education (ICME) has established working groups on adults and mathematics and produced related publications. Members of ALM have contributed to the Programme for the International Assessment of Adult Competencies (PIAAC) for the Organisation for Economic Co-operation and Development (OECD).

**Note:**

All conference paper and poster presentations submitted for publication and meeting editors’ requirements for style and presentation were reviewed and are published in the ALM 20 Conference Proceedings.

Presenters for the ALM 20 conference were also able to choose whether or not they wanted to submit their articles for a special edition of the ALM International Journal and go through the formal, blind peer review process. Those papers which went through this process are marked with an asterisk (*) next to the title.

Presentations for which no paper was submitted are represented by their programme abstract. PowerPoint slides for most presentations are also available on the ALM website: www.ALM-online.net.
Acknowledgements

The ALM is grateful to the many people who have contributed to the ALM20 conference and to the production of these Proceedings:

- The participants, without whom there would have been no conference and no Proceedings.
- ALM Officers and Trustees for ensuring the continuity of the organisation between the conferences.
- The University of South Wales, Caerleon Campus, Newport for sponsoring full conference.
- Dr. Anestine Hector-Mason, Supervising Editor of ALM Conference Proceedings.
- Janette Gibney, Local organiser and Conference Committee Chair at the University of South Wales.
- Graham Griffiths, Local organiser and ALM Trustee for supporting the review process and coordinating correspondeces with editors and authors.
- Staff and students at USW with especial thanks to Judith Archer, Joanne Harris, Rachel Stubley, Sue Jeffrey, Andrea Neve and Alison Durston.
- Helen Arney, for after conference meal entertainment.

The work of this team is greatly appreciated and hereby acknowledged by ALM20 Editorial Committee. Last, but not least, we wish to thank all ALM members who contributed to both the conference and the Proceedings for ALM 20.
Mathematically related quiz

On a lighter note, the conference opened with a mathematics related quiz. The questions are reproduced here with answers at the end.

Round 1 - Mathematics trivia and facts

1. If the length, width, and height of a rectangular solid box were each increased by 50%, by what percentage would the volume be increased?
2. How many numbers between 1 and 1000 have at least one digit 9?
3. What shape does the equation \((x^2 + y^2 - 1)^3 - x^2y^3 = 0\) make?
4. A googol is ten to the power of what?
5. What is special about the number 1729?
6. What is special about a Reuleaux triangle?
7. What is the phrase ‘may I have a large container of coffee?’ a mnemonic for?
8. How many triangles are in the following?

9. Argentina uses the peso as currency which has the following coins: 5, 10, 25 and 50 centos. How many different ways are there of getting 50 centos? \(25 + 10 + 10 + 5\) is the same as \(10 + 25 + 5 + 10\).
10. What whole number is nearest to the sum of \(\pi\), \(e\) and \(\phi\) (the golden ratio)?
Round 2 – Mathematics and languages

Review the following table, and identify the languages that the number words/numeral systems in the table come from. Choose a language from the list below the table. Note that four of the languages are redundant.

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Languages: Armenian, Cantonese, Czech, Finnish, Gaelic, Hindi, Japanese, Korean, Persian, Polish, Swahili, Thai, Welsh, Yoruba
Round 3 - Mathematics in the movies and TV

1. Which comedians calculated that 7 times 13 was 28 while ‘In the Navy’ in 1941?
2. Which 60s US TV series involved the rapidly breeding, hermaphrodite Tribbles who multiplied from 1 to 1771561 in three days?
3. Which animated character spent time in Mathmagic Land in 1959?
4. In this 1994 film, Albert Einstein comes to the aid of a young garage mechanic (who has fallen in love with Einstein’s mathematically brilliant niece), by helping him to pretend to be a great physicist. Tim Robbins plays the mechanic who discusses Zeno’s paradox with Meg Ryan’s character. What is the name of the film?
5. In this late 80s film, teacher Jaime Escalante encourages his Hispanic students to take the Advanced Place Calculus test. Inspired by real events, what is the name of the film?
6. Which performer plays a teacher in the 1958 film Merry Andrew who delivers a song and dance rendition of Pythagoras’ Theorem?
7. In the second episode of a long running animated series set in fictional Springfield, this male character (voiced by actress Nancy Cartright) – day dreams of trains travelling in opposite directions (in a parody of mathematics problems) while sitting a school test. What is the name of the character?
8. Fermat's Room (La habitación de Fermat) is a 2007 Spanish thriller film in which three mathematicians and one inventor are invited to a house and told to use pseudonyms based on famous historical mathematicians. "Fermat" (Pierre de Fermat) is the (apparent) host, "Galois" (Évariste Galois), "Oliva" (Oliva Sabuco) and "Pascal" (Blaise Pascal) are three of the visitors. What is the fourth pseudonym based on a German mathematician?
9. Who is the director of the 1998 film entitled Pi in which Max Cohen is a number theorist who believes that everything in nature can be understood through numbers? (lenient on spelling)
10. What is the name of the CBS television crime drama series produced by Ridley and Tony Scott in which mathematics is used to solve crimes? (precise name)

Round 4 - Mathematicians across geography and time

Re arrange the following to get the names of some important figures in the history of mathematics.

1. up bratha mag (Indian – one part)
2. chevon khogle (Swedish – three parts)
3. pat yahi (Egyptian / Greek – one part)
4. needa strecrés (French – two parts)
5. josh hann (US – two parts)
6. hailion wanor willamm (Irish – three parts)
7. chimo chiz shiniuki (Japanese – two parts)
8. derrec obertor (Welsh – two parts)
9. yoteen hermm (German – two parts)
10. mavand reikor (Russian – two parts)
Round 5 - Mathematics and music

1. Who sang (and co-wrote) the US/UK 1960 hit declaring that he did not know much about trigonometry or what a slide rule is for?

2. More recently, in 2011, who sang “I don’t know much about algebra, but I know one plus one equals two. And it’s me and you, that’s all we’ll have when the world is through”

3. Who sang the decimal expansion of pi as the chorus to a song, getting it wrong in the 53rd decimal place?

4. The rapper, Drake, accompanied which singer with the following rhyme “I heard you good with them soft lips, Yeah you know word of mouth, the square root of 69 is 8 something, cuz I’ve been trying to work it out”?

5. Now back to the 60s, who sang ‘Multiplication’? ‘Multiplication… that’s the name of the game! And each generation… they play the same!, Let me tell ya’ now: I say one and one is five, You can call me a silly goat! But, ya’ take two minks, add two winks, Ah… ya’ got one mink coat!”

6. Which Swedish band, better known for ‘All that she wants’ in the 90s, reformed recently and sang to their ‘Golden ratio’?

7. Mos’ Def proved he could count on the b’ side ‘Mathematics’ which was also on his 1999 debut album. What was the name of the album?

8. The term math rock has been applied to a number of rock groups employing complex rhythms. Which Chicago based sound engineer and producer, a founder member of Big Black, is associated with the scene?

9. Which performer expressed his concern that only a child could do ‘new math’?

10. Douglas Hofstader made some links between mathematics, art and music in his 1979 book subtitled ‘The Golden Braid’. Who was the classical composer in the title?
SECTION 1:
Introduction/Plenaries/Keynotes
WELCOME PLENARY: CRITICAL MOMENTS IN THE RESEARCH PRACTICE OF ALM

Dr. Theresa Maguire (ALM Chair)
Institute of Technology Tallaght, Dublin, Ireland

At the opening of the 20th annual ALM conference, this brief presentation will highlight key developments in the research practice of ALM over the last 20 years and highlight the changing environment within which ALM members now operate. This presentation will also identify how ALM will continue to support its members into the future.

Biography

Dr. Terry Maguire has been involved in adult education for almost 25 years. She is currently the Head of Lifelong Learning at the Institute of Technology, Dublin, Ireland. She is the current chair of ALM—an international research forum. Her research interests include identifying good models of professional development for tutors of adult mathematics; uncovering the hidden mathematics of the workplace; and contributing to setting up a coherent framework for adult mathematics in Ireland. More recently she has launched an innovative approach to teaching mathematics ‘Developing Maths Eyes’ that is being used in primary and post primary schools, and adult education centres in Ireland. Please check out www.haveyougotmathseyes.com for more details.
KEYNOTE PRESENTATION 1: ENGAGING CRITICALLY WITH POWERFUL NUMBERS IN PUBLIC DISCOURSE

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In many countries, national policy is now strongly shaped by international influences which are partly realised through globalised social statistics. I will show how these new systems of measurement translate the complex, local diversities of adult experience and achievement into categories and classification systems that become naturalised within public discourse, deeply affecting our sense of what literacy and numeracy are and might be. I will argue that these systems of measurement offer powerful but constrained ways of imagining the aspects of social reality they aim to describe.

It is important to understand how the survey results are constructed in order to engage critically with them in the public sphere as a condition for democratic policy action. I will use examples from the recent Skills for Life policy in England and associated international surveys to look at how numbers enter into the policy discourse and how they are used to imagine and order the fields of adult literacy and numeracy. I will discuss the discursive contribution of mathematical/statistical argument, visualisation and symbolism to policy narratives, drawing on the social semiotic theorists Theo Van Leeuwen, Kay O’Halloran and Jay Lemke.

Biography
Mary Hamilton is Professor of Adult Learning and Literacy in the Department of Educational Research at Lancaster University; Associate Director of the Lancaster Literacy Research Centre and a founder member of the Research and Practice in Adult Literacy group. Her current research is in literacy policy and governance, socio-material theory, practitioner enquiry, academic literacies and change.
KEYNOTE PRESENTATION 2: MORE OR LESS? DEVELOPING A CRITICAL PEDAGOGY OF ADULT NUMERACY

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In recent years, adult numeracy tutors have been encouraged to add more to the learning experience – more context, more realia, more activity. But is this a sufficient pedagogic response to the insights from social practices theory?

I will argue that it is not – that instead, a critical pedagogy is required which may require that the tutor bring less, not more, to the learning experience.

Biography
Aileen’s career has encompassed a diverse portfolio of literacies work in which she gained experience of most sectors of Scottish education, formal and informal. From 1995 – 2003 her work was primarily in the voluntary sector, as a tutor and organiser with the Workers’ Educational Association (WEA). Now at the University of Aberdeen, where she is involved in professional development programmes for adult learning practitioners in community, workplace and further education settings, Aileen has led the curriculum development of the Professional Graduate Diploma in Education (Adult Literacies), the new professional qualification for Adult Literacy and Numeracy tutors in Scotland. Her research explores the relationships between social practices theory and adult literacies policy and practice. She can be contacted at a.ackland[at]abdn.ac.uk
KEYNOTE PRESENTATION 2: MORE OR LESS? DEVELOPING A CRITICAL PEDAGOGY OF ADULT NUMERACY *

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Abstract
The development of socio-cultural understandings of mathematics combined with policy interest in adult numeracy as a result of international studies, which compare skill levels in different countries, have impacted adult education practice in recent years. In Scotland, a ‘social practice approach’ is espoused and adult numeracy tutors are encouraged to add more to the learning experience – more context, more activity. But is this a sufficient pedagogic response to the insights from social practices theory and a socio-cultural perspective of mathematics? This paper draws on evidence from studies of practitioners’ understandings of social practices theory to argue that these responses are limited and potentially limiting of adult learners, and represent a neo-deficit approach. Instead a critical pedagogy is required, which may require that the tutor bring less, not more, to the learning experience. Critical pedagogies would involve exploring with learners the powerful uses of mathematics in society. Adult numeracy learners could learn not only to understand the mathematics in use but to use mathematics for their own projects. The paper concludes with some thoughts on the kind of teacher education required to support tutors to become more critical in their pedagogy.

Key words: Adult numeracy, social practices, critical pedagogy

Introduction
This paper argues that the changes to adult numeracy practice evident in recent years are an insufficient response to current theoretical perspectives on mathematics in society and potentially limiting of adult learners. It arises out of a number of personal and professional concerns: to promote education for social justice, to synthesise literacy and numeracy issues, to share insights about practice across different sectors of education. It is informed by my experience in schools, further education colleges and as a tutor and organiser for a voluntary sector provider of adult education for democracy. The argument has been developed through my work as teacher educator involved in designing and delivering professional development for Adult Literacies practitioners in Scotland between 2005 and 2012. A research project undertaken in this period, with practitioners participating in the work based professional development programme, provides evidence in support of my arguments.

Writing for a journal with mathematics in the title, I am however, beset by imposter syndrome. An arts graduate, teacher of English, literacy tutor and qualitative researcher, I find myself subject to doubts about my capability and credibility to contribute to academic debate about maths. Boaler (2009) provides one explanation for my feelings of unworthiness. She describes as ‘the elephant in the

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1 Between 2005 and 2012, I was Curriculum and Research Leader for the Scottish TQAL Consortium which consists of the Universities of Aberdeen, Dundee & Strathclyde. The Consortium was contracted by Scottish Government to develop and deliver a teaching qualification for adult literacies tutors (TQAL), which became the Professional Graduate Diploma in Education (Adult Literacies).
classroom’ (p.2), the assumption that success in maths is a sign of general intelligence. Such an assumption breeds adult insecurities as they assess their own value in relation to the value accorded their different kinds of knowledge. Boaler reminds us that the mathematics afforded such power – school maths - is a narrow subject restricted to classroom contexts: ‘a strange mutated version’ (p.2) of ‘real mathematics’. Nevertheless, ‘people who teach maths’, the voice in my head goes, ‘are much cleverer than me’. I share this reflection because power is at the core of my argument about the teaching of adult numeracy. My proposal is for pedagogies, which confront the elephant and expose assumptions about different forms of knowledge to examination.

Although I will base my argument primarily on the situation in Scotland, I believe it has validity internationally at a time when a culture of global comparisons of educational outcomes drive harmonisation of educational practice in different countries. Whilst claims have been made about the distinctiveness of Scotland’s approach to what is termed here, adult literacies (Scottish Government, 2011), the direction of practice developments is similar to many other countries and related to the hegemony of the neo-liberal capitalist project.

The paper begins with a brief description of the Scottish context for adult literacy and numeracy. Since the ‘social practice approach’ endorsed in Scotland appears to derive from socio-cultural understandings of literacy and numeracy as social practices, these perspectives are presented and their implications for educational practice considered. Drawing on data from studies of Scottish practitioners’ understandings of a ‘social practice approach’ I suggest that much adult literacy and numeracy practice does not in fact reflect these implications. The assumptions behind some new practices of numeracy teaching and learning are then examined. Following an assertion that these assumptions could indicate what Auerbach (1995) labels a neo-deficit approach, I propose alternative critical pedagogies, providing some examples from the school sector as well as adult education.

Finally, I conclude with a consideration of the need to develop critical pedagogies of teacher education.

The Scottish adult literacy and numeracy context

In 2001 the Scottish Executive responded to the International Adult Literacy Survey results (OECD, 2000) with a policy initiative for Adult Literacy and Numeracy (Scottish Executive, 2001). The strategy acknowledges that ‘Literacy and numeracy are skills whose sufficiency may only be judged within a specific social, cultural, economic or political context’ (Scottish Executive, 2001, p. 7) and defined literacy in broad terms as ‘the ability to read and write and use numeracy, to handle information, to express ideas and opinions, to make decisions and solve problems, as family members, workers, citizens and lifelong learners’ (p.7).

The socio-cultural perspective implicit in these statements was further reflected in a subsequent shift in terminology in policy and in practice - from Adult Literacy and Numeracy (ALN) to ‘adult literacies’ (plural), an umbrella term which encompasses literacy, numeracy, ICT and ESOL. The plural term recognises the diversity of literacies as well as the interconnectedness of these four domains in social practices. The Curriculum Framework (2005) advocated ‘a Scottish approach to adult literacy and numeracy learning’ described as a ‘social practices approach’ (Scottish Executive, 2005, p.5).

The broad definition and the use of the concept of adult literacies blurred the boundaries in practice between, in particular, literacy and numeracy and many tutors who had previously taught one or the other were now required to teach both. There was concern, however, that in contrast with literacy, adult numeracy may be overlooked and that practitioners, some of whom may be themselves ‘maths anxious’, required support to provide effective numeracy learning opportunities. Professor
Diana Coben was commissioned to produce a report making recommendations for the development of an effective adult numeracy strategy for Scotland. Adult Numeracy: shifting the focus (Coben, 2005) elaborated the Scottish definition of literacies with a working definition of numeracy:

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, 2000, p.35, emphasis in the original)

Whilst emphasising the importance of numeracy not being overshadowed by literacy, the report recognises correspondences between literacy and numeracy as social practices. Social practices theory and the implications for teaching and learning have, however, been ‘articulated more clearly with respect to adult literacy than to numeracy’ (Coben, 2005, 28). Coben articulates a ‘social practices approach’ to numeracy as critical numeracy requiring connectionist teaching and realistic mathematics.

This group of approaches starts from the position that adults are active agents in the world, rather than seeing them as inadequate individuals with a numeracy deficit. ‘Adult education … is seen as a tool for social justice, aiming to equip people with knowledge and tools to examine, criticise and seek to change the economic, political, and social realities of their lives’ (Coben, 2005, p.23). She recommended a number of ways in which this approach could be progressed in Scotland.

To summarise, in Scotland adult numeracy is encompassed within the term adult literacies. A social practices approach is advocated, in contrast to a ‘…deficit approach…where the individual is encouraged to take a test that will demonstrate a failure to meet a set of standards…’ (Scottish Government, 2011, p.14). Coben articulated this Scottish social practice approach to numeracy as critical numeracy. In the years since these key texts, ‘the social practice approach’ has become the doxa of practice in Scotland.

Literacy and numeracy as social practices

As Coben acknowledged, the conceptualisation of literacy as social practices has received more attention than similar socio-cultural understandings of numeracy. The social practices theory of literacies in society advanced by the New Literacy Studies (NLS) (see for example Street, 1984; Barton, 1994; Barton and Hamilton, 1998; Gee, 2008) emphasises the inherent power relationships affecting uses of literacy in a social context and illuminates the situated nature of literacies acquisition. The NLS view of literacy as situated, socially constructed and inherently ideological challenges what Street refers to as the autonomous model (Street, 1984), which assumes literacy to be a value and context free individual cognitive competence. Crowther et al. highlight the ideological dimension in the title of their edited book, Powerful Literacies (2001). They demonstrate in a variety of practice contexts how work with literacies learners requires practitioners to be aware of power relations and to critically examine with learners sociocultural literacies practices. Gee (2008) provides a very clear illustration of such a critical approach in his examination of the ‘aspirin bottle problem’. His analysis of the warning text on an aspirin bottle demonstrates how teaching the ‘reading’ of such a text must go beyond decoding to engage with questions about drug companies, social relations and the structure of society. As Freire and Macedo (1987) put it, literacy requires ‘reading the word and the world’.

Understandings of numeracy as social practices have mainly been explored in ethnomathematics (see Powell and Frankenstein, 1997), and through ethnographic research (e.g., the new Mathematics project in Liberia; Cole, 2000). Benn (1997) explored the implications of this perspective for adult education. She states the fundamental tenet of this perspective as ‘that mathematical knowledge is a
social construct... created by human beings whose thinking is influenced by a historical and political context’ (p.27). Chapter 3, ‘Mathematics: a peek into the mind of God?’ provides a historical and social analysis of mathematics and traces a move from an absolutist to a fallibilist view. ‘The absolutist views mathematics as neutral and value free as opposed to subjective and value-laden’ (p.31). This shift corresponds with Street’s distinction between the autonomous and ideological views of literacy. A social practices view recognises that numeracy as well as literacy practices exclude, position, and implicate people in relation to ideological assumptions (Kerka, 1995). Benn (1997) argues that in adult numeracy learning values must therefore be made overt within a critical pedagogy.

According to Ernest (2002, p.5), a critical mathematics education would develop the following aspects of understanding and awareness:

- Critically understanding the uses of mathematics in society: to identify, interpret, evaluate and critique the mathematics embedded in social, commercial and political systems and claims, from advertisements to government and interest group pronouncements.
- Being aware of how and the extent to which mathematical thinking permeates everyday and shop floor life and current affairs.
- Having a sense of mathematics as a central element of culture, art and life, present and past, which permeates and underpins science, technology and all aspects of human culture.
- Being aware of the historical development of mathematics, the social contexts of the origins of mathematical concepts, symbolism, theories and problems.
- Understanding that there are multiple views of the nature of mathematics and controversy over the philosophical foundations of its knowledge.

Although Ernest here refers to a critical mathematics education, increasingly the term numeracy is used in adult education to indicate the wider perspective, to acknowledge mathematics as a discourse and to distinguish between real mathematics and school maths (Yasukawa et al., 1995). Numeracy here is more than mathematics and it is only numeracy if it is political; if, in other words, it recognizes the power dimension.

Practitioners' understandings of a social practices approach

Above I have sketched out the theoretical views apparently influencing adult literacies practice in Scotland. In these views, the espoused Scottish ‘social practice approach’ entails critical pedagogies. Maclaclan and Tett (2006) found little evidence of critical practice, however, and Hillier (2008) questioned the extent to which the social practice perspective of literacies was actually transforming practice in Scotland. Involved at this time in the development of the new teaching qualification for adult literacies tutors, I was concerned with how the theory of social practices was currently being construed in practice to better appreciate the challenge of how the radical socio-cultural understandings could be translated into changes in practice. Between 2008 and 2010 I undertook research with a group of practitioners undertaking the professional qualification. The research used a variety of methods inspired by Personal Construct Theory (Kelly, 1955) - including individual and group reflective activities, and structured interviews - to explore how practitioners were construing ‘a social practice approach’. (For full details of this research and its methodology see Ackland, 2013.)

Practitioners in this study associated the social practices approach with two main characteristics – learner-centeredness and relevance. The following quotes, from an activity in which students had 5 minutes to write their definition of the approach, are representative of how these two characteristics are repeated throughout the data:
My understanding of the Social Practice of literacies is that it's directed by the needs of the learner; Learner-centred….making the learning process relevant; creates a relevant link to the learner’s life. It individualises learning; Social practices is you’re asking learner what they want to improve; it’s taking the learner’s perspective into account and, if appropriate, adapting my practice to their social norms.

Within this discourse, the learner (singular) tends to be isolated in the learning environment but linked to their individual everyday life, which is unquestioned. The relationship between teacher and learner is generally interpreted as one of service. Teachers should be ‘empathic’ and ‘non-directive’. Care for the learner is paramount and summed up in the notion of practice being ‘non-threatening’ (these terms appeared frequently in the interview data). In all the data there is little trace of the critical pedagogy implied by the social practices perspectives as examined previously, or with the articulations by Benn (1997), Papen (2005) and Coben (2008) of the implications for adult literacy and numeracy. Yet one practitioner reflected that ‘you don’t really need to have a wonderful theoretical grasp of it, it’s just… to me it’s natural’.

My findings are supported by research by Swinney (2013), which included analysis of Scottish adult literacies practitioners’ narratives of practice. She found that a marked consistency of discourse of ‘social practice’ and ‘literacies’ masked significant differences in underlying philosophies of adult education. She describes how practitioners use the term ‘social practice approach’, ‘as encapsulating an array of ‘learner centred’, ‘informal’ and ‘contextualised’ approaches to learning and teaching which placed an emphasis on emotional and relationship aspects of learning’ (p.241). She concludes that ‘there was no evidence to suggest practitioners, in using ‘literacies’, intended to convey a politicised understanding that…is implied by a ‘social practice’ analysis…’. The practitioner in her study who reflected that ‘the social practice approach was nothing new to most of the workers that we had here’ (p. 239) may be expressing a similar taken-for-grantedness about characteristics of practice as the student quoted above.

**Characteristics of practice – more, more, more**

From both studies it is clear that practitioners in Scotland believe that their practice conforms to the orthodoxy of the Scottish ‘social practice approach’ and is distinct from a deficit approach. In the following section, quotes from practitioners in my study (Ackland, 2013) indicate some of the elements of their practice that they associate with the new approach. What this appears to mean in the detail of practice is more…particularly more work for the tutor:

I feel the social practice model is so important to literacies as it is creates a relevant link to the learner's life. It individualises the learning, which makes for a lot more preparation for us, but demonstrates the difference between adult and children's learning.

More individual learning planning is evident:

…after some discussion with the learner about what they need their literacy/numeracy for, what areas of their life is their need for literacy most necessary, then a program of learner led literacy/numeracy would be developed and worked on. This will enhance inclusion, confidence, and employability and allow the learner to participate more confidently in everyday life, whether it is shopping, going for a meal, paying bills and so on.

To support individual learning planning, an interactive tool, ‘The Curriculum Wheel’, was developed (Scottish Executive, 2005) and its use ‘rolled out’ to all adult literacy and numeracy partnerships. Individual learning planning was given even greater priority as the focus of a Practitioner-Led Action Research project in 2008 (St. Clair et al., 2009). The project aimed ‘to support practitioners in leading a research project looking at the individual learning planning (ILP) process. ILPs are central to the literacies field in Scotland, as they are used for defining objectives, planning instruction, and assessing achievement by learners’ (p. 1). The shift in this introductory
statement, from the singular ‘process’ to the plural ‘ILPs’, is indicative. It is plans that have proliferated, in many cases as quite extensive textual artefacts incorporating a degree of initial diagnosis as well as identification and evaluation of relevant learning. They are sometimes experienced by tutors as more paperwork, ‘not part of the ‘real’ work of literacy teaching and learning’ (Hamilton, 2009). Hamilton demonstrates how ILPs can shape the relationships between tutors and learners and align both their identities with system goals. Although in Scotland the guidance on developing ILPs is perhaps even more permissive than in England where Hamilton was studying ILPs, her analysis contains important insights about how the forms can constrain the possibilities for learners. For instance, as more formal accreditation is required to demonstrate learner progress (HMIE, 2010), the learning outcomes of the qualifications influence learners’ goals. Learning goals written on ILPs are also identified within discourses about literacy and numeracy ‘needs’, mainly linked to economic participation, and in Scotland, inside the discourse of ‘relevance’.

The planning process focuses learning on the individual needs and requires tutors and learners to identify learning goals associated with their everyday lives:

It [social practices] is when people work on the things they need to be able to do for specific activities in their lives, for example if they have a new job and need to be able to convert metric and imperial measurements or be able to use an electronic till – it’s a sort of ‘functional literacy.

Another issue, then, is contextualisation:

Social Practices is about ensuring that all learning that goes on in our service is contextualised and embedded in the learner’s chosen vocational area or interests.

In relation to numeracy the contexts drawn upon tend to be shopping, budgeting, work, and sometimes, leisure interests such as sewing or DIY. There can be a number of problems, in my view, with this interpretation of ‘contextualised’ in relation to numeracy. In some cases the contextualisation is superficial and may mathematise a problem that in ordinary circumstances would not involve the use of mathematics. For example, the following problem is set in an everyday context. There is, however, no purpose to the problem, other than to demonstrate the ability to create a graph.

A gardener plants a variety of bulbs for the spring in both his front and rear gardens. Detailed below:

<table>
<thead>
<tr>
<th>Bulbs</th>
<th>Front Garden</th>
<th>Rear Garden</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 Tulip bulbs</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>60 Snowdrop bulbs</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>80 Daffodil bulbs all in front garden</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 Crocus bulbs</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>30 Hyacinth bulbs</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

Create a suitable graphical form (table, graph, chart or diagram) to illustrate his planting.

Figure 1. Numeracy assessment, Core Skills Numeracy modules²

Contextualisation such as this, I suggest, is a mere dressing up of school maths with the backdrop of everyday life. Problems are not structured in the context of real life purposes, rather only elaborated with textual detail. This can lead to another more… more words. Numeracy tasks become literacy tasks. Whilst mathematics in societal contexts is often entangled with language, text that is not crucial to the purpose of a classroom task can serve simply to create an additional barrier. For example:

Jimmy needs to wallpaper his bedroom. The dimensions of the room are 3m by 4m by 2.5m. There is one door - 2m x 1m - and one window 1.5m x 1m. A standard roll of wallpaper is .53m x 10m. How many rolls of wallpaper does Jimmy need?

² http://www.aloscotland.com/alo/viewresource.htm?id=2819
In real life, Jimmy is unlikely to make a narrative of the problem in this way. He is more likely to tackle it physically and with concrete objects. An extra dimension of difficulty is introduced into the spatial and numerical problem by its translation into the language of the maths problem. The requirement to decode language such as ‘dimension’ and to understand the conventions of giving width and height measurements adds a superfluous literacy task.

Even where the context suggested has a real purpose, the adult literacies tutor’s commitment to not challenging the everyday life of their learners can pose problems. The following is the transcription of an excerpt from a recording of practitioners discussing a social practice approach as part of the research project:

A  For the sake of argument… if a learner comes and says I want to learn weights and measures coz I want to be a drug dealer… do you say ‘no problem, we’ll start here then…. ’ or start questioning their motives?

B (laughing) I once did ratios and the topic was…the question was…‘where would you use ratios in everyday life?’… and it actually came up. And I’m going ‘I’m no teaching this!’ …. but that’s what they are doing anyway …

C ….if that’s what they can relate to…

D …but if you go against your employer…

A ….we’re agents of the state…

B Well see as long as I wasn’t advocating that this was a good thing I would take their scenario…

C I’ve done that too

B…coz at the end of the day if you can get them to learn………………(laughs) to dae it properly… (all laugh) …no but….

This is an extreme example, perhaps, but one that raises serious issues about the dangers of carrying contextualisation too far without critical consideration of purpose.

In many cases the commitment to contextualisation brings with it the requirement for tutors to furnish their groups with realia. More stuff. From my experience of lesson observations, this frequently involves food – pizzas and chocolate bars to cut up and share, supermarket goods to compare prices. Shopping catalogues are also popular. As well as providing artefacts for the contextualisation, these are often justified in relation to the need to accommodate different learning styles. In the new numeracy classroom, teaching must be adapted to more learning styles and particularly for kinaesthetic learners. The allegiance to the concept of learning styles and to the necessity of tutors catering to different styles continues to be very strong despite critiques of learning styles theory and practice (Coffield et al., 2004) which draw attention to the ways in which it can restrict rather than empower. It has become part of the culture of care, in which not identifying an individual’s style and providing for it is considered disrespectful.

I have enumerated a number of ways in which I believe tutors are adding more material to the adult learning experience with a focus on meeting individual needs with ‘relevant’ activities. In adult numeracy ‘relevance’ concentrates on arithmetic calculations in everyday activities such as budgeting; indeed literacies now encompasses a further literacy - financial literacy. Financial capabilities are referred to repeatedly throughout the refreshed Scottish adult literacies strategy (Scottish Government, 2011). Whilst these changes to approach are a positive shift from a culture of ‘death by worksheet’, I believe they can be limiting of adult learners’ possibilities and represent a limited response to socio-cultural understandings which emphasise the power relations inherent in social practices.
Firstly, there is evidence that learners have motivations for wanting to attend numeracy classes beyond the everyday application. Swain (2005) concludes that ‘mathematics does not have to be ‘functional’ to capture students’ interest, involvement…’. He found that one of the main reasons they want to learn ‘is …to prove their ability to learn a high status subject which they believe to be a signifier of intelligence’ (p. 305). This is congruent with Boaler’s point mentioned in the introduction. As she implies, the assumed link between maths and intelligence has great power, and not just in the classroom. Ernest (2002) explores how success in mathematics can ‘give students advanced power through enhanced life chances in study, the world of work and social affairs… Qualifications in mathematics are accorded a privileged role and have unique social significance as gatekeepers’. The concentration on everyday application may ignore the broader empowerment issues Ernest identifies. Whilst numeracy teachers and researchers may use the term to denote more than maths, it may be experienced by learners as less than maths – a basic functional level of the subject without status and power. There are class issues also in the embedding of numeracy in vocational interests, as Bernstein warns: ‘Vocationalism appears to offer the lower working class a legitimation of their own pedagogic interests and in doing so appears to include them as significant pedagogic subjects yet at the same time closes off their own personal and occupational possibilities’ (Bernstein, 2004, p.213).

Whilst I am by no means suggesting that adult numeracy teaching does not have an empowerment agenda, I am worried that the ‘functional’ discourse is erasing the more critical ingredients. In Scotland, literacies were described as complex capabilities consisting of knowledge, skills and understanding (Scottish Executive, 2005), understanding being linked to the more critical dimension. In texts between 2000 and 2012, the three terms gradually reduce to two – ie knowledge and skills, with understanding disappearing. At UK level, The National Institute of Adult Continuing Education’s (NIACE) report on adult numeracy presents a variety of case studies of effective practice. Effective practice is represented as ‘…relevant, interesting and enjoyable’ focusing on ‘….practical and relevant skills’ (Southwood and Dixon, 2012, p. 3). The case studies provide examples of learning for:

- Shopping for bargains
- Budgeting
- Measuring for DIY
- Decorating

The ‘vital ingredients’ of adults learning maths do not appear to include any critical approaches. Here too there is silence about the political dimensions of numeracy. I have no doubt that examples of critical approaches exist across the UK, but where this approach is invisible in authoritative documents, it may cease to be a legitimate practice, even in Scotland where the rhetoric of the social practices approach persists.

Echoing Freire and Macedo (1987), Frankenstein (1998) refers to ‘reading the world with math’. Like Gee in his aspirin bottle problem (2008) she argues that it is insufficient to support learners to merely calculate budgets or best deals correctly - budgeting tasks can make ‘money and family finance ‘neutral’” (Frankenstein, 1998): ‘Even trivial math applications like totaling grocery bills carry the ideological message that paying for food is natural and that society can only be organized in such a way that people buy food from grocery stores...’. A critical pedagogy is required which would explore the power relations of supermarkets, global corporations, consumers and capitalism. The discourses of financial literacy and employability so prevalent now in adult numeracy conceal the assumptions of a neo-liberal ideology. Skills for ‘employability’ are predicated on the requirements of the global economic race. A functionalist approach does not question these requirements.

Allman (1999) discriminates between normalizing/limited reproductive praxis and critical/social transformation praxis. Despite the discourse in Scotland of the ‘social practice approach’, the
findings of research with practitioners (Maclaclan and Tett, 2006; Ackland, 2013; Swinney; 2013) suggest that praxis tends to be of the first kind; learner-centeredness and relevance is mainly concerned with supporting people to operate within the structures - ‘a better fit for the world’ (Freire 1972, p.57). This falls short of the critical stance implied, as argued above, by a social practices perspective.

The rhetoric of ‘a social practice approach’ and its apparent anti-deficit stance has become an orthodoxy of literacies practice in Scotland (Ackland, 2013). This masks underlying differences in values, ideologies and pedagogical approaches. In the main Scottish practitioners’ construe ‘a social practice’ approach as similar to the learner centred approach which prevailed in adult basic education prior to the emergence of the new literacy studies (Hamilton and Hillier, 2006); the language has changed but this is experienced as a new way of talking about what was already accepted and ‘natural’ practice. Writing in relation to family learning, Auerbach (1995) describes this ‘post-deficit’ situation as dangerous; she examines how discourses which apparently reject a deficit model, as ‘the social practice approach’ claims to do, continue to be based on traditional deficit assumptions of the requirement for individual change to adapt to unquestioned social structures. As she does with family learning discourses, I have tried to problematize some of the claims of ‘a social practice approach’ to adult numeracy with the concern that unexamined the rhetoric may serve ‘a rationalising function, masking underlying deficit views with an aura of credibility’ (Auerbach, 1995, p.651). In Adult Literacies in Scotland 2020 (ALIS 2020, Scottish Government, 2011) the neoliberal economic project is explicitly connected to the language of socio-cultural theory. Adult Literacies for economic participation is ‘most successfully taught using a “social practice” approach’ (Scottish Government, 2010, p.7). Auerbach (1995) describes this as a ‘neo-deficit’ discourse in which the emphasis on power relations and the requirement for critical pedagogies implied by social practices perspectives are excluded.

Less is more – a critical pedagogy of numeracy

How then can numeracy education reflect more effectively the implications of social practices perspectives? Such pedagogy, I believe, requires that tutors bring less to the learning experience, taking a problem-posing stance in which they examine with learners mathematics in use in society. Even a superficial skim of the daily media demonstrates how contemporary life is saturated with numbers and statistics entangled with text. Numbers have a powerful effect on language: ‘The power of numbers is such that they render visible and hence incontestable the complex array of judgements and decisions that go into measurement, a scale, a number’ (Rose, 1999, p. 208). A critical pedagogy would engage with the power of numbers, explore calculation as ‘qualculation’ (Callon and Law, 2005), infused with values and ideologies.

It may begin, as practitioners often say, with the motivations and interests of learners but in this case the question of what and why they want to learn - maths, mathematics or numeracy - would be discussed critically, with the elephants clearly visible in the room. Within a critical pedagogy, rather than merely reflecting on their own mathematics history, learners might investigate the history of mathematics in different cultures as a means of engaging with a fallibilist perspective. It is sometimes believed that learners must master the basic processes of a subject before they can engage critically at a meta level. Based perhaps on Bloom’s taxonomy, critical thinking, it is assumed, comes higher up the hierarchical triangle of capabilities. Although a critical pedagogy of numeracy should also develop learners’ capacity to use mathematical processes for their own projects, its starting point might reverse the hierarchy to assume adults’ capabilities as critical thinkers.

Hierarchical thinking can also permeate numeracy curricula as a building block mentality where simple rote operations build systematically to more complex problems. Realistic mathematics is
Much messier and Frankenstein (1998) argues that ‘problems with neat pared down data and clear cut solutions give a false picture of how mathematics can help us ‘read the world’’. She advocates studying mathematical topics through deep and complicated problems and outlines a number of examples of investigating mathematics in use – such as unemployment statistics – which could meet the 4 goals of a critical mathematical curriculum, which she defines as:

1. Understanding the mathematics
2. Understanding the mathematics of political knowledge
3. Understanding the politics of mathematical knowledge
4. Understanding the politics of knowledge (p.53)

As in a Freirian pedagogy (1972) the complex problems can come from the learning group’s observations of their own surroundings. In this case the tutor does not bring the context to the classroom but takes the learning process into the context. Numeracy groups might use ethnographic techniques to examine numeracy practices or numeracy in the media in similar ways as have been used in literacy (see for example, Roberts and Prowse in Papen, 2005, pp. 143-146 who describe how literacy learners explored their favourite soaps critically).

Gutstein (2003; 2006; 2008; 2012) describes the development of mathematics curricula for social justice in an urban Latino school. Here current community issues, such as the redrawing of a school catchment area, provide the problems to be investigated mathematically with school pupils. This goes beyond exploring other people’s uses of mathematics to develop the capabilities to use mathematics to address and represent community projects.

Gutstein (2006) also engaged parents in a critical dialogue about the school maths curriculum. Given that Swain’s research (2005) noted that another powerful motivator for adults attending numeracy classes is to help their children with maths, this is an important extension of developing new curricula. Some adult numeracy courses of the ‘Keeping up with the kids’ variety, respond to parents’ fear of confusing their children by not knowing the ‘right way’ to do school maths, by giving them a better knowledge of the school’s approach so that what they do will ‘fit’ with this. E.g.

All parents want their children to do well at school and to succeed. However, many simply don't know where to start. Everything seems to have changed since your own schooldays, and you don't want to confuse your children by using different methods to their teacher. Family Learning can help. (Family Learning website³)

The danger is that this may reinforce an absolutist view of mathematics. It is not congruent with Boaler’s (2009, p. 138 –40) assertion that the children who are most successful at maths are those who can decompose and reconstitute problems using a variety of strategies. In her view, parents should not only be supported to help their children ‘play’ with maths problems developing confidence in a variety of strategies, parents can also have a powerful role in challenging narrow maths curricula and traditional pedagogies in schools (pp195 -206). A critical pedagogical approach with parents whose motivations are to help their children, then, would problematize schools curricula. It might involve critical dialogue about changing fashions in teaching and learning and about the relationships between maths, mathematics and numeracy. Rather than a relationship being established in which the school tells parents about how they teach maths, as is sometimes the case, the relationship could be one of critical dialogue between parents and schools in which adults are empowered to challenge the authority of school curricula.

Other aspects of family life are ripe for critical numeracy investigations. Critical approaches to examining text for author, purpose, values, positioning etc. are standard in literacy groups. A model for applying a similar critical ‘reading’ process to numeracy texts has been developed from Freebody

³http://www.familylearning.org.uk/
and Luke’s (1990) Four Resource Model of Critical Literacy. This model could be used with adults to examine commonplace texts and question how numbers, measurements and statistics are being used within power relations. Below is an example using a numeracy text from a common family breakfast cereal box.

![Breakfast cereal box](image)

**Figure 2.** Breakfast cereal box

Dr Terry Maguire’s work on developing maths eyes with children, parents and in communities explores the power of large numbers in public discourse. The question of ‘how big is a billion?’ might lead, in a critical pedagogy, to investigations about relative spending at international level and the values implicit in government budgets for war, welfare and poverty. Investigations on such issues might make use of Internet sources such as, *what can $611 billion buy?* or *Information is Beautiful* which provide different representations, including info graphics, about economic decisions.

Info graphics are becoming a significant feature of multimedia and appear daily in news stories in print, on television and on the Internet. A critical pedagogy might explore why this is the case, what makes them powerful communicators and communicators of power. As new communication technologies shift to support authorship rather than readership, learners could create their own info graphics to represent their own analyses of issues. In this section, I have sketched out just a few illustrations of a critical pedagogy of numeracy drawing from examples relating to schools as well as adult education and making links between literacy and numeracy. This problem-posing stance engages not just with the personal concerns of learners but with political issues. Gutstein insists that such curricula require teachers to build political relationships with students (2008), in which they do not merely meet people’s needs but support their projects. This may be challenging for some numeracy tutors. I share Freire’s view that education is never neutral (1972) but this view is not shared by all teachers, some of whom see this position as containing the threat that they will unduly influence learners or appear judgmental of alternative political or cultural perspectives. Being ‘non-judgemental’ and ‘non-threatening’ are linked in the adult education culture of care. De Freitas (2008, p. 205) suggests that some maths teachers may even be drawn to the subject by a perception of its neutrality. Perhaps if we concentrate on teachers bringing questions rather than answers, respect for learners may become decoupled from the need to remain non-judgemental and non-threatening. A

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4 http://www.haveyougotmathseyes.com/
6 http://www.informationisbeautiful.net/visualizations/the-billion-dollar-gram/
7 http://www.educatorstechnology.com/2012/05/eight-free-tools-for-teachers-to-make.html
critical pedagogy is one in which all are challenged to examine the taken for granted. It inevitably involves discomfort.

**Critical teacher education**

What kind of professional development might, then, support a shift to more critical pedagogies of adult numeracy? I believe its starting point must be that education is never neutral. It must explore the purposes of adult education and examine why educational content, curricula and pedagogies are the way they are not merely how to teach (Ackland and Wallace, 2006). As in any critical pedagogy of adult learning, questions, not answers, should initiate practitioners’ own investigations in which theory, policy and practice are regarded as contingent and power-laden. The process might involve Freirian decoding of representations of education. Throughout this paper I have used the three terms maths, mathematics and numeracy at different times and to denote different things according to my understandings. The significations of these three terms are fluid and they are in use in education loaded with quite different assumptions. As stated previously, numeracy is favoured by some adult educators and researchers to encompass the social practices and fallibilist perspective. In my experience it is used by many tutors, and in policy, to relate to a more functionalist view of mathematics. Recently listening to some maths colleagues in teacher education discuss their development of a new course for the primary school sector, I was intrigued to hear them insist that they would not use the term numeracy at any point. Their use of the term was pejorative, implying that it carried associations of a ‘dumbing down’ of maths. Adult learners may also perceive numeracy as more basic than maths and perhaps as a more current form of the old term arithmetic which was used in Scottish schools for a subject taught to pupils in ‘lower sets’. Numeracy is a contentious term. In teacher education, exploring the distinctions between the terms can stimulate reflexivity as practitioners surface their own assumptions but also dialogue about the power of different forms of knowledge. I have found a triad activity drawn from Personal Construct Theory (Kelly, 1955) very powerful. The three terms are presented on cards as so:

<table>
<thead>
<tr>
<th>Maths</th>
<th>Numeracy</th>
<th>Mathematics</th>
</tr>
</thead>
</table>

Participants are asked to group them as two that they think are similar and one that they think is different. They are then asked to explain why they have arranged them in this way. Questions are used to prompt an exploration of the assumptions implicit in the arrangement.

Other taken for granted concepts of adult education must also be examined. The shift in language from education to learning has been adopted ALM20 universally, but it is not without critiques (e.g. Biesta, 2005). Learner-centeredness, as I have explored above, is not automatically empowering. These shibboleths and what is held to be ‘natural’ (see practitioner quote in Practitioners’ understandings of a social practices approach section above) and accepted practice should form the core of deconstructive dialogues in a critical pedagogy of teacher education. Assumptions about the practice of other sectors, schools for example, as opposed to community based learning, and popular contrasts between andragogy and pedagogy could be deconstructed. In Scotland, the claims to the distinctive of ‘the social practice approach’ should be examined within the bigger picture of the political and ideological hegemonies that frame practice within the UK, Europe and internationally. This would entail critical discourse analysis of the policies which shape practice (such as in Oughton, 2007) combined with critical analyses of how numbers are used in policy (Hamilton, keynote presentation ALM20). We should not forget too to discuss how numbers get used in practice for justification and recognition. (In Scotland, statistics from the International Literacy Survey – 23% of...
Scots have insufficient skills – quickly achieved factual status as they were repeated at all levels of practice to substantiate the need for adult literacies work at local level.)

An understanding of learners is a requirement in most standards of teacher competence. A narrow interpretation of this requires teachers to know about the circumstances and characteristics of learners to consider the barriers they might experience to learning. Whilst knowledge of communities is important, and can be developed through trainee teachers’ ethnographic investigations, it is insufficient to support critical pedagogies. ‘Community knowledge’ should be combined with ‘critical knowledge’ (Gutstein, 2012, p. 301) – a sociological appreciation of history, economics and political relations - and would entail examining roots as well as manifestations, perhaps using problem solving tree diagrams. Learning styles for example, might be examined not merely as a phenomenon to react to but one, which may have cultural roots, mechanisms of reinforcement and a role in the maintenance of existing socio-cultural privileges.

Fundamentally, the culture of cares in which being non-judgemental and non-threatening are held as sacred principles must be questioned as potentially limiting. When participants in teacher education are themselves challenged to move out of their comfort zone, they easily see the parallels with their learners’ experience:

We ask learners to go outside their comfort zones in their learning... so why should we not be pushed outside ours? And it’s good to see how this feels (on reflection of course!) and be reminded of how valuable it is to face challenge. (TQAL participant comment8)

Risk, discomfort and uncertainty, reflexively explored, can build confidence in teachers to confront challenge for themselves and with their learners.

Conclusion

In this paper, I have explored the implications of social practices theory for adult numeracy and examined some current practices in relation to these. I argue that the discourse of ‘the social practice approach’ in Scotland may mask neo-deficit ideologies implicit in practices focussed on learner-centeredness and relevance. I have proposed some alternative practices towards more critical pedagogies of adult numeracy. Professional development, which also commits to a critical pedagogy, is key, I believe, and might write back the critical into current discourses of practice.

Acknowledgements

This paper developed from a keynote presentation at the Adults Learning Mathematics research group conference of July 2013. I am very grateful to the conference organisers for the invitation to address the group and for the opportunity to meet with researchers, many of whom have influenced my thinking as I have traversed the boundaries between literacy and numeracy.

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8 Professional development through professional enquiry http://www.nrdc.org.uk/content.asp?CategoryID=1548


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Eight Free tools for Teachers to Make Awesome Infographics
http://www.educatorstechnology.com/2012/05/eight-free-tools-for-teachers-to-make.html[accessed 29/01/14]

Family Learning: http://www.familylearning.org.uk/ [accessed 29/01/14]

How big is a billion: http://www.boston.com/news/nation/gallery/251007war_costs/ or http://www.informationisbeautiful.net/visualizations/the-billion-dollar-gram/[accessed 29/01/14]

Maths Eyes: http://www.haveyougotmathseyes.com/ [accessed 29/01/14]

Numeracy assessments, Adult Literacies Online resource: http://www.aloscotland.com/alq/viewresource.htm?id=2819[accessed 29/01/14]


Professional development through professional enquiry http://www.nrde.org.uk/content.asp?CategoryId=1548 [accessed 29/01/14]
At ALM-18, I ran a workshop entitled ‘(When) can we trust ourselves to think straight? – and (when) does it really matter?’ which raised some issues about the use by adults of mathematical thinking in decision-making. In this session I will invite participants to explore one of these issues: do we think differently when tackling abstract and contextualised problems? Do we make different / "better" decisions when we try to be logical or when we choose to be rational? I think this is particularly important because of all the effort that is going into supporting adults in classrooms to develop mathematical thinking skills in the hope that they will then use those skills to tackle problems outside the classroom. In the session you will be invited to observe and explore your own responses to some abstract and contextualised tasks.

**Biography**

I’ve been involved in adult numeracy since 1976, working mainly as a teacher, teacher-trainer (continuing professional development), and contributor to research and development projects. All of my adult teaching, and most of my other work, has been in England; I’ve also done a little research and development work in Ireland. Adult numeracy issues I’m interested in include:

- how “non-experts” (people who don’t think of themselves as expert either as mathematicians or as mathematics teachers) can support adults to learn and use mathematics
- how and why adults use or don’t use mathematical thinking when making real-life decisions in their personal, civic or work lives
- the endless struggle to make the best of challenging teaching situations, circumscribed by unhelpful curriculum or funding or assessment regimes
- mathematical jokes
Presentation slides 1-6 - making real-life decisions: does logic help, or is it better to be rational?

<table>
<thead>
<tr>
<th>Slide 1</th>
<th>Slide 4</th>
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<tbody>
<tr>
<td>Making real-life decisions: should pure logic rule, or is it more rational to be emotional?</td>
<td>Models of Decision-Making</td>
</tr>
<tr>
<td>Joan O’Hagan</td>
<td></td>
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<tr>
<td>ALM 20</td>
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<td>Wed 3 July 2013</td>
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<tr>
<th>Slide 2</th>
<th>Slide 5</th>
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<tbody>
<tr>
<td>Some things we believe?</td>
<td>Classical decision theory</td>
</tr>
<tr>
<td>• Mathematising is good.</td>
<td>Good, logical, consistent decisions</td>
</tr>
<tr>
<td>• Logic is good.</td>
<td>Logical, axiomatic thinking. Homo Economicus / Femina Economica</td>
</tr>
<tr>
<td>• Emotion is the enemy of logic.</td>
<td></td>
</tr>
<tr>
<td>• Emotion gets in the way of logical thinking.</td>
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<tr>
<th>Slide 3</th>
<th>Slide 6</th>
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<tbody>
<tr>
<td>Some things we believe about making choices?</td>
<td>Classical decision theory+</td>
</tr>
<tr>
<td>• More information is always better</td>
<td>Slightly better decisions than homo economicus, provided we rectify our deficiencies?</td>
</tr>
<tr>
<td>• More choice is always better</td>
<td>experimental economics, cognitive psychology, behavioural psychology – homo/femina should try to correct own logical deficiencies</td>
</tr>
<tr>
<td>• Logical reasoning is the ideal; that is, reasoning that conforms to classical rules</td>
<td>Homo / Femina Deficientious?</td>
</tr>
<tr>
<td>• Modelling choices using maths is good (Functional Maths)</td>
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</tbody>
</table>
Presentation slides 7-12 - making real-life decisions: does logic help, or is it better to be rational?

**Slide 7**

Heuristical decision theory

Decisions that are good enough. Decisions that are often better than "logical" ones would have been, especially where information available is limited. But how do we decide which tool to use?

Humans rarely have access to all the information we might need when making decisions. Nor are we perfectly "logical" - we do not have unlimited cognitive processing power. Instead we choose from a tool-box of strategies.

*Homo / Femina heuristica?*

**Slide 10**

- The Topic Group "Maths and decision-making" explored probabilistic thinking
- Today we’ll dabble in deductive reasoning

**Slide 8**

Darwinian decision theory

Decisions that are usually better than "logical" (impossible to achieve) ones would have been.

Humans have evolved effective decision-making tools, and strategies for tool-selection. *Animali rationally?*

**Slide 11**

The Wason Tasks

**Slide 9**

- So we humans – like other animals - have evolved some powerful decision-making strategies.
- We are also able to think about how our emotions affect our decision-making mechanisms.

**Slide 12**

You’re looking at four cards, each of which has a number on one side and a letter on the other.

Check – by turning over as few cards as possible - if this set of cards obeys the following rule... "Any card with a consonant on one side has an even number on the other"
Presentation slides 13-18 - making real-life decisions: does logic help, or is it better to be rational?

**Slide 13**

Donal is aged 18
Sean is drinking alcohol
Siobhan is drinking apple juice
Aine is aged 29

You’re in a bar, looking at four people, all of whom are drinking something.

You want to know if anybody’s breaking the “nobody under 21 is allowed to drink alcohol” rule.

Who do you want to question?
Question as few people as possible.

**Slide 16**

“Therapies”

In experiments of the abstract kind - “consonant / even tasks” 4% - 25% get it right, ie make the most efficient card choices.

“Therapies” including discussion with participants, and exposing them to their inconsistencies, raised that to about 46%.


**Slide 14**

John is doing something dangerous
Paul is wearing safety gear
George is not wearing safety gear
Fiona is not doing anything dangerous

You’re a Health and Safety manager responsible for four staff.
If they’re doing a dangerous task they should be wearing safety gear.
You can see that John is doing something dangerous but Fiona isn’t and that Paul is wearing safety gear but George isn’t.
To make sure they’re all sticking to the safety rule, who do you want to talk to?
Talk to as few as possible.

**Slide 17**

Are we more competent if we “own” the task?

If we have an “enforcer” role in a situation we’re familiar with or at least understand, we find the task easier and we almost always get it right.


**Slide 15**

What made some of these problems easier than others?

**Slide 18**

Hooked on Wason?
Have a look at......

http://www.psych.ucsb.edu/research/cep/orcsx/wason.htm

Or go to www.psych.ucsb (University of California at Santa Barbara) and search for “Wason”.

O’Hagan, J. (2014). Making real life decisions: Does logic help or is it better to be rational?
Presentation slides 19-24 - making real-life decisions: does logic help, or is it better to be rational?

<table>
<thead>
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<th>Slide 19</th>
<th>Slide 22</th>
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<tbody>
<tr>
<td>I’m not saying though that having an emotional stake always leads to good outcomes...</td>
<td>Vi’s answer was “£100”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slide 20</th>
<th>Slide 23</th>
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</table>
| But acknowledging and understanding your emotional engagement can be very effective... | Question 25
Over the course of a week the numbers of e-mails received are as shown below.
<table>
<thead>
<tr>
<th>Day</th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>emails</td>
<td>17</td>
<td>23</td>
<td>13</td>
<td>15</td>
<td>16</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>What is the median number of e-mails received over the week?</td>
<td>Vi’s answer was “16”</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<tr>
<th>Slide 21</th>
<th>Slide 24</th>
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</thead>
</table>
| A story about Vi
Vi, an adult student on a pre-GCSE course, did an initial assessment paper which included one question about the mean and another about the median. | Vi and I discussed her responses.
Vi: I can probably do them all (mean, median, mode) but I don’t know which one is which.
Joan: What would you do if you were asked to get “the average” of a set of numbers?
Vi: I’d go for the adding them all up and dividing: that’s the best answer, it’s the most accurate... You could line them all up in order and pick the middle one but it’s not as mathematically accurate. |
Presentation slides 25-30 - making real-life decisions: does logic help, or is it better to be rational?

<table>
<thead>
<tr>
<th>Slide 25</th>
<th>Slide 28</th>
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</table>
| Vi: If there were some really low numbers and one very high one, the middle one would be way off the accurate answer.  
Joan: If you had to choose an “average-sized” cake from a selection on a table, what would you do?  
Vi: I think I’d go for the middle one. I wouldn’t take the big one because it looks greedy, but not the smallest one, I’d mentally line them up and go for the middle one. Anyway you can’t be cutting bits off cakes to do an accurate thing. |
| But why did Vi connect the “mean” with “lots of decimal places”?  
She said that “mean” almost never worked out as whole numbers, but medians mostly did.  
So if you want a “good”, “accurate” answer, do the mean. |

<table>
<thead>
<tr>
<th>Slide 26</th>
<th>Slide 29</th>
</tr>
</thead>
</table>
| Vi’s views on “accuracy”  
Having lots of decimal places makes an answer “more accurate”.  
“More accurate answer” = “more correct answer” = “better answer”. |
| How had she arrived at this conclusion?  
Probably because so many “learner-friendly maths problems” use whole number data sets.  
The median is then likely to be a whole number, and the mean is likely to have lots of decimal places. Vi had (probably) spotted this. |

<table>
<thead>
<tr>
<th>Slide 27</th>
<th>Slide 30</th>
</tr>
</thead>
</table>
| Why did all these decimal places matter so much to Vi?  
Getting her personal financial calculations right - to the last £0.01 – had been very important to her.  
Hence, she told me, she’d made a link between “lots of decimal places”, “more accurate answer” and “better answer”. |
| The moral of this story?  
Behind every ✓ or ✗ on an assessment, there may be a story.  
A computerised reader of Vi’s assessment paper might have recommended that “Vi should learn how to do the median”. It was only through conversation that both Vi and I, in a critical moment, realised what was really going on. |
KEYNOTE PRESENTATION - 4: TURNING NEGATIVE TO POSITIVE: THE
CHALLENGE OF ESSENTIAL NUMERACY FOR ALL

Lynn Churchman

National Numeracy, England and Wales

‘We believe that with appropriate support and perseverance, everyone can be numerate...’ (National Numeracy)

National Numeracy (NN) is an independent charity, formed in 2012, that focuses on adults and children with low levels of numeracy. NN aims to work with partner organisations and others to challenge prevailing attitudes, influence public policy and research, identify and promote effective approaches to improving numeracy. You can find out more about the work of National Numeracy here: http://www.nationalnumeracy.org.uk/home/index.html

Biography

Lynn Churchman’s professional life in mathematics education is driven by her passion for both the subject and the capacity of people to learn it successfully. She is a nationally well-known and regarded figure in the mathematics education field, and has since 2007 been the Chair of the National Association of Mathematics Advisers (NAMA), a professional Association for mathematics education Advisers, Inspectors and Consultants. She is the Director of the National Mathematics Partnership and has been a member of the Association of Teachers of Mathematics since 1980. She has been both an Adviser and a Consultant to the National Centre for Excellence in Teaching Mathematics (NCETM), a Director of Mathematics at ARK Schools, a Specialist Adviser of Mathematics to Ofsted from 2001 to 2006 and the Principal Manager for the Mathematics Team at QCA from 1998 to 2002. She is currently a trustee of National Numeracy.
KEYNOTE PRESENTATION - 5: AN UPDATE ON 'ACTION ON ADULT MATHS'

Sue Southwood

National Institute of Adult Continuing Education, England and Wales

In October 2012, the National Institute of Adult Continuing Education (NIACE) was charged with developing and leading a plan to engage and enthuse adults about mathematics, working with national partners to develop a long term national joint strategy. Action on Adult Maths became known as Maths4Us and this presentation outlines the work carried out so far, its underpinning ethos and plans for the future. You can find out more at http://www.niace.org.uk/

Biography
Sue Southwood is Programme Manager of the Centre for Life Skills, National Institute of Adult continuing Education (NIACE). She currently leads on Functional Skills maths and English for NIACE. Her role is to advocate for adults with the lowest skills, to widen participation and to improve quality in adult learning. Sue trained as a teacher in 1986 and worked for Norfolk County Council where she taught Literacy and GCSE English to adults. She has held a number of posts including working as a Curriculum Manager for City and Islington College and spending a year in Spain as an EFL Teacher. Before joining NIACE in August 2004, Sue set up and managed workplace basic skills programmes for Northern Foods, Ford Motor Company and Transport for London. Sue tweets [at] SueSouthwood and runs a Functional Skills discussion group on Linkedin.
SECTION 2: Papers
IS THE PRAGMATIC APPROACH AND USE OF VIDEOS DEPICTING FAMILY LEARNING PEDAGOGICALLY JUSTIFIED?

Jackie Ashton
Learning Unlimited, London, England

Ann McDonnell
University of London, England

Abstract
This paper reflects an unresolved debate that has arisen from our involvement in a national government funded project led by National Institute of Continuing Education (NIACE) that is concerned with creating online resources for engaging adults with mathematics. One of the units of the project is aimed at helping parents to support their child’s developing mathematics. This paper addresses some questions that have arisen about the use of videos depicting family learning and whether it is pedagogically justified.

Background
Family learning is popular and research suggests it is successful in the UK (Desforges & Abouchaar, 2003; Feinstein et al., 2004; Nutbrown et al., 2005). One definition of the principles of family learning states:

The pedagogical approach can be summarised as one that promotes the family as a learning environment, builds on home culture and experience, encourages participatory learning, promotes family relationships as supporting well-being and readiness to learn, promotes a culture of aspirations in adults and children, and provides opportunities to build confidence, try out new skills and ideas. (Lamb, 2009, p. 3)

If we accepted these principles, the challenge was to create an online based family maths course that upheld this pedagogical approach and that was unique and different from other internet resources. This prompted a unique production of unscripted video recording of parents interacting with their children, playing games, doing activities and talking about maths. The use of video was not without controversy. In particular we considered the following: Is the pragmatic approach and use of videos depicting family learning pedagogically justified?

Video has been used as a teaching aid in recent years in a range of educational contexts and levels. There are different rationales for choosing video in class such as appealing to visual learners and promoting discussion. “Audiovisual material provides a rich medium for teaching and learning. Video can effectively communicate complex information to a student and, if used creatively, can become a powerful expressive tool” (www.jiscdigitALMedia). Children, in particular, are felt to be engaged by the medium of video. It has also been found, in a study relating to the teaching of social skills, that they will copy behaviour seen in a video they have watched: Video modelling “helps
children acquire new skills by viewing, from videotape, behaviour that was performed by another individual, and then imitating that behaviour” (www.tdsocialskills).

Discussion

However, there is no data on whether video can be successfully used in the home to help an adult to support a child’s learning. We had two major concerns when deciding to base the unit around video as the focal point for learning. One concern centred on the skills that adults might require in order to use the videos to ‘teach’ their child. Some studies have suggested that parental support means that parents are engaging in some aspect of teaching and that this requires some form of training (McMullen & Abreu, 2010). Another concern relates to parents whose first language is not English since it was found that some ESOL learners had limited success trying to support with maths at home due to difficulties with language (Ashton et al., 2011).

The second concern related to the use of video and whether it was pedagogically justified in the context of family learning and raised such questions as:

1. Would watching videos of another parent and child help parents to develop their skills in supporting their children or would it put pressure on them to be too perfect?

2. Would videos be flexible enough to show the viewers that they show ideas / suggestions for how to support your child at home informally or would they come across as too prescriptive?

3. Are parents likely to watch videos aimed at helping them see how they can support their child with maths at home?

When considering the questions relating to the second point we made a conscious effort to use real families and to ensure that what was filmed was not too perfect by trying to make it as natural as possible, for example by not having a script. One factor counteracting this aim was the fact that they were being filmed and there was a need to get good visuals and sound, which often required more than one take, resulting in children losing focus and reducing some of their natural enjoyment in doing activities with their parents.

We were also careful to add comments that emphasise that what is shown are ideas and suggestions for how to support children’s developing numeracy skills and that the viewer may have other ideas.

These questions will only be answered once the materials have been properly trialled with families. However initial feedback on the materials from practitioners has so far been overwhelmingly positive, with much of the praise directed at the video element. Practitioners were also asked to consider the potential for using the videos in a classroom–based family learning context. One family learning practitioner gave this feedback:

The videos would be useful for showing to parents in family learning classes particularly those where the children are not involved directly in the sessions. They would enable parents to understand how they could do the activities in playing with their child between sessions, using resources easily available at home, and suitable language and praise. The videos show that both parent and child(ren) enjoy doing them! They would be particularly useful for parents who are also ESOL learners, as a spoken language resource. Caroline Penn (Herts Adult and Family Learning Service)

Reflecting on early feedback

This feedback indicates that the use of video on a family learning course could be pedagogically justified. In this situation the course tutor would be on hand to support their effective use in modelling suggested ways for parents or other adult carers to interact with children and help them develop their numeracy skills. It remains to be seen whether the resources could be used successfully at home.

without the support, guidance and motivation associated with attending a family learning course. However it is important that the various needs, attitudes and motivations are considered when evaluating the use of the materials in both the classroom setting and the home. Ashton et al. (2011) categorised family learning participants according to their attitude towards mathematics, levels of confidence in their mathematical ability and motivations for attending a family numeracy course:

One group consisted of confident parents who want to discover the current methods used in school and get ideas for supporting their child. Would a video show them that they are in fact already supporting their children or would they feel happier with a course that shows them the methods being used in school?

Another group consisted of those who are not so confident in their mathematical ability but have a positive attitude and want to help their child. Would the videos give them the confidence to do mathematical activities and games with their child or would they prefer a course where they could hone their own skills in maths before trying to help their children?

There was also a group of adults with low confidence and a negative attitude possibly linked to maths anxiety. Would they feel more confident trying to help their child at home than exposing themselves in a group of people who may be strangers or who may be known to them as fellow parents? Would a video give them the skills they need – could it change attitudes if they realise that you can help your child quite simply by talking to them while doing normal activities? Or would they feel that the person in the video is more skilled and able than them and be turned off even more?

It is hoped that trials of the materials will be able to address the questions above and therefore supply the answer to whether the pragmatic approach and use of videos depicting family learning is pedagogically justified.

References


Using Video in Teaching and Learning (Available online at http://www.tdsocialskills.com/using_video_to_teach_social_skill.htm) (accessed 05.10.13)
CONSTRUING MATHEMATICS-CONTAINING ACTIVITIES IN ADULTS’ WORKPLACE COMPETENCES: ANALYSIS OF INSTITUTIONAL AND MULTIMODAL ASPECTS *

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Abstract
In this paper we propose and discuss a framework for analysing adults’ work competences while construing mathematics-containing “themes” in two workplace settings: road haulage and nursing. The data consist of videos and transcribed interviews from the work of two lorry-loaders, and a nurses’ aide at an orthopaedic department. In the analysis we adopt a multimodal approach where all forms of communicative resources (e.g., body, speech, tools, symbols) are taken into account. We also incorporate the institutional norms of workplace activities into the analysis. We coordinate a multimodal social-semiotic perspective with a learning design sequence model (Selander, 2008) which makes explicit the institutional framing. Adopting this framework enables us to understand learning as communication within a domain, with an emphasis on content matters, interpersonal aspects, and roles of communicative resources and artefacts. A tentative theme, Measuring: precision through function and time, is described and we illuminate how workplace specific resources for measuring provide efficiency and function.

Keywords: workplace, mathematics, competence, multimodality, learning, institutional norms, interpersonal

Introduction
An overarching aim of the project to which this paper is connected is to analyse and understand adults’ mathematics-containing work competences (Wedege, 2013). In doing this we want to investigate how we can learn from the workplace without taking assumptions of school mathematics for granted. In subsequent investigations and papers we will relate these findings to vocational education and general schooling. In this paper we propose and discuss an analytical framework for analysing mathematics-containing activities in adults’ work competences where different functions of multimodal communication and institutional aspects are addressed. Two situations from our data, both video collected, will serve as a starting point for the article. They will be briefly described in the beginning of this article, then discussed later in the article.

In one situation, we followed two lorry-loaders when they loaded a trailer. As will be shown later on, one essential resource in this task was the loading pallets on which most of the goods were positioned. We will describe how we can identify measuring in the work performed by these lorry-
loaders and how our analytical framework helps us to broaden our understanding of the mathematics-containing activity. In another situation we visited a nurses’ aide at an orthopaedic department. Her main responsibility was to put plaster cast on injured limbs. Measuring was also identified here and was elaborated using the framework.

**Research on and approaches to workplace mathematics**

In the literature concerning workplace mathematics we have distinguished a number of themes that are particularly relevant to us. They are described here and we pay extra attention to research in relation to measuring. In addition, different possible approaches for research in this field are described.

**Mathematics in the workplace**

Research on mathematical practices in the workplace has been carried out since at least the beginning of the 1980s: For example, the Cockcroft report (1982) which initiated several other studies.

Research on workplace mathematics has been described as a field which has passed through different phases (Bessot & Ridgway, 2000; FitzSimons, 2002, 2013; Hoyles, Noss, Kent, & Bakker, 2010; Wedege, 2010a). In the early years researchers presumed that mathematics was easily observable and visible in workplace activities, and frequently such studies resulted in (long) lists of mathematical contents described in “school mathematics” terms (Fitzgerald, 1976). Many of these studies have been criticized for having been conducted with, what has been described as a mathematical lens (Zevenbergen & Zevenbergen, 2009) or mathematical gaze (Dowling, 1996, 1998), or with a far too narrow conception of mathematics/numeracy (Harris, 1991; Noss, 1998).

Seminal works on the use of mathematics in informal workplace or everyday settings during the 1980s and 1990s draw attention to, for example, differences in strategies and cognitive structures between “school mathematics” and “out-of-school mathematics” and to the fact that schooled and unschooled individuals perform and succeed differently in everyday and workplace practices as compared to school contexts (Lave, 1988; Nunes, Schliemann, & Carraher, 1993).

Research on workplace mathematics has, during recent years, been dominated by socio-cultural perspectives. Increasingly sensitive theoretical and methodological tools have been used to reveal the complexity of mathematical practices at work. One finding is the fact that mathematics in work is often hidden in activity, culture, social practice, and artefacts. This has been used to explain why it is so difficult to classify these mathematical practices in school-mathematical terms and, when so classified, how the complex use of mathematics in workplaces is reduced to simple computations, measurements, and arithmetic (Gustafsson & Mouwitz, 2008; Hoyles, Noss, & Pozzi, 2001; Keogh, Maguire, & O’Donoghue, 2010).

**Mathematics as activity: The example of measuring**

Bishop (1988) identified six pan-cultural activities which can be characterized as mathematical activities. These are: counting, locating, measuring, designing, playing, and explaining. In this paper, we focus mainly on measuring which, according to Bishop, is concerned with “comparing, with ordering, and with quantifying qualities which are of value and importance” (p. 34).

We are looking at practices which include measuring in a broad sense. Measuring is central in mathematical activities in people’s everyday lives and in workplace practices in all cultures. Several studies have shown the importance of measuring in different occupations (for an overview see, e.g., Baxter et al., 2006). Among these are studies on carpenters, carpet layers, nurses, process- and manufacturing industry workers, and so forth. Other more recent examples are Bakker, Wijers, Jonker, and Akkerman (2011) who write about the use, nature, and purposes of measurement in
workplaces; a study of process improvement in manufacturing industry (Kent, Bakker, Hoyles, & Noss, 2011); a study of boat-building (Zevenbergen & Zevenbergen, 2009); and a study of telecommunication technicians (Triantafillou & Potari, 2010).

Measuring is closely linked to estimating, and the boundaries between these activities are not obvious. Adams and Harrel (2010) have, as part of a more extensive study, presented observations and interviews from four occupations, and concluded that experienced workers often replace measuring with estimation. One important conclusion is that estimation is a complex activity that is learned by experience, and is based on a different rationality from conventional school-methods for measurement which may focus on units and calculations (at least in secondary school). In this article we will use the term measuring linking to the concept of activity (ie doing) rather than the generic label measurement, to address the human activity of measuring. We also include estimating in the concept of measuring.

Adopting a subjective approach when researching adults’ competence

In the literature on mathematics in the workplace, two approaches can be identified (Wedege, 2013). In the subjective approach, the interest lies in mathematics as part of personal needs and professional competences in working communities and in various situations. In the general approach, the interest lies in societal demands or demands made from the perspective of school mathematics. Drawing on Bernstein’s (2000) pedagogical models, performance and competence, Wedege (2013) also identifies professional competence as construed from the workplace rather than taking school mathematics as a starting point. In the research described here, we draw on the subjective approach when we strive towards capturing the mathematics-containing activities within workers’ competences. In this article we present a tentative finding of what could be called a theme in professional competence within the sectors of nursing/caring and vehicle/transport. Adopting our analytical framework from this article, we are able to construe wider themes between activities in two sectors of work. These themes will in subsequent research and papers be connected to a general approach when we compare our findings to the demands made within school.

In this article, we draw on the notion of competence. Ellström (1992) describes competence as an individual’s readiness for action with respect to a certain task, situation or context. Wedege (2001) concurs and opposes a view of competence as consisting of “objective” competencies defined as being independent of individuals and situations. According to Wedege (2001), 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 (p. 27).

The term competence can be further understood from two perspectives: (a) formal competence in terms of authorisation; for example, that a person has adequate education for a given position; and (b) real competence in terms of whether a person will really be able to demonstrate the abilities that are identified; for example in a particular certification (Wedege, 2001; 2003). In terms of our research interest here, the second meaning is more relevant.

Addressing the socio-political through the notion of institutional framing

We position this paper in a socio-political paradigm – paradigm is here understood according to Lerman (2006) – in mathematics education. This is connected to sociology and critical theories (Valero & Zevenbergen, 2004; see also Ernest, Greer, & Sriraman (Eds.), 2009). Mathematics
incorporates means for understanding, building, or changing a society (Mellin-Olsen, 1987). Skovsmose (2005) acknowledges this (see also Jablonka, 2003; Gellert & Jablonka, 2009), whilst also stressing that mathematics does not hold any intrinsic good; instead mathematics can be used for different purposes in society and people’s lives. Thus, there is a need to address the role of the use of mathematics in society and in this article we incorporate institutional aspects of workers’ mathematics-containing activities.

We view the institutional context as always present. An early example of a theoretical discussion of this is given by Popkewitz (1988), who considers institutional framings as one way to address social and critical aspects in studies of school mathematics (see also Mellin-Olsen, 1987). Also, in work-places the institutional context and societal dimensions are always present (e.g., Salling Olsen, 2008). Here are included dominant discourses, the use of artefacts developed over time, the division of time, established routines, workplace structures, and authoritative rules (Selander, 2008, drawing on Douglas, 1986). A similar view is described by Bishop (1988, p. 36) when he writes about the development of units, and systems of units: “there is a clear progression, with the main idea being that of the stronger the environmental and social need the more detailed, systematic and accurate the measure”. As we will show in our analysis and findings, what constitutes an accurate measuring unit may be quite different in the workplace from what is usually emphasised in school.

Institutional aspects were addressed by Wedege (2010b) when she proposed the concept of sociomathematics. She described sociomathematics as both a subject field combining mathematics, people, and society, and a research field. We are also inspired by FitzSimons and Wedege (2007) who adopted Bernstein’s (2000) concept of horizontal and vertical discourses (see also FitzSimons, Mlcek, Hull, & Wright, 2005). Bernstein refers Vertical discourse to knowledge within a discipline, such as academic mathematics. This knowledge is coherent and systematic, The horizontal discourse refers to contextual knowledge and a relevant example for us is the context bound mathematics used and developed in the workplace. In the study by FitzSimons et. al (2005), activity theory (Engeström, 2001) was adopted as a theoretical framework, and the main findings were that mathematically straightforward skills become “transformed into workplace numeracy competence, when the complexities associated with successful task completion as well as the supportive role of mediating artefacts and the workplace community of practice are taken into account” (p. 49).

Analytical framework

In this section we present our analytical framework where a theory of communication – multimodal social semiotics (e.g., Van Leeuwen, 2005) – is coordinated with a model of a learning design sequence. Design is here understood in a broad sense, for example including both aesthetic and functional aspects. The term coordinate implies that the two theoretical approaches are compatible with respect to underlying assumptions (Prediger, Bikner-Ahsbahs, & Arzarello, 2008).

Learning as multimodal communication

In this article we attempt to problematise learning in order to avoid the term learning becoming a black box (Ellström, 2010). Ellström uses the term black box to refer to learning as it is in studies on innovations in workplaces. Learning is here described as a key concept, but it is not really spelled out how it is operationalised in the studies. We view learning as closely connected to human activity and understood as meaning-making towards an increased communication in the world through the communicative resources of a discipline (Selander & Kress, 2010; see also Björklund Boistrup, 2010). Learning in a work-place constitutes, at least in part the competence that the worker gains over time. This competence is not something fixed, but changes and may evolve over time. In operationalising learning, we discuss knowing that is part of workplace activities, and hence the worker’s competence, rather than discussing learning as such. By using the term knowing instead of knowledge we want
make clear that we do not take into account an objective knowledge “out there” to be learnt. Instead, knowing is viewed as constructed and construed in communication among humans throughout history (Foucault, 2002; see also, e.g., Delandshere, 2002; Valero, 2004b, Volmink, 1994). What valid knowing is and how it is demonstrated in communication is not set in stone. At different times throughout history, the perception of what qualifies as important knowing has changed and will continue to do so.

In this article we draw on a multimodal approach when we adopt social semiotics as part of an analytical framework (Van Leeuwen, 2005). In a multimodal approach, described by Selander (2008; see also Björklund Boistrup & Selander, 2009), all modes of communication are recognised. Communication in a multimodal perspective is not understood in the same way as communication in a narrow linguistic perspective, focussing on verbal interaction only. Rather, all kinds of modes are taken into consideration, such as gestures, and gazes, pictorial elements and moving images, sound, and the like. Modes are socially and culturally designed in different processes of meaning-making, so that their meaning changes over time. It is also the case that “content” in one kind of configuration (e.g., as a measure on a dip stick), will not necessarily be exactly the same content in another configuration (e.g., as a number on a device for filling the oil):

Different representations of the world are not the “same” in terms of content. Rather, different aspects are foregrounded. In verbal texts we read linearly, within a time frame, whilst a drawing will be read within a space frame. And a graph does not represent a knowledge domain in the same way as numbers does [sic]. The modes that are “chosen” in a specific situation reflect the interest of the sign maker, and they are therefore not arbitrary. (Björklund Boistrup & Selander, 2009, p. 1566)

We argue for the importance of understanding multimodal communication to be able to fully understand a phenomenon such as mathematics knowing and learning in a workplace. In social semiotics, three meta-functions are often operationalized in analysis (Halliday, 2004). Halliday focused mainly on written and spoken language in his work but in this article, drawing on Van Leeuwen (2005), we adopt the meta-functions in connection with a multimodal approach. These meta-functions are: the ideational, the interpersonal, and the textual. In Morgan (2006), these functions are used with a focus on the construction of the nature of school mathematics activity. In this article, we start out with the meta-functions as used by Kress et.al. (2001; see also Björklund Boistrup & Selander, 2009). The ideational meta-function is related to human experience and representations of the world (Halliday, 2004). Here there is a possibility to address the content, the “what-question” of a communication. In this article we look for measuring activities and resources in lorry-loaders’ and nurses aides’ practices and competences. The interpersonal meta-function is about how language (used in a broad sense in this article) enacts “our personal and social relationships with the other people around us” (Halliday, 2004, p 29). In this article we examine the roles of measuring activities for and in relations between the people involved. The textual meta-function is related to the construction of a “text” and this refers to the formation of whole entities (Halliday, 2004). With a multimodal approach, the term text refers to multimodal ensembles which are communicatively meaningful and part of the overall pattern of the actual communication. Here we are interested in what roles resources and communicative modes play in the measuring activity.

**A model for understanding learning in other-than-school contexts**

We draw on a model where a multimodal approach is connected to an institutional framing (Selander, 2008; Selander & Kress, 2010): a design theoretical perspective of learning.
This first model (Figure 1) gives the general principles for how communication, learning, and knowing can be addressed without starting from the perspective of a school setting, but considering meaning-making and learning as something always present. The starting point, the “situation”, is here to be taken as any other-than-school setting, for example a workplace. The worker and his/her work are embedded in a social practice with different kinds of social norms and with different semiotic resources at hand. The duration of the process that the model captures can be rather short (seconds) but also longer (like hours or days). Selander (2008) writes:

In many instances we are put in situations where we try to figure out the challenge and what standpoint and action that is meaningful. It could be situations where we ask ourselves if the bus ticket still is of value or if we can swap a book, for example given as a present, for another one in the book store. In each such micro situation we also learn something about what is usual or “proper”, about restrictions and regulations etc. And there are also moments of creativity when we try out different solutions. (p. 14-15)

It could be possible to use this general learning design sequence to analyse what a person is doing at work. A person who is performing a well-known task is now and then met by an explicit learning purpose while working. It may be a situation where an innovation of some kind is needed in order to facilitate the work (Ellström, 2010). Even more explicit is the learning purpose when the person is new at her/his job. Even though the model by Selander (2008) is relevant for a study of learning and knowing mathematics at a workplace, we find the next model more suitable for our purpose. The reason for this is that we, as the research team, change the situation when we are present, and even more when we pose questions during the filming of the activity. The model that we use as our analytical frame is the Semi-Formal Learning Design Sequence.
The idea behind the semi-formal learning sequence in Figure 2, is that the starting point is a *setting* (not a *situation*, as before) where the learner is confronted by an articulated learning purpose. In our case it is mainly the workplace that constitutes the setting where there are institutional norms affecting what is taking place and what is counted as relevant knowing. When we as researchers pose questions (see below for a description of our interviews), the worker is invited to meta-reflect on her/his work. There are then transformations taking place when the worker communicates through her/his actions, engaging with different artefacts, and then describes and explains the working process through speech and gesture, and so forth. In this sense both the primary transformation unit – the actual work – and the secondary transformation unit – answering our questions and showing us the tools and processes of the work – are going on at the same time.

**Methodology**

The research design of the qualitative study for which this article is written is a case study. When using the term *case study*, we draw on Yin’s definition (1989):

A case study is an empirical inquiry that:

- investigates a contemporary phenomenon within its real-life context, when
- the boundaries between phenomenon and context are not clearly evident, and in which
- multiple sources of evidence are used (p. 23)

The phenomenon we are interested in here is to learn more about mathematics within the work and competences of lorry-loaders and nurses’ aides. More specifically we are interested in how we can analyse the complexity of mathematics interwoven in work. Our data gathering methods consist of:

- *Videos* which were filmed at one or two visits at each work-place. We followed one worker (or two), who was doing her/his regular work, with a hand held camera for about one hour. As

To support our research, we also recorded sound with additional sound recorders. In total, we visited six workplaces, three in each sector.

- **Apprenticeship interviews** which were performed when possible during the filming. With apprenticeship interviews, we mean that we took the role of a person trying to learn the work processes that the worker was engaged in. We then posed curious questions to the worker during her/his work.

- **Photographs** which were taken during our visits with a special focus on signs, notices, artefacts, etc.

- **Interviews** which were performed after the first visit at the workplace. These have so far been performed by Maria C Johansson as part of her PhD process (Johansson, 2013; in preparation). We used excerpts from these interviews to inform our understanding of the video data.

This article is based on data from two workplaces: one road-haulage company and a plaster unit at an orthopaedic department of a hospital.

### Analysis and example of findings: measuring activities

The analytical framework that we present in this article is connected to the subjective approach mentioned earlier (Wedge, 2012). Here, we pay attention to adults’ work competences and the activities we can construe as being possible to connect with mathematics. Our emphasis is on learning/communication in a workplace setting and we view workers’ actions as communication, as well as learning and knowing.

In the following, we utilise the analytical framework of the three meta-functions outlined above (ideational, interpersonal, textual) to describe the measuring activities as part of lorry-loaders’ work competence and of nurses’ aides’ work competence. The kind of measuring that we focus on in this analysis is what Bishop (1988, p. 34) labels “quantifying qualities which are of value and importance.” We also use the Learning Design Sequence model above, in how we view the presence of the institutional framing. The three meta-functions are actually interwoven and it is an analytical construction to tease them apart. This may, in a systematic and structured way, bring forth findings that we otherwise would not capture. This also causes the same “events” to turn up more than once in the analysis, but with different emphasis.

#### Lorry-loaders

At the road-carrier company, we visited lorry-loaders, one of whose tasks was to load trailers according to specifications provided in written forms. The form was developed by administrative staff in the office. While we were there, one trailer was loaded using forklifts, and in discussions we were told about the written loading form (see Figure 3) which specified, for example, the number of pallets, the weights of the goods, the companies’ names for delivery (these names have been deleted in the photograph), and where different pallets were intended to be unloaded. In the first excerpt, the two lorry-loaders are talking with two persons from the research project before they start to load one trailer. One of them, Con (pseudonym), describes how they decide whether to load the trailer in one or two layers (Excerpt 1). The transcripts are made multimodally. In Excerpt 1, we identify Time, Speech (what people say and how they say it), Body (what people do including resources and artefacts), and Gaze (where people look).
Later on, when the workers started loading, the use of the pallets becomes clearer. Either each pallet was positioned “horizontally” in the trailer, like this: . In this case there is room for two pallets beside each other along the trailer’s width. If instead they were positioned vertically there was room for three. This was also explained in a communication after the trailer was finished loading. Con explained how the size of the pallets, 800 mm x 1200 mm, makes this possible. In Figure 3 the pallets in the trailer are shown and it is also possible to get a glimpse of the loading form that Con describes and shows with his hands early in Excerpt 1.

Figure 3. Images from the road-carrier company.
In the following, we describe our analysis where we operationalise the social semiotic meta-functions and where we also coordinate with the learning design sequence by Selander (2008). The concepts from the Learning Design Sequence (Figure 2) are in italics and the analysis is mainly organised through the meta-functions.

- **Ideational meta-function:** We analysed the data from the lorry-loaders, looking for human experiences and representations of the world (the content, the what-question) in relation to the measuring we could construe. We then construed a measuring activity in the institutionally framed setting where the lorry-loaders used the loading pallets (i.e. resources) as measuring units for the actual goods to be carried. Here the workers did not use the measuring means and units normally used in school, such as using a measuring tape to find out the two lengths in centimetres, and then calculate the area.

- **Interpersonal meta-function:** When analysing the data from the lorry-loaders for personal and social relationships, we were able to capture how the informal measuring activity via the pallets entailed their involvement in the process on behalf of the customer, and also gave a certain amount of control to the loaders. Our assumption is that the use of pallets as measuring resources saves time, which in the end lowers the cost for the customer. This may be seen as one purpose with the use of the pallets. The pallets were also communicative resources for the two lorry-loaders who, ALMost without any talking, communicated on how to position the pallets on the trailer when carrying them on the forklifts. When Con told the research team about his work we could identify engagement and an interest in making clear what he meant and generally in his work. This analysis is based on his speech and the many gestures. During this meta-reflection there were many transformations between speech and gestures.

- **Textual meta-function:** When looking at the multimodal text that was communicated to us as visitors through actions, speech, gestures, etc., we analysed the roles of, in this case, the informal measuring activity through the resources of the pallets. Our finding is that the pallets took the role of facilitating the measuring, as they provided a measuring function in themselves as well as a means for efficiency and effectiveness. Another resource, the written form, made the measuring activity visible for people involved. As shown in Excerpt 1, we could identify how there are transformations between different communicative modes which also forms the activity. One transformation goes from the written loading form to the loading process. This transformation concerns both media (from written form to physical activity) and modes (from writing in words and symbols to speech, body movements, and gaze). During the loading, Con ticks off the things that are loaded, an activity which constitutes a new transformation.

- **Institutional norms:** The loading form is normally used at this workplace and formed the situation. In this workplace, its use is a long-standing tradition. The pallets are standardised according to the transport sector regulations.

**Nurses’ aide (plastering)**

In the orthopaedic department of a hospital, we visited a nurses’ aid who specialised in plastering. During our visit, she put plaster on an arm and hand of a patient who had an injury to his thumb. In this situation we were mainly silent and the chat was between the nurses’ aide and the patient. For this example we have chosen only to present pictures. In Figure 4 some details from the room where it took place are shown. It is also possible to see how the nurses’ aide rolls out dry plaster wrap on the arm. The analysis mainly is focused on this action.
In the following we describe our analysis of measuring activity from the work performed by this nurses’ aide. Similar to the previous section, the concepts from the learning design sequence (Selander, 2008) are in italics and the analysis is mainly organised through the social semiotic meta-functions.

- **Ideational meta-function:** We were able to construe a measuring activity where the setting was a room that was designed for plastering. There were boxes with different kinds of plaster stored on shelves and there were appropriate tools present (resources). Prior to the actual plastering process, the nurses’ aide measured up with the dry plaster wrap directly on the patient’s arm. The aide then used the first measuring as a unit and made repeated folds based on this unit before finally adhering it to the patient’s arm. The resource for measuring here is the plaster itself.

- **Interpersonal meta-function:** This plastering activity is very important with respect to the patient (in the healing process). Measuring directly on the arm may then be the most accurate. It should also look neat and tidy (caring about the patient). The nurses’ aide described the procedure of plastering to the patient as she worked. This also seemed to act as a cALMing function and simultaneously gave her an opportunity for meta-reflection on her activity. Here we could identify interest and interaction.

- **Textual meta-function:** The plaster has several roles here. The main function was to stabilise the arm and hand during the healing process. Moreover, it fulfilled a measuring function, and its correlation to the length of the arm was part of the function. The transformations took place both during the primary and secondary transformation unit. In the primary transformation unit, one example is where a specific distance on the arm was transformed from the body to the plaster (resource) by the nurses’ aide when she measured up. This unit was then transformed to a longer piece of plaster during the repeated folds. In the secondary transformation unit, there were transformations from modes such as body and artefacts into speech when the nurses’ aide explained the process to the patient.

- **Institutional norms:** Methods for plastering are designed together at this workplace. Some may be general between hospitals, and some are specific to this workplace. Speed is important: Another patient is waiting, but the long-term function for this patient is the highest priority.
A general theme of measuring activity: Precision through function and time

Here we connect the two cases described above and we construe a general measuring activity between the two sectors of vehicle and transport, and of nursing and caring, which we expect to be found in many workplaces within these sectors.

*Ideational.* This measuring activity is an alternative to school-traditional precision measuring with tools. The worker uses “rough” measuring units. At a first glance it seems like function, result, and/or time is superior to precision. At a second glance we interpret that the accurate precision for the loading process or healing process is accomplished *through* this workplace specific measuring activity. "Rough” in this case does not contradict that the method is well adapted to the situation and that accuracy is judged by the situational needs and constraints/restrictions.”

*Interpersonal.* In this activity we captured relationships between the worker and the workplace and (in)directly the customer (company or patient). Ethical considerations are that it is important to do a good job so that the customer is satisfied. This could for example include economic considerations such as not to spend too much time which would increase the cost and decrease the profit. Interpersonal aspects also concern what the employer may impose on the workers (a good job, customer satisfaction, expediency). Also aesthetic aspects, such as “looking neat and tidy”, are part of what is regarded as a good job and what may make the customer satisfied.

*Textual.* The workplace specific resources for measuring provided efficiency and functionality. Resources can then have the role of facilitating the work; for example, the task is completed more quickly through the use of “rough” measuring units. When a measuring needs to be recorded, appropriate documents are included.

*Institutional.* Resources contribute to standardisation within the workplace, as well as between workplaces. Written forms can take this role as well as other resources for measuring. Notions concerning a “good job” also concern the institutional framing. The client is thus part of the institutional framing.

Concluding discussion

As stated previously we position this article within a social and critical paradigm. For our work, this quote by Valero and Zevenbergen (2004) is particularly relevant:

> In mathematics education it is always possible to ask whose knowledge is being represented in society, schools and classrooms, and with what effects for the different participants in it. The recognition of the different and multiple positions that social actors can adopt in relation to and with the use of (school) mathematical knowledge is at the core of discussions of equity, social justice and democracy in mathematics education. (p. 2)

They continue by arguing that such social aspects are essential to an understanding of mathematics education practices in broader institutional contexts (see also Valero, 2004a). At the same time, such aspects form this broader understanding of the social. In terms of research on mathematics-containing activities in workplaces, our standpoint is that such an understanding incorporates an interest in whose and what kind of knowing is represented in school mathematics, and also how this is connected to the broader social context. We know from earlier research (Fahrmeier, 1984; Lave, 1988; Masingila, Davidenko, & Prus-Wisniowska, 1996; Nunes Carraher, Carraher, & Schliemann, 1985; Nunes, et al., 1993; Scribner, 1985) that the mathematics that can be construed from workplace activities has connections to, but is not the same as, school mathematics. One way to put it is that workers’ voices are missing in the school context, often also in prevocational studies.
The complexities of the workplace could be brought into school mathematics if we want to represent also the knowing of workers in different sectors. This is described by Steen (2003) in this way:

The contrast between these two perspectives—mathematics in school versus mathematics at work—is especially striking (Forman and Steen 1999). *Mathematics in the workplace makes sophisticated use of elementary mathematics rather than, as in the classroom, elementary use of sophisticated mathematics.* Work-related mathematics is rich in data, interspersed with conjecture, dependent on technology, and tied to useful applications. Work contexts often require multi-step solutions to open-ended problems, a high degree of accuracy, and proper regard for required tolerances. None of these features is found in typical classroom exercises. (p. 55; our emphasis).

What we have accomplished through utilising our analytical framework, based on a multimodal approach and a design theoretical approach, is to connect the people, the workers and their competence, to the workplace, and to the institutional framing. The three meta-functions have served the purpose of connecting the content (ideational) – the measuring, with relations between the people involved (interpersonal), with a special attention to the roles of resources (textual). The model by Selander (2008; see also Selander & Kress, 2010) helped us understand the institutional framing, and also the different kinds of communications that took place when we, on one hand, observed the work-processes, and, on the other hand, posed questions about it. What became clear to us in the analysis is what measuring accurately (Bishop, 1988) may mean in a workplace context, for example that precision for the loading process or healing process was accomplished through workplace-specific measuring units.

We would argue that our research is part of a development of research methods and analytical frameworks sensitive enough to do justice to the complexity and to the power of mathematical practices other than school-mathematics, for example, in workplaces. Included here is a view of the worker as self-governed and competent (Wedge, 2001) as well as an approach that there is much to learn from workplaces that can be brought into vocational education and training (VET) settings. This article is consequently an example of a study within what Wedge (2010b, p. 452) labels as sociomathematics: “a research field where problems concerning the relationships between people, mathematics and society are identified, formulated and studied.”

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I remember the whole board being full of different calculations and trying to make some sense of it: The influence of significant moments in adult numeracy teachers’ own learning experiences on their teaching practice.

“I REMEMBER THE WHOLE BOARD BEING FULL OF DIFFERENT CALCULATIONS AND TRYING TO MAKE SOME SENSE OF IT”

(The influence of significant moments in adult numeracy teachers’ own learning experiences on their teaching practice) *

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Abstract

In researching how adult numeracy teachers actively motivate and enable learners to apply the numeracy skills they learn to their own real life practices, a case study of two adult numeracy teachers and their learner groups was undertaken. This paper compares the teachers’ contrasting personal experiences of mathematics learning to consider how significant moments in their own learning experiences may have influenced their beliefs about, and approaches to, their adult numeracy teaching practice. Similarities and differences between teachers’ approaches are explored and compared, to conclude that teachers’ learning experiences greatly influenced their beliefs and teaching practices.

Key words: mathematics; numeracy; learning; experience; teaching; practice

Introduction

The transfer of mathematics skills from classroom to real life contexts is both complex and problematic (Kanes, 2002; Kelly, 2011; Nunes & Lave, 1988; Schliemann & Carraher, 1993), but that is what teachers of Functional Mathematics¹⁰, in the UK, are required to facilitate in order to “help people to gain the most out of life, learning and work” (Qualifications & Curriculum Authority, 2007, p.3). When researching the specific ways in which adult numeracy teachers actively motivate and help learners to apply the numeracy skills they learn to their own real life practices, both teachers had successfully completed their specialism teaching qualification, the Numeracy Diploma in Teaching in the Lifelong Learning Sector, with me, the researcher, as their tutor, on a part-time basis over two years. The data identified both similarities and differences in teachers’ practices and approaches. Having asked the teachers about their own mathematics learning experiences, I became curious about the ways in which their previous experiences may have shaped their numeracy teaching practices, and that is the focus of this research paper.

Research identifies beliefs, contexts, thought processes and development programmes as influences on teachers practices, suggesting that teachers’ own learning experiences are just one factor in shaping their teaching approaches. Ernest (1994) suggests the practice of teaching mathematics depends primarily on the teacher’s system of beliefs about mathematics and mathematics’ learning and teaching, the constraints and opportunities provided by the social context of the teaching situation, and the teacher’s reflection and level of thought processes, including their ability to reconcile their practice with their beliefs. The social context includes the adopted curriculum and assessment systems as well as learners’, peers’, and managers’ expectations, and these factors can be highly influential in affecting a teacher’s approaches in the classroom. The teacher’s level of consciousness of his or her own beliefs about and approaches to mathematics, and the learning and

¹⁰ Functional Mathematics is a qualification available in compulsory and non-compulsory education in the UK, which is designed, for learners to acquire skills, which enable them to apply mathematical skills in work and life situations.
teaching of mathematics, is also important; Ernest (1989) suggests that having an awareness of what the alternative beliefs and approaches might be, as well as the teacher’s ability to “reconcile and integrate classroom practices with beliefs” (p.253), are key to determining a teacher’s practice.

Swan and Swain (2010) used a teacher development programme and resources, which became available nationally as Thinking Through Mathematics (Swan & Wall, 2007), to challenge and change adult teachers’ beliefs and teaching practices. The programme’s aims were to engage teachers in using challenging and ‘connected’ approaches in which students were more collaborative and active in their learning, focussing on activities which enabled learners to develop their conceptual understanding. Some teachers on the programme reported that pressures from management hindered their use of the approaches, which supports Ernest’s (1994) suggestions about the influence of the social context. Overall, the teachers developed a more connectionist orientation, moving away from transmission and discovery views of teaching and learning mathematics. Swan and Swain (2010) concluded that changes in teachers’ beliefs were instigated by the changes in practice which teachers tried out, discussed and reflected upon.

The approaches and activities promoted within Swan’s Thinking Through Mathematics resources were modelled by the tutor/researcher on the case study teachers’ qualification courses, and the teachers were actively encouraged to try out the activities in their own practice, and to reflect on their effectiveness. In addition a social practice approach was also promoted, and teachers were encouraged to take account of their learners’ real-life uses of numeracy, and to use authentic materials (Appleby & Barton, 2008) to help learners make links between the concepts they were learning and their potential application outside of the classroom. Therefore, during their courses, their tutor challenged and may have influenced the two case study teachers’ beliefs about numeracy and about numeracy teaching and learning.

But, how were their beliefs formed in the first place? Who else shaped their ideas and beliefs about numeracy and about numeracy teaching and learning? What other experiences may have helped determine the kind of teacher they have become? These are some of the questions that arose during the data analysis stage of the primary study.

The following section considers a range of researchers’ views about what, in a person’s background and experiences, affects their beliefs and practices as teachers. Then, the research methodology is outlined before the findings are presented in terms of teachers’ experiences and their methods and approaches. Finally the findings are analysed to draw conclusions about the way in which personal learning experiences influence teachers’ practice.

**The effect of teachers’ backgrounds on their teaching practice: a literature review**

Guillaume and Kirtman (2010) undertook a study of 144 pre-service elementary (primary) teachers in the USA, to investigate how previous mathematics “experiences contribute to teachers’ images of themselves as teachers and notions of what it means to teach well” (p.121). The authors point out that mostly, “teachers are products of the school systems that they pass through as students and re-enter as professionals” (p.124) and that both school and non-school experiences influence the beliefs and values they have. The research showed that most of the trainees’ stories identified both “powerfully positive” and “poignantly negative” (p.128) peaks and troughs in their self-reported performance levels in, and attitudes towards, mathematics over time. The peaks and troughs were often linked to participants’ reactions to: particularly powerful teachers, specific content, or by significant experiences such as examinations or phases in their own social or emotional development. A subset of the respondents received messages, whether intended or unintended, about their own intelligence and ability (or lack of it) to do mathematics. Ninety-eight (68%) of the participants identified the
power that a teacher had on their self-esteem and their outlook on mathematics. Of these, 73 (around half the total sample) identified that a teacher had changed their views of mathematics in a way which had a long lasting effects. Guillaume and Kirtman (2010) suggest that because out-of-school experiences (for their participants) were limited in mathematics, the role of teachers in shaping students’ attitudes towards mathematics, and their ability to learn it, was particularly prominent.

Williams (2011) also considers teachers’ experiences of learning throughout their schooling, as well as the influence that other teachers may have had on their teaching approaches, as trainees and as qualified teachers. Both the teachers Williams researched worked as ‘A’ Level\textsuperscript{11} mathematics teachers in sixth form colleges, and were recommended as highly successful teachers.

In Williams’ research, John (pseudonym for a participant), focusses primarily on “finishing the syllabus and getting the grades” (2011, p.133). His lessons focus on presenting the mathematics and examples followed by learners practising questions, giving one-to-one support as well as further group explanations where necessary. In addition, John supports struggling students on a one-to-one basis outside the classroom. Williams’ findings are that John’s beliefs about learning and teaching are significantly shaped by his experiences as a learner. For example, a personal tutor helped John to realise that with practice he could master the procedures involved (p.134); and his own A-level (Mechanics) teacher, who had a very traditional approach, inspired him. At university John became unable to understand much of the mathematics he was taught and instead explains that he learnt by “tricks” (p.135). Williams discovered that although during his career John spent some time being a more innovative teacher, focussing on implementing approaches encouraged by his teacher education course, over time his focus reverted to a more traditional approach, influenced by both his social context and by his personal role models or “heroes” as Williams calls them.

Sally (pseudonym of another participant in Williams, 2011) focusses primarily on conceptual development. Her lessons involve “group work, problem-solving and discussion as well as whole-class activity where group work is communicated” (2011, p133). Sally explained that when she was a learner, she would take home her notes from lessons taught by rote, to work on until she was able to make sense of the ideas herself. Her experiences as a private tutor helped her understand how essential self-confidence and self-belief are to enable learners to think things out for themselves. As a sixth form teacher she went back to her working class roots to offer herself as something of a role model to her learners: someone who can achieve success despite their low socio-economic background. Williams’ (2011) findings are that Sally, too, draws powerfully on her own learning experiences, and also that both teachers teach in a way that would support their own approaches to learning as learners of mathematics themselves. Williams explains: “the stories crucially figure learners-in-general as being like the learners they used to be” (p.140). Sally does not draw much on her own teachers’ styles; the few teacher experiences she does draw on shows them as “anti-heroes” (Williams, 2011) i.e., figures she does not wish to emulate.

Amin (2012) explores the stories of three mathematics teachers’ experiences of their own mathematics learning in South Africa, where they grew up “in the shadows of apartheid” (p.2), subject to socio-political and racial adversity, and economic deprivation, resulting in limited access to education and career choices. Amin explores their memories of their own education and the significant others that helped them achieve success in mathematics, and also explores their own approaches to teaching.

In her research, Amin analyses the stories of one male and two female teachers. Aziz, male, had a father who pointed out the mathematics in the everyday things around them. For example, whilst

\textsuperscript{11} Advanced Level (‘A’ Level) qualifications follow compulsory schooling in the UK, and prepare learners to go onto further academic study (e.g. university degrees).
Brooks, C. (2014). *I remember the whole board being full of different calculations and trying to make some sense of it: The influence of significant moments in adult numeracy teachers’ own learning experiences on their teaching practice.*

shopping they had to calculate the sales tax on items, and he would explain “how mathematics was used in the construction of roads and buildings” (2012, p.5). Aziz explains that due to his father’s teaching, rather than his school teachers’ lessons, he sailed through mathematics at school. He now sees parents rather than teachers as those who most affect the outcome of the children he teaches, and Amin suggests that as a result of this, Aziz “resisted the role of inspiring, creative teacher” (p.7), instead teaching “vague and abstract” mathematics (p.6). In the absence of parental involvement, he does not have high expectations for his learners.

Sindiswe, one of the female teachers in Amin’s (2012) research, was taught by a teacher who “spoke a lot about Pythagoras” (p.4) but never told his learners what made Pythagoras such a great mathematician. He told the learners that only he (the teacher) knew about mathematics and that they “were too stupid to do mathematics” (p.4). Sindiswe recounts: “I believed him, for a while” (p.4). However a change of job for her father meant the family moved to another city and Sindiswe went to a new school where she was able to learn mathematics and be successful in her examinations. Therefore Sindiswe experienced both poor and good teaching and, perhaps as a result of this, sees the role of the teacher as crucial to learner success.

Nisha, the second female teacher in Amin’s (2012) research, explained that she was, overall, a very good learner, but weak in mathematics because of the “unkind and very unsocial” (p5) maths teachers she had: one who spent much time focussing on just writing numbers, another “killed [them] with mental tests” (p.5), stressing the importance of speed, and another was unable to explain how he solved the problems he gave them. At the interview, Nisha reflects that she is probably trying to be the kind of teacher that her own teachers were not (i.e., she spends time explaining things and she tries to make maths fun so that she is not a bad maths teacher herself). Nisha was a self-reliant and independent learner (2012); she explains that she basically taught herself, and as a result of this, she, unlike her own teachers, wants “to make it work for kids” (p.5).

Skovsmose (2012), on whom Amin (2012) draws, suggests that whilst social, economic, political and cultural factors influence a person, the “person’s experiences and interpretations of possibilities, tendencies, propensities, obstructions, barriers, hindrances” (p.2) also shapes their ever-developing “foreground”. I interpret Skovmose’s concept of a person’s foreground to mean someone’s self-perceived opportunities or potential. Skovsmose explains that both external and subjective factors shape a person’s foreground. I suggest that those subjective factors might be a mixture of both cognitive and affective responses, and it is these which define a person’s perceptions. Skovsmose proposes that the construction of meaning may be supported by creating classroom activities which relate to scenarios relevant to learners’ backgrounds, but that showing an active interest in a student is more powerful in helping establish meaningfulness.

Skovsmose explores the idea of “ruined foregrounds” (p.5) where a lack of social and economic resources, and stereo-typing, crush the opportunity of a person reaching their aspirations. In terms of a learning situation it could simply be something that appears unattainable to a learner or to a group of learners, and Skovsmose (2012) suggests that such a “ruined foreground[s] can be the most direct cause of failure in school” (p6).

Wedege explores Bourdieu’s concept of habitus, which she describes as “a system of dispositions which allow the individual to act, think and orient him or herself in the social world” (1999, p211). Skovmose’s concept of ‘foreground’ has some resemblance to this. Wedege points out that the system of dispositions that Bourdieu explores are durable (Bourdieu, 1980 – translated by R. Nice, 1990 – as cited in Wedege, 1999), so although they are strong, they can nonetheless be changed, i.e. they are not permanent. Skovsmose’s concept of foreground is that of an ever-developing perception of one’s own potential, i.e. something that is changeable, although at times potentially quite
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impenetrable. Therefore, this suggests that teachers’ beliefs, although strong, can change; Guillame and Kirtman (2010), and Williams (2011) suggest that other teachers can effect such change.

The literature described above suggest that teachers’ beliefs, social teaching contexts, and level of thought processes all influence a teacher’s practice. Teachers’ own experiences of the school system, as learners, and in identifying teaching approaches, are thought to help shape their beliefs about teaching and learning. Research also suggests that use of alternative teaching approaches, through development programmes, can influence a change in teaching beliefs and approaches. These ideas were drawn upon when trying to analyse and interpret whether, in the case study data, there appeared to be any connections between teachers’ learning experiences and their teaching approaches. The methodology is outlined below before the findings and analysis are discussed.

**Methodology and Methods**

A collective case study of two adult numeracy teachers from the further education sector was undertaken, as part of a wider MA study. The two teachers (Anne and Katie) were selected by purposive sampling (Cohen, Manion & Morrison, 2011), i.e., they were specifically chosen because I had previously observed them actively seeking to make links between mathematical concepts and real-life contexts in which the mathematics could be used. Having obtained ethics approval from Anglia Ruskin University, permission from the participants’ learning organisations, and informed consent from the two teachers and their learners, data were collected from discrete numeracy classes in two different Adult and Community Learning settings during May-June 2012. One learner group was working towards an adult numeracy qualification, the other was a family learning group, there to learn how to support their children’s mathematics learning.

Semi-structured interviews were held with each teacher to discuss their backgrounds, aims and methods; these were audio-recorded then fully transcribed for the purpose of analysis. The use of open questions (e.g., ‘what was your own experience of learning maths at school?’) helped maximize data integrity. For each teacher, two two-hour observations of their teaching were carried out, to observe the methods teachers use to help learners make links between their numeracy learning and the use of numeracy outside the classroom. The purpose of carrying out the observations was to enable me to verify what teachers said they did at the interview stage (Robson, 2011), and to capture approaches that may not have been voiced. Field notes were made during the observation to record non-audio information and audio-recordings were made using a digital recorder. Relevant parts of the audio recordings were transcribed for the purpose of analysis, and integrated with the field notes.

During analysis of the primary study I was interested to note that the teachers’ own experiences of learning mathematics contrasted, and therefore for this paper I used the data I had already collected to investigate this further. As identified in the Introduction, questions which arose were: How were the teachers’ beliefs formed in the first place? Who else shaped their ideas and beliefs about numeracy and about numeracy teaching and learning? What other experiences may have helped determine the kind of teacher they have become? The interviews did not explore the teachers’ personal backgrounds (e.g., how their beliefs about mathematics and their views of themselves as learners may have been influenced by their own parental role models, and their childhood and adult experiences outside of school), therefore the first question remains outside the scope of this paper. Given the available data, the focus was to investigate how previous mathematics teachers and mathematics and numeracy learning experiences may have shaped these teachers’ beliefs and practices. The findings of the research are intended to contribute to the work of teacher educators and teachers in considering the development of teaching practice.
Brooks, C. (2014). I remember the whole board being full of different calculations and trying to make some sense of it: The influence of significant moments in adult numeracy teachers' own learning experiences on their teaching practice.

A thematic coding approach was used as the basis for analysing the transcribed interviews and observation notes, to identify themes arising (Robson, 2011). To identify the types of activities used in practice, some pre-determined codes were identified at the outset, informed by a review of the literature (e.g. Kelly, 2011) and prior experience, but these were amended and other codes arose during data analysis. Corbin and Strauss (2008, p66) liken the process of coding data to “‘mining’ the data, digging beneath the surface to discover the hidden treasures contained within data.” This approach was essential in minimising researcher bias and in seeking to represent the data as truly as possible. The types of teaching and learning activities were categorized according to how ‘abstract’ they were, i.e., devoid of any non-mathematical context, and, at the other extreme, how ‘situated’ they were, i.e., immersed in a real-life context. Categories that sat between these two extremes were also identified during coding and analysis, e.g., ‘Quasi’ methods, which include the kinds of mathematical word problems which are included in mathematics and numeracy textbooks, worksheets and test/exam questions, but which commonly bear little resemblance to real life (Dowling, 1998). The number of occurrences of different types of activities that were either observed or outlined by teachers during their interviews was used to establish the extent to which the two teachers used similar or different types of activities. The order in which different types of activities were sequenced, during classes, was also analysed.

Having gained a picture of the similarities and differences between teachers’ approaches, instances where teachers had talked about their own mathematics learning experiences were analysed to identify themes and connections arising from these memories, which might inform teachers’ beliefs, and possibly their practices. These instances were considered alongside those where they talked about their learners, again helping to discover their underlying beliefs. Having identified very contrasting personal learning experiences, I analysed the possible relationship between teachers’ learning experiences and their respective teaching approaches, as arising from the data, then turned to the literature to support further analysis of this.

The next sections outline the findings, starting with teachers own learning experiences, then considering their teaching approaches, before moving onto analysis of possible relationships between them.

**Teachers’ experiences of learning mathematics**

**Anne**

Anne is a numeracy tutor in an adult community college, working on a sessional basis, and she supports family learning classes in the community as well as general adult Functional Mathematics classes in her college. Anne left school at sixteen with qualifications which include CSE Arithmetic, to work in the investment banking sector in London. During her parental career break she gained a GCSE in Mathematics and an AS level in English Literature, before achieving her teaching qualification, and is currently undertaking an MA in Education.

Anne found her experiences of learning mathematics at school largely abstract, explaining: “I don’t ever remember it being anything to do with...everyday life. I can only ever remember chalk

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12 The Certificate of Secondary Education (CSE) was, prior to 1988, a qualification available for those learners in compulsory education who were not deemed sufficiently academic to achieve the alternative ‘O’ Level qualifications.

13 General Certificate of Secondary Education (GCSE). GCSEs are currently the most common form of qualification available in compulsory schooling. They replaced the CSE and ‘O’ Level qualifications.

14 AS Level qualifications form the first half of an Advanced Level (‘A’ Level) qualification. These are academic qualifications aimed at 16-19 years olds to prepare them for university. (They follow on from GCSEs).

15 Master of Arts degree
Brooks, C. (2014). *I remember the whole board being full of different calculations and trying to make some sense of it: The influence of significant moments in adult numeracy teachers’ own learning experiences on their teaching practice.*

and talk type approach – on the board and then you do it”. She recalls a mental image of one of her teachers:

She was going through multiplication…the column method…through the rules of this is how you do it.
I remember, kind of, the whole board being full of different calculations and trying to make some sense of it. That’s…my real memory of maths at school.

This negative memory of the impenetrable wall of abstract algorithms is an important one for Anne.

Anne says she “lagged behind” at primary school and she specifically remembers feeling “quite worthless”, explaining: “I remember actually sitting there thinking I really don’t get it, I really don’t get it, but I can’t put my hand up…” This compared to a more positive experience in secondary school, where for the first three years she explains: “I had quite a good teacher, and I quite enjoyed it, and even though it was quite abstract, she was kind of gentle, and it was a different approach”. However, as a rebelling teenager, other factors affected her learning and ultimately she was entered for a CSE rather than an ‘O’ Level exam. Her school explained to her that “because [she] wasn’t clever enough in maths, [she] had to take arithmetic…” (p2); Anne feels she could have done better.

As an adult learner she became a much more independent learner, seeking information from books and websites in addition to her teachers.

Anne expanded on the idea of feeling quite worthless:

…that feeling of not being good enough. You’re not good enough for that set, or you’re not good enough for that level…It’s not a positive message about learning in general because I think it does go to other things. People think if you’re good at maths then you’re good at everything, don’t they?

Here Anne is drawing on the idea of maths as a signifier of intelligence, suggesting that because she wasn’t very good at maths, people (including her teachers and perhaps herself) thought she wasn’t very clever generally. Her words also suggest that being told she wasn’t good enough in maths shaped her beliefs about herself more generally. In her role as a parent she supports her children with their learning to try to ensure they do not experience the same negative feelings.

Katie

Katie is a numeracy tutor in an adult community college, supporting adult Functional Mathematics groups within her college, working on a sessional basis. She stayed on at school to take Physics, Chemistry, Mathematics and Further Mathematics at A level, before achieving a BA in Engineering from the University of Cambridge. Following graduation she became a management consultant and then had several management roles in a large international company. Following a parental career break, she achieved her teaching qualification.

Katie’s overriding memory of school mathematics was also that it was largely abstract: “I remember learning rules and routines, with very little application to real life”, with the possible exception of primary school where she remembers: “doing basic measurement and things like that”. She describes her later experience of Further Mathematics as “horrendously abstract”, explaining: “I actually knew that I was having difficulty, thinking how on earth can this be used in real life?”. Nonetheless, Katie’s qualification choices and successes suggest that she was very good at mathematics throughout her schooling, and that she had few problems learning it.

A particularly memorable event for Katie was her entry test for university. She explains:

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16 The Ordinary Level (‘O’ Level) was, prior to 1988, an academic qualification available to learners in compulsory education which prepared them to go onto further study.
17 Bachelor of Arts degree
I can remember very specifically one question; it was about working out moments and momentum, and we’d done that in a purely abstract fashion, and the question was if you twiddled a Rubik’s cube into different shapes and formats how that changed it…It was a real, real challenge to actually apply it to a real object that you were familiar with.

During her engineering degree, which started to “put things in a practical context”, this difficulty continued. She explains:

I actually found it very difficult to link the kind of pure mathematics with an actual application. It’s not that I couldn’t see the purpose of it, but I actually found doing the maths was hard in that context…it was difficult to see why that bit of maths was the relevant maths to use.

Katie found her mathematics knowledge useful to her in many of her jobs, including as a management consultant, where she was required to analyse company accounts and project present value into the future along with other types of modelling. In a later job, as a Marketing Manager for a multinational organisation, she was required to undertake market research and explains that she “had to learn maths on the job to be able to do that” as she had not previously studied statistics. She describes this as “a very practical application of maths, in order to make very expensive decisions based on the analysis”.

**Teachers’ methods and approaches: findings**

**Similarities and differences: methods**

Two types of activities stood out as being the most commonly used by both teachers. The most common was where teachers and/or learners made links between real-life contexts and the mathematics they were exploring in the classroom, through discussion. The next was where the focus was on the abstract, either the numbers themselves, or on the underlying patterns, relationships and concepts.

The third most frequent category differed between the two teachers. Katie used ‘Quasi’ methods, which include the kinds of mathematical word problems which are included in mathematics and numeracy textbooks, worksheets and test/exam questions, but which commonly bear little resemblance to real life (Dowling, 1998). In contrast, ‘Situated’ methods was the next category in Anne’s practice, where learners and/or teachers provided examples of their actual uses of mathematics within a real life context, e.g. a learner, who is a care worker, unable to check her pay-slip because it was presented to her in hours and decimals of hours rather than in hours and minutes.

The sequences of activities observed in the classroom and discussed at interview were also analysed to identify any patterns emerging from the order of different types of activities. What emerged from this analysis was that the teachers have converse approaches to teaching overall. In general, Anne tends to start with real life contexts, using these to identify the maths within, and then addresses the mathematics identified using more abstract activities. In contrast, Katie generally starts with more abstract concepts and calculations and then makes the links between these concepts and real life contexts.

**Approaches: Anne**

Themed analysis of the interview data provided a deeper exploration of these differences. Anne always starts with what her learners know, explaining “I don’t see that I can make any connections if I don’t do that”, regularly getting learners to produce mind maps to pool their knowledge. Her approach is for the learning to come from the learners, rather than her, or from text books. She avoids “being autocratic”, and explained her dismay when one of her volunteers ‘took over’ an activity that a
Brooks, C. (2014). *I remember the whole board being full of different calculations and trying to make some sense of it: The influence of significant moments in adult numeracy teachers’ own learning experiences on their teaching practice.*

group of students were doing, saying: “before I know it, he’s writing different fractions on the board and it’s really busy, and I didn’t even want to write a fraction – I wanted them to write the fraction!” She explained that this incident upset a student as well as herself.

Her drive is to help learners to feel good about themselves and their ability to learn mathematics. She takes time to value her learners: “Each week without fail I always make sure I share what students are doing, to look at different approaches, to praise the diversity of what students bring in”. She articulates: “it’s about how they [learners] feel about themselves…about their own self concept…that’s what I feel”, and later she draws on this idea again, relating it to her own experiences, saying: “It’s about what’s inside and how you feel about yourself”.

Anne discussed the importance of being learner focussed, and identifying contexts that are relevant to all learners. She identified that each learner has different numeracy needs and contexts, e.g. one learner needs to understand her wage statement, others wish to learn the mathematics they couldn’t master at school so they can help their own children, and others do not live independently. She explains it is challenging, but possible, to find contexts that are relevant to all learners. It is evident she knows all her learners and their life contexts well. Her overall style for her scheme of work is topic-based teaching (Ness & Bouch, 2007), mapping the learning to the curriculum, within the umbrella topic. For example, using the broad topic of Energy Use, her learners chose to explore aspects that were of specific interest to them such as electrical units used by a hairdryer or a kettle, or hot water used in a bath.

**Approaches: Katie**

Katie identifies the difficulty of balancing her own aims for learners with her organisation’s aims:

> I know I won’t have a job if they don’t get funding, so it’s absolutely in my interest for people to pass the qualifications and take them. Whereas…I know that some of the learners don’t actually need the qualification; they’re only in the class for their own personal gain.

Here Katie voices some of the conflicting aims that teachers seek to mediate. This perhaps explains why, although Katie is sensitive to learners’ individual needs, the curriculum drives the organisation of her schemes of work. Her style is to spend periods of three to four weeks developing knowledge, methods and concepts of some aspects of the curriculum, then to consolidate this by using a carousel of activities, which are designed to stretch learners to apply their learning to real-life problem solving scenarios. The time pressure of covering all the necessary mathematics skills and concepts drives the pace of learning, which at times may be too fast for some learners, which Katie is uncomfortable with. However she tends to revisit subjects throughout her scheme of work, in different ways, to enable learners to gradually make their own sense of concepts.

Katie suggests that starting with the abstract concept, rather than a situated context can help learners. As an example she refers to the place value system and using it to make sense of multiplying and dividing by 10, 100, etc., explaining that sometimes “putting it into a context isn’t necessarily a helpful thing to do straight off…[because] metric measurement is so confusing for some people”. She also suggests that when starting off in a context-free way, learners are often motivated to relate it to a context they know, e.g. money, to help explain their thinking, during discussions.

Nonetheless Katie tries to regularly incorporate real life contexts that are meaningful to learners, but suggests that this is not straight forward: “You pick any one thing that’s right for one person and it might not be right for anyone else”, so although she tries to put things into context, “whether it’s the learners’ own contexts is another question”. She admits that “if I understand everyone well enough I can try and do that [put it into their contexts], but I don’t really understand all their backgrounds and
Brooks, C. (2014). I remember the whole board being full of different calculations and trying to make some sense of it: The influence of significant moments in adult numeracy teachers’ own learning experiences on their teaching practice.

what they’re doing”. Her solution to this is to give multiple examples that people are likely to be familiar with in some way, to hopefully prompt them to make their own links. An example of this is using the weather forecast and temperature, as well as a bank balance and a profit and loss account, to show how positive and negative numbers can be related to real-life contexts.

Analysis of the links between teachers’ own mathematics learning experiences and their approaches to teaching numeracy

Following data analysis it occurred to me that the different course outcomes (I observed Anne’s family learning class and Katie’s general numeracy class) may account for the teachers’ different methods and approaches. However a brief follow up telephone interview with Anne identified that her approaches are consistent across both her family learning and her general adult numeracy classes. This suggests that the differences are more to do with personal approaches to teaching than course outcomes.

Anne

Anne experienced both peaks and troughs in her performance and attitude towards mathematics during her schooling, perhaps not dissimilar to some of the other teachers in Guillame and Kirtman’s (2010) research, and like those teachers, the changes were influenced by her reactions to teachers as well as to phases in her own development. Despite being told she wasn’t clever enough to take higher level mathematics, she retained a perception of herself that she could have done better, so perhaps the balance of positive as well as negative experiences prevented her foreground from being ruined (Skovsmose, 2012).

Nonetheless the feeling of not being good enough formed part of her foreground. She acknowledges that it was not solely her school experiences that prevented her from reaching her full potential, but clearly her teachers had a significant impact. Perhaps this taught her that she could not rely totally on her teachers to help her reach her full potential, which made her a more independent learner as an adult. However, like Sindiswe (Amin, 2012), Anne sees the role of the teacher as very important to her learners’ success. It is evident that she also sees her learners themselves as a very important learning resource.

Her most prominent memory of learning mathematics from school is of struggling to make sense of a board full of multiplication calculations. In contrast, a teacher she liked she described as ‘kind of gentle’. In her own teaching practice I would argue that Anne draws on the former teacher as an “anti-hero” (a figure she does not wish to emulate) and the latter as a “hero” (Williams, 2011). This is demonstrated by her learner-led approach throughout her practice, including her high attentiveness to her learners’ feelings, and her dismay at her volunteer writing fractions all over the board.

Katie

Katie was successful throughout her mathematics education, and was likely to have experienced a consistently high level of performance and a positive attitude towards mathematics (Guillame & Kirtman, 2010). Although not explicit in the data, I suggest that in contrast to Anne, Katie was identified as ‘clever’, contributing to a very positive foreground (Skovsmose, 2012) which helped her to become a high achiever.

Nonetheless she was aware of the limitations of her knowledge and her teachers, as her “horrendously abstract” Further Mathematics learning meant that at times she struggled to apply the mathematics to real objects and to her Engineering degree. Therefore, like Sindiswe (Amin, 2012) and Anne, I think Katie also sees the role of teacher as important to her learners’ success.
Brooks, C. (2014). I remember the whole board being full of different calculations and trying to make some sense of it: The influence of significant moments in adult numeracy teachers’ own learning experiences on their teaching practice.

It is clear that Katie is very aware of the contrasting experiences her learners had to her own, with most unsuccessful in achieving mathematics qualifications at school. She acknowledges that she doesn’t understand all her learners’ backgrounds, but she genuinely believes that “everybody has a lot of capability in numeracy, but they don’t always realise they’ve got it” and she sees it as her role to help learners to realise this and to believe in themselves. In this way Katie is different to Aziz (Amin, 2012), who was also very successful in mathematics learning, but who saw the family rather than the teacher as having the main role in facilitating mathematics learning.

Katie did not mention specific teachers in her interview, but she makes significant efforts in her own practice to help learners relate the abstract concepts to practical, real life problem solving. Therefore I suggest that to some extent she draws on her Further Mathematics teacher, at least, as a kind of anti-hero (Williams, 2011), i.e. as the kind of teacher she does not wish to emulate. This is demonstrated in the way that she gives her learners multiple examples of real-life uses of concepts such as negative numbers, and also in the problem solving carousel activities which are a regular feature in her schemes of work.

Both teachers

In contrast to Anne, Katie is perhaps less resistant to the influences of her organisation and management goals, or perhaps the culture of qualification success is more prevalent in her college than in Anne’s (Ernest, 1994). Consequently Katie tries to maintain a balance between situating the learning in real life contexts and preparing her learners for their test.

Williams (2011) suggests that teachers see “learners-in-general as being like the learners they used to be” (p140), and there is evidence to suggest that, to some extent, this is the case for Anne, who seems to understand, and empathise with, her learners on several levels, but less so by Katie, who recognises that the learners she is working with are different to the kind of learner she was. Nonetheless, as a learner, being able to apply the mathematics was important, and she tries to help her learners to do this, so perhaps in this way she sees them as like her.

Conclusion and Recommendations

This paper has explored ways in which teachers’ own mathematics and numeracy learning experiences have influenced their system of beliefs about numeracy and numeracy learning and teaching. It seems that their own mathematics learning experiences have been highly influential in shaping their beliefs about mathematics learning and teaching, and in cultivating their underlying approaches to their own teaching practice, including the influence of previous teachers providing roles as ‘heroes’ and ‘anti-heroes’. There was also some evidence to support the idea that teachers teach learners in a way that would support teachers’ own approaches to learning, and that their work context may influence their practice.

Therefore it is important to raise numeracy teachers’ awareness of the influences on their practice. Teachers should be supported to explore the links between their own life and learning experiences and their teaching practice approaches, to discuss and challenge their beliefs, and to support them to test and evaluate alternative approaches, to see which work best for their own learners. In this way it might be possible to enhance teachers’ practices, despite their seemingly deep-rooted beliefs, to find a balance that maximizes learners’ learning as well as meets their organisation’s goals.

References

Brooks, C. (2014). *I remember the whole board being full of different calculations and trying to make some sense of it: The influence of significant moments in adult numeracy teachers’ own learning experiences on their teaching practice.*


BEYOND QUESTIONNAIRES – EXPLORING ADULT EDUCATION TEACHERS’ MATHEMATICAL BELIEFS WITH PICTURES AND INTERVIEWS *

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Abstract

Because of the impact that mathematical beliefs have on an individual’s behaviour, they are generally well researched. However, little mathematical belief research has taken place in the field of adult education. This paper presents preliminary results from a study conducted in this field in Switzerland. It is based on Ernest’s (1989) description of mathematics as an instrumental, Platonist or problem solving construct. The analysis uses pictures drawn by the participants and interviews conducted with them as data. Using a categorising scheme developed by Rolka and Halverscheid (2011), the author argues that adults’ mathematical beliefs are complex and especially personal aspects are difficult to capture with said scheme. Particularly the analysis of visual data requires a more refined method of analysis.

Key words: adult education teachers, mathematical beliefs, qualitative methods, content analysis

Introduction

Beliefs and their influence on an individual’s actions have been researched for over a century. In the field of education belief research has gained momentum after the cognitive revolution, which led to more interest in teachers’ thinking and decision-making processes (Thompson, 1992). More specifically, beliefs relating to mathematics and the teaching of mathematics have been investigated in a number of contexts, and while in some areas concrete results have been produced, open questions remain. The “unevenness” of mathematical belief research not only applies to the geographic distribution and to particular thematic areas, as identified by Pehkonen (2004), but also to specific target groups. The field of adult education, more specifically adult basic education, seems to be particularly neglected. While Taylor (2002; 2003) or Dirkx and Spruinding (1992) discuss general beliefs of adult educators, only a limited number of studies on mathematical beliefs of adult educators could be identified18. The study presented in this paper, therefore, aims at contributing to this neglected field and describes the mathematical beliefs of five Swiss adult education teachers. In line with its exploratory nature, its overall approach is a qualitative one. On the basis of the work of Rolka and Halverscheid (2011) pictures created by the participants themselves are used in combination with interview data to explore these adult education teachers’ mathematical beliefs. In addition to interpreting these data, the usefulness of different data sources as well as the suitability of the employed methodology is assessed.

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18 Among these few two contributions from previous ALM proceedings are worth mentioning: Henningsen and Wedege (2003) discussed the issue of values and mathematics, and Stone (2009) looks at how the institutions in which teachers work affect their beliefs and practice in the classroom.
Theoretical framework

The need for a generally accepted definition for beliefs has already been postulated more than twenty years ago, for example by Pajares (1992) and Thompson (1992). Yet even in the seminal work on mathematical beliefs by Leder, Pehkonen and Törner (2002), no generally agreed upon definition has been identified or proposed. Beliefs are considered “a messy construct” (Pajares, 1992) and the wide variety of definitions is occasionally considered one of the reasons for the lack of progress in this research field (Pajares, 1992). Very often terms such as conceptions, attitudes, values, judgements or personal theories – to name a few – are used synonymously. Some of them are broader than others and they stress cognitive and affective aspects to different extents (Pehkonen, 2004). As this study is based on a specific methodological approach presented by Rolka and Halverscheid (2011), it also follows these authors’ understanding of beliefs, namely that beliefs are considered to be a person’s world view (Rolka & Halverscheid, 2011, p. 521). It therefore adopts a very broad and inclusive approach, integrates cognitive as well as affective aspects and accommodates the view that beliefs entail both conscious and sub-conscious elements (for a more extensive discussion of these issues see Pajares, 1992; Furinghetti & Pehkonen, 2002; Pehkonen, 2004).

When it comes to mathematical world views, there is more agreement, particularly regarding the fact that there is not one right view of mathematics. Ernest (1989) describes three contrasting views of mathematics, namely (1) a problem-solving, (2) an instrumentalist and (3) a Platonist view. Again they have also been used as a reference by Rolka and Halverscheid (2011) and are therefore also an integrated part of this study. These views can be summarised as explained by Ernest (1989, p. 21):

1. A “view that mathematics is a useful but unrelated collection of facts, rules and skills.”
2. A “view of mathematics as a static but unified body of knowledge, consisting of interconnecting structures and truths.”
3. “A dynamic, problem-driven view of mathematics as a continually expanding field of human inquiry.”

In addition to beliefs about mathematics, beliefs about the teaching and learning of mathematics are relevant for any person teaching mathematics. However, as they are not the focus of this paper, these areas of beliefs will not be discussed any further.

Methodological framework, procedure and participants

A broad variety of research instruments has been employed when researching beliefs, including large scale questionnaires, various types of interviews or the analysis of specific materials such as lesson plans or journals kept by teachers (see for example Leder & Forgasz, 2002; Speer, 2005; Forgasz & Leder, 2008). One key aspect of educational research is that the issues under investigation are often not easily accessible, something which also holds true for beliefs: people are not always conscious of their beliefs – a fact which presents specific methodological challenges. In her discussion of photo elicitation, Rose (2012) argues that “elicitation interviews with participant-generated visual materials are particularly helpful in exploring everyday, taken-for-granted things” (Rose, 2012, p. 306). This aspect combined with the experience that language can slow down the creative process, as it requires higher cognitive demands, provide important arguments for the use of drawings not only with children, but also with adults (Burton, 2010). This study therefore chose to adopt an approach used by Rolka and various colleagues who have used students’ drawings to explore children’s world views.

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19 There are other authors who present very similar threefold perspectives, among them Dionne who called them the traditional, the formalist and the constructivist perspective (Dionne, 1984) and Törner and Grigutsch (1994) who presented the toolbox, system and process aspect of mathematics.

Their experiences are summarised in one article, in which they also present the classification scheme developed for the analysis of the drawings (Rolka & Halverscheid, 2011). The authors present two critical characteristics for each of Ernest’s (1989) three views of mathematics and identify key questions and essential points for all of them (see Table 1 for details of this scheme).

Table 1. Characteristic features of Ernest’s three world views (based on Rolka & Halverscheid, 2011, p. 528).

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Characteristics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrumental</td>
<td>Non-coherent sequences (1a)</td>
<td>Are there several objects within the work which belong to a particular field of mathematics but do not show any relation with one another?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Does the text consist of an enumeration or a classification of items rather than showing the parallels in-between?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Essential: the items instead of their characteristics are considered to be important, that is, the items are more important than their meaning in a wider context</td>
</tr>
<tr>
<td></td>
<td>Facile conception of usefulness/application of mathematics in the course of life (1b)</td>
<td>Is there a slight evidence of the importance of mathematics and its application?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is the attention drawn to the fact that applications are useful rather than in which way?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Essential: the central motivation point for practicing mathematics is the convenience one can gain where the character of usefulness always comes to the fore</td>
</tr>
<tr>
<td>Platonist</td>
<td>Display of mathematical coherence (2a)</td>
<td>Are there any references drawn between any mathematical items in the work?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Does the text show a cohesive character within the implementations?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Essential: relations are identified but not necessarily self-drawn</td>
</tr>
<tr>
<td></td>
<td>Theory/history of mathematics (2b)</td>
<td>Is the development of mathematics referred to as a determined, somewhat stable construct of knowledge?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Are scholars who once made mathematics crucial to the work?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Essential: mathematics as a static entity predetermined by nature</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>Autonomous mathematical activities (3a)</td>
<td>Does the setting of tasks offer the occasion for using mathematics actively and self-dependently?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do certain actions enclose mathematical items as well and are not mentioned without any reference?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Essential: not only meta-mathematical explanations, but something inventive; an extract out of a mathematical process allowing not only to counterfeit, but also permitting independent thinking</td>
</tr>
<tr>
<td></td>
<td>The development of mathematics (3b)</td>
<td>Is the development of mathematics indicated by being a process?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Does the description transcend the image of mathematics being a complete and static product?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is there somebody mentioned who actually produces mathematics?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Essential: dynamic of mathematics (through the author or somebody else) is described as a process</td>
</tr>
</tbody>
</table>

As Rolka and Halverscheid (2011) have pointed out, using pictures as sole data sources entails highly subjective interpretations, which is why they have additionally asked their participants to write a text and, in some cases, also conducted interviews. Similarly, Rose refers to Collier who as one of the first...
to use photo elicitation already argued that the information entailed in an image can only be accessed through interviews (Collier, 1967 as cited by Rose, 2012, pp. 300-301). This study therefore follows the idea of data triangulation and also makes use of interviews conducted with the participants about the creation and content of their picture. The semi-standardised interviews allows enough flexibility with respect to the individual pictures, but also ensures that key issues are addressed in all interviews (see annex for a list of the questions used). The verbal data was analysed using the method of qualitative content analysis as described by Mayring (2010). At the heart of this approach is a set of categories (codes) which are defined and revised in the course of the work (feedback loop).

The codes used in this study are on one hand derived from the scheme by Rolka and Halverscheid (2011) as it is described in Table 1 (deductive codes), on the other hand they were developed from the available data (inductive codes). In addition to the six characteristics listed in the presented table above, the inductive codes consist of two large groups of codes, namely ‘Mathematics’ and ‘Other issues’. The category ‘Mathematics’ consists of two subcodes, that is ‘Characteristics of mathematics’ and ‘Mathematical terms and fields’ which were mainly used to specify particular aspects of the six characteristics presented in the table above. The category ‘Other issues’ identifies themes frequently mentioned in the interviews, but which cannot easily be integrated into the deductive codes. It encompasses a wide variety of themes, namely: ‘Personal issues’ (subdivided into ‘Emotions’ and ‘Personal experiences’), ‘Language’, ‘Definition of everyday mathematics’, ‘Education’ and ‘Nature’. The system of inductive codes was established in three steps, first on the basis of the pictures, secondly on the basis of the interviews and thirdly the two systems were integrated into one encompassing scheme. As the full interview material collected in this study goes beyond the issue of the created pictures, the presented code scheme will be altered once the rest of the interview material is analysed.

The data for this study were collected in the summer of 2012 in Switzerland. All participants are members of the Swiss network for everyday mathematics20 through which they were recruited. Ten days before the first interview they received a letter asking them to create a picture answering the question what mathematics is for them21. Together with this task they received an A3-format piece of paper, which they had to use for the creation and presentation of their picture. They were asked to return the picture to the author no later than two days before the first meeting, as it was the basis for the first interview. A second interview focused on the participants’ biography and teaching. The average time between the two interviews was one month and on average they lasted 82 minutes (minimum 58 min., maximum 138 min.). Most interviews took place on the premises of the participants’ work place. They were conducted in Swiss German, recorded digitally and later transcribed in standard German. Only a small part of the interview data is included in the analysis on which this paper is based, namely the first section of the first interviews where the participants talk about the pictures.

Twelve individuals volunteered to participate in the study after being informed about the project and the corresponding requirements22, eight of them were selected for the interviews. Out of this group, five were selected in order to have as homogenous a group as possible. All of these five

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20 The network is called “Netzwerk Alltagsmathematik” and is comprised of some 100 people from German speaking Switzerland who are interested in numeracy. See http://www.netzwerk-alltagsmathematik.ch/ (last accessed June 17, 2013).
21 The literal translation of the task is as follows: “Imagine you were an artist and have accepted the following contract work: What is mathematics? A personal view. Present your views in a pictorial, creative manner, working with materials and techniques of your choice (coloured pencils, watercolour, collage, etc.).”
22 The only requirement was that applicants were teaching adults and address mathematical topics in their classes. They were informed that they would need to invest a maximum of four hours of their time, during which they would have to complete a small non-mathematical task and participate in two interviews in a location of their choice.
participants have attended one of the first two numeracy\textsuperscript{23} trainings for adult education teachers in Switzerland\textsuperscript{24} and none of them studied mathematics at the tertiary level. Furthermore, all are currently working as adult education teachers, though to different extents, in different subjects and with different students. Three of them are teachers of German as a second language, one of them is a self-employed public relations worker (and teaching part time), the last is working as a course leader in the social affairs department of a large Swiss city. They have an average age of 50 years (between 43 and 57), three of them are male, two female. Their educational backgrounds are very diverse and many of them have been educated and trained in different jobs. Table 2 below presents a short overview of the five individuals labelled P1, P2, P3, P4 and P5 in the remaining text.

\textbf{Table 2. Overview of the participants.}

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>F</td>
<td>M</td>
<td>F</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Age (in years)</td>
<td>57</td>
<td>53</td>
<td>52</td>
<td>43</td>
<td>45</td>
</tr>
<tr>
<td>Education</td>
<td>High school, commerce diploma, translator, music school, adult educator</td>
<td>Compulsory school, chemical technician, forestry manager, adult educator</td>
<td>High school, teacher training, speech therapy</td>
<td>High school, teacher training, public relations and communication specialist</td>
<td>Compulsory school, commercial apprenticeship, social work, adult educator</td>
</tr>
<tr>
<td>Work experience</td>
<td>Secretary, own company, translator, mother, adult education teacher</td>
<td>Chemical technician, craftsman in France and Spain, outdoor social worker, father, adult education teacher</td>
<td>Teacher, various small jobs, speech therapist, mother, adult education teacher</td>
<td>Radio journalist, self employed consultant, adult education teacher, trainer</td>
<td>Banking, IT coordination, social work, adult education teacher</td>
</tr>
<tr>
<td>Current position</td>
<td>German as a second language teacher with low qualified people</td>
<td>Course leader</td>
<td>German as a second language teacher, speech therapist, trainer</td>
<td>Self employed public relations consultant; trainer</td>
<td>German as a second language teacher, developing numeracy material</td>
</tr>
<tr>
<td>Time spent working on mathematics (P’s own estimation)</td>
<td>0% *</td>
<td>10%</td>
<td>0% *</td>
<td>10%-15%</td>
<td>40%</td>
</tr>
</tbody>
</table>

* 0% indicates that these two people were not teaching specific numeracy classes at the time of the interviews. Most of these classes do not take place due to low enrolment rates, but both address related issues in their other classes.

\textsuperscript{23} Without going into the details of conceptual discussions of mathematics and numeracy, the latter term is used in the context of this paper whenever the work situation of the informants is referred to, as they clearly see themselves as teachers of everyday mathematics (numeracy) and not mathematics in general. Numeracy is considered to be the appropriate translation for the German term everyday mathematics in this context.

\textsuperscript{24} Specific numeracy training for adult education teachers is new in Switzerland. Currently the fourth training course aimed at trained adult educators with „no reservations towards mathematics“ is on-going (see also: http://www.alice.ch/index.php?id=1330, last accessed January 6, 2014). Some 45 individuals have attended the eight day course so far.

Findings

Visual data

Before analysing the pictures with the scheme presented in Table 1, they are first described in terms of the techniques used in their creation to provide a better understanding of their diversity as well as the shared characteristics. Four out of the five informants have chosen to present their view of mathematics in form of a collage: They put together various small bits and pieces and in one case combined these items with paintings and drawings (see figures 1 to 5 for reprints of the five pictures). Only one person (P5) presented an integral painting. Incidentally this was one of two who gave a title to their picture, namely “Chaos and Order” (the title of the picture of P4 roughly translates to “One Day Mathematics”, see figure 2). Looking more specifically at the items used for the pictures, the following types can be distinguished: (i) artefacts such as receipts, timetables, programmes, money, stamps, or a playing card (mainly used by P4); (ii) newspaper or magazine clippings (mainly used by P3) or pictures printed from the internet (mainly used by P1); and (iii) own writings and drawings, printed and cut out (mainly used by P2).

When asked why they chose this particular mode of creating the picture, the informants said it suited them or that it was the only way such as task could be approached. While all informants said to have thought about the task and how to approach it, before completing it, only one of them went about it systemically: P1 wrote down a list of words she associated with mathematics and then systematically looked for images which illustrated each term. The others worked more spontaneously, for example emptying his wallet (P2) or using those pictures from magazines that appealed to her (P3). P5 relied on a painting technique he was familiar with and liked. During the interview the informants had the chance to add to a copied version of their picture, however, none of them chose to do so and in spite of some of them identifying specific gaps when explicitly asked for them, they all were satisfied with their creation in the end and said that the picture represents them well as a numeracy teacher.

In the following paragraphs each of the characteristics presented in Table 1 will be discussed briefly in order to analyse the five pictures systematically. If necessary, references to interview statements will be included, and some specific methodological observations will be made.

Non-coherent sequences (1a)

While collages can be presented as integral pictures, as it has been done by P3 and P4, they can also be seen as illustrative of presenting non-coherent sequences, the first of the classification criteria described by Rolka and Halverscheid (2011). A prototypical example of such a presentation is the picture created by P1, which consists of eight individual elements, laid out systematically:

![Figure 1. Picture created by P1, illustrating non-coherent sequences.](image)
Similarly when talking about their pictures, the participants in some cases moved from one element to the next (particularly P1), while others talked in more coherent and general perspectives about mathematics. However, it is worth noting, that there are hardly any “objects [...] which belong to a particular field of mathematics” (Rolka & Halverscheid, 2011, p. 528) depicted in the pictures. Again the creation by P1 is a good example: None of the eight pictures can be identified as an object belonging to a field of mathematics. The pictures by P2 and P3 contain some elements which can easily be allocated to fields of mathematics (for example equations belonging to the field of algebra), but they clearly do not constitute large shares of their pictures. The majority of the specific elements show mathematics in a wider and applied context, such as shopping or time keeping. In the remarks made by P1 it becomes clear, that her elements are actually representing characteristics of mathematics rather than objects of mathematics – each item stands for a specific aspect of mathematics, such as regularity, symmetry or confusion. And even though they all seem unconnected and unrelated, P1 stresses that “They [the eight small pictures] are related to me, to my experience of mathematics. [...] Amongst themselves they are not directly – they represent the same in different ways. They represent mathematics” (P1).

In short, while many of the pictures present unrelated objects, the stories the informants tell convey a different message, namely that the specific elements do belong together and can be seen as different sides of the concept mathematics. Furthermore they indicate that the wider context is eminently important – an aspect that is highlighted in the next point.

Facile conception of usefulness/application of mathematics in the course of life (1b)

When it comes to the usefulness and application of mathematics it is interesting to note that applications are dominant in most of the pictures and that in the interviews many informants stress how present mathematics is in everyday life. The picture created by P4 is an illustration of the presence of mathematics in everyday life, as it consists mainly of real objects such as money, a stamp or a lottery ticket. The creator of the picture also stresses, that one cannot choose to do mathematics respectively numeracy, one has to do it: “It is part of our everyday life, well, yes. But also it is smashed into your face. One has to do it. [...] It is not simply, just flowing along somehow.” (P4)
This focus on mathematical aspects of everyday life is not surprising, considering the participants’ background as numeracy teachers. Their pictures present rich illustrations of the many contexts in which mathematics is found: in games, timetables or receipts, measuring time or money. These applications also illustrate one characteristic highlighted by many, namely that mathematics is frequently hidden and needs to be identified first. It is therefore interesting to note that in their talks the participants often refer to basic activities such as counting, categorising or organising when speaking of mathematics, rather than identifying specific operations such as adding, multiplying or calculating percentages which stand behind these applications. Furthermore, they all very clearly divide mathematics into two areas – applied mathematics, which is what they know and do, and abstract mathematics, which is beyond them. This duality is very often referred to in the context of their own educational experiences:

To a certain extent, math25 was playful for me. I understood it well, I liked doing equations. […] But, when it was too abstract or so, at some point maths became a problem zone [pointing to the same word she had glued on her collage]. (P3)

Or: “Being a linguist, I’ve quite a high affinity for math. I had that at school as well. I was left behind when it was not connected to everyday life.” (P4)

There is a strong sense of the relevance of applications in everyday life and at the same time a division of mathematics into an applied and an abstract or theoretical part, an issue which will be discussed in the next section.

One last point which needs to be mentioned in this context is an illustrative example of the difficulty of interpreting pictures, as it has also been pointed out by Rolka and Halverscheid (2011). P3 has drawn a series of artefacts on her picture and commented:

At some point it occurred to me that actually all inventions that we have such as a car, a plane, a submarine and here the mouse and the computer – all of them have to do with math. […] Our modern cities would not be possible without math. (P3)

Both the mentioned images as well as this statement can easily be interpreted as illustrations of mathematics being useful. But when asked about the usefulness of mathematics, P3 answered:

Pffft, that is a question I have never asked myself. I think that, well categorising and sorting, those are excellent skills that one needs to have in order to do math. I think. And at the same time they are also cognitive functions. (P3)

The interviewee does not provide a direct answer; also she never used the word useful in her answers herself. So while her picture clearly could be interpreted as showing the usefulness of mathematics, the informant does not stress that aspect herself at all.

In short, when looking at the aspects constituting the instrumental view of mathematics, it can be said that visually a few of the pictures imply the presentation of non-coherent sequences, but that this view is modified by their verbal explanations. Furthermore, the application of mathematics is dominant, in both the pictures, and the interviews. There is also a particularly strong notion of a division of mathematics into an applied and an abstract part.

Display of mathematical coherence (2a)

This characteristic is one that is most difficult to analyse in the five pictures. As stated above, there are very few mathematical items are presented, therefore it is difficult to identify references between them. Particularly interesting in this context are the two pictures by P3 and P4. At first glance they

25 As Swiss German is predominantly an oral language in which the term mathematics does not exist, the English equivalent term math is used in all quotations to reflect this aspect.
depict a coherent image, but when looking closer both consist of various individual elements. And while many of these elements could be sorted or grouped (for example visual presentations, formulas or measurement tools in the image included below), this is not done by the creators of the image.

Figure 3. Picture created by P3, presenting a mix of technologies used.

When examining the statements made during the interviews, all of the pictures can be considered to contain at least some cohesive elements, as the interviewees identify references between the elements. Since coherence was visually not always present, the participants were specifically asked for it and only P2 says that he is not sure that the elements on his picture have any connections, except to him as a person and his thinking: “They are really the thought clouds that I associate with it [mathematics]. In the end it should illustrate a little bit the ambivalent attitude that I have towards math” (P2).

And while this sentiment of the creating person itself as the connecting aspect of the picture is partially reflected by others, two people said that all shown elements “have something to do with math [...] it meets on the meta level of math” (P3). This and other statements imply that the participants do see mathematics as a unified (and unifying) body comprised of different parts or levels: “The depth is reflected in the colour blue, but also in the sea and the waves [...] also from the easy to the difficult, always this, from the profound to the superficial, from the simple to the complex” (P3).

Or:

For me, math as a concept is not really interesting. Until the point, when I reach some limit and then I have to go one [level] deeper and say, okay, what does it look like more abstractly; what are the structures that are behind it. (P4)

These statements again reflect the profound duality of mathematics that has been identified before, namely the two parts of applied mathematics – or in terms of the participants those aspects of mathematics they are able to do – and the abstract, conceptual side of mathematics.
Theory/history of mathematics (2b)

This characteristic is clearly absent in all pictures – there are no references to any mathematical scholars or historic events. Similarly in the oral discussion, history of mathematics or its development are very rarely touched upon and are definitely not a reoccurring theme. In some statements development is implied, for example: “I believe that in math we are currently at this point, most likely also, because time and again we were curious” (P3).

This statement implies not only a history of mathematics, but also leaves other possibilities for the future. At the same time it shows clearly that this development is not determined and stable. Similarly the following statement: “At some point there was a decision for the decimal system” (P4).

This observation additionally implies that there are actors who actively influence the development of mathematics by taking specific decisions. Mathematics is therefore clearly not seen as being “a static entity predetermined by nature” (Rolka & Halverscheid, 2011, p. 528). However, it is worth noting, that though largely absent in the pictures, nature is a key issue in the interviews. It is mentioned by four participants and all identify a close relationship between mathematics and nature, namely that there is a lot of regularity and symmetry in nature and that this can be described with mathematics. However, it is clearly people who “put patterns over nature. [...] It [picture of a daily routine] stands for the human who has made this division of something that is determined by the sun” (P1).²⁶ But this active use of mathematics is the core theme of the problem solving view of mathematics, which is described after a short paragraph summarising the key elements of the Platonist perspective.

When it comes to assessing the aspects constituting the Platonist perspective it can be said that virtually no aspect of this view is represented in the participants’ pictures: Coherence in their pictures is strongly linked to the participants themselves as the pivotal point of the presented elements, rather than being identified between the items in the work. Scholars or historic issues are not depicted at all and the only element, which is implicitly present, is a methodical part of mathematics, namely everything that is not applied mathematics. However, that aspect remains very vague and needs to be explored further.

Autonomous mathematical activities (3a)

The focus of this aspect lies on the independent thinking by the person using mathematics. The picture by P2 is an example which – upon closer inspection – is very illustrative of this process: It consists of creative adaptations of word problems (sentence in the centre at the bottom), an own presentation of the number Pi (little square in the upper middle) as well as other changed and adapted quotations or principles (the line around spider web is a free adaptation of the Haiku, a Japanese form of poetry where the precise number of phonetic units is decisive):

²⁶ Interestingly P5 does not refer to nature itself, he refers to the environment in cities, namely people and public transport and he assigns mathematics a very similar role in this context, namely that it describes and explains patterns in our environment, in this case the man-made: “If you look around, if you walk around the city, you get a feeling that people walk around chaotically. And if you have the correct algorithm, you find an order in it, how it all works and so on. Or also a train, how the entire thing works. It looks very chaotic, but it is all planned meticulously.” (P5)
The development of mathematics (3b)

This issue has already been touched upon when discussing the aspect of history of mathematics, where it was shown that if history is talked about by the participants it is understood as a process. And while no names of people producing mathematics are mentioned, there are references which imply that such people exist:

And I think math is something to be developed. Even though one can define laws and the like, they are defined on the basis of our own boundedness. That means, because we are limited, what we define here
can also only be a form of boundedness. […] But it doesn’t really reflect anything complete, because we are not complete, so it can’t be complete either. (P5)

Many of the participants mention the possibility of being creative with the application of mathematics, for example cheating when keeping scores in games, but are at the same time aware of the fact that there are clear limits as to what one can do:

I can’t, suddenly, well, I can claim something absurd in math, but then to prove it is a lot harder than for example in other areas. […] In math that is quite difficult. There is relatively little room for manoeuvre. And I don’t really know whether that has already been exhausted. (P2)

Out of the three perspectives of viewing mathematics, the perspective of problem solving is undoubtedly the most present one in the analysed data. The pictures very clearly present views of mathematics implying a strong personal engagement, particularly in specific applications of mathematics. Furthermore, the statements indicate that mathematics is dynamic rather than complete and static – even though the participants recognise that these developments are clearly beyond their own capabilities.

Summarising and very broadly speaking, it can be said that on the basis of the dominant characteristics in their pictures, the participants’ views of mathematics are clearly mixed. It is equally clear, that the least relevant view is the Platonist, as neither mathematical coherence nor its theory or history feature prominently in the presented pictures. The analysis has also shown that it is indeed very difficult to work with pictures only, when trying to understand and describe their creators’ view of mathematics. The picture created by P5 is a good example of this fact that visual data on its own can be very hard to interpret. Without the accompanying interview this picture could not have been classified. However, once formulated, its key message comes across very clearly:

For me, the circle represents absolute order […] Order also means to be able to orient yourself in the chaos and if one takes the relation to math, math to me is like a language with which you can create order in a chaos. So if from the outside something looks chaotic and you then look closer, with the help of math you can explain certain things or identify new dimensions within and a new understanding.” (P5)

Figure 5. Picture created by P5, representing an integrated presentation of mathematics.

In order to complete this sketchy analysis based on the pictures, some select issues which only surface in the interviews will briefly be presented in the next section. This will help to get a better understanding of the complex views that the interviewed adult education teachers have.

**Verbal data**

While the analysis of the pictures has particularly highlighted the relevance of application for the creators of the pictures, and in some instances also their autonomous mathematical activities, they not only raised a number of questions with respect to the interpretation of specific elements, but also left out a number of issues which only emerged from the analysis of the interviews. As a first element of
this section the issue of language, which does not arise at all from the pictures will be discussed, afterwards a number of issues, which are only marginally or implicitly present in the pictures will be presented.

**Language**

One issue which was addressed by all interviewees at least once, but cannot be identified in the pictures is language. Mathematics was seen as complementary to language in mastering everyday life: “And numeracy is more like [...] let’s say decisions and organising or I don’t know exactly what. Either way, it is not only language, I have to deal with something else as well.” (P2) And: “It [mathematics] is a help, like language. Language helps mastering your life and communication, sure, and math also helps mastering your life, doesn’t it?” (P1)

As this statement already indicates, the participants identified similarities between language and mathematics, not only that both have an instrumental function for mastering everyday life, but also at a more fundamental level: “For me math is like a language where one can create order in a chaos. [...] And math is the same for me, it is like a language for me to also explain something, phenomena.” (P5)

More specifically, two interviewees mentioned that mathematics is like the grammar in language which explains how things work and by contrast, “numeracy is in this sense the expression of what I do in daily life. Like I can speak without ever wasting any thought on grammar or linguistic structures or on metalinguistic condition.” (P3) Other points mentioned include differences between mathematics and language, for example the fact that language has developed more organically, without seemingly arbitrary decisions such as the naming of numbers (P4), or difficulties of non-native speakers with word problems (P2).

**School**

There is only one element on the picture by P2 which can be clearly attributed to a school context, namely a piece of an exercise book with several crossed out attempts of solving a problem. Contrary to this single artefact, school was mentioned several times in the interviews: On one hand in the context already mentioned when discussing the pictures, namely the experience that all of the participants at some point of their educational career reached a point where mathematics became too abstract. On the other hand, several references were made to the way mathematics is taught and experienced at school in general. In their role as adult educators the interviewees are often confronted with students who had very negative experiences with school in general and particularly mathematics classes. They are very aware of this aspect and clearly state that in adult education (or in their classes) other principles apply to the teaching of mathematics:

But it was stressful at some point and I can imagine that my participants, that they are simply stressed. They get somewhere where they can’t continue, it just doesn’t go any further with their imagination. […] And that as a course leader you are always aware of that, that each individual has his or her limits. I notice precisely if a person simply can’t, that doesn’t work and then I don’t insist, because I don’t want them to panic. […] As adult educator I can do that. I have the liberty of simply stopping. (P1)

**Personal experiences**

The interviewees’ own educational experiences with respect to mathematics teachers and classes are an important aspect that is not directly reflected in the pictures, but is constitutive of how they see mathematics. In addition to their specific school experiences which did not leave any of them “a typically traumatised person” as P5 said, many positive memories connected to mathematical
activities were mentioned, for example solving puzzles, mental arithmetic when shopping, playing cards or being particularly good in a specific field of mathematics area such as solving equations or probability. Again, some of the participants make a direct link from their experiences to their students’ by stating that one of their goals in their courses is that their participants are also able to experience mathematics as something fun, that they are able to enjoy doing it – like they themselves did at some point.

Affective issues

Personal experiences are closely related to emotions which can be equally difficult to express in images. Even seemingly explicit presentations, such as the stick man wedding couple in the picture by P1, can stand for something very different, as the interviewee explains:

Here [pointing to the picture] I actually googled stick man, this represents a stick man. […] It is probably not the right image, […] but it is a symbol for dumbing down. And for the two dimensional presentation of something that is three dimensional and has so many sides. Well, and if you just want to flatten something on to a plain and reduce it to some lines which do not conform to reality […] a simplified presentation […] And it came to my mind that also with math – we are sometimes dumbed down by the mindless calculations and by how we learn math in school. (P1)

Overall it is interesting to note, that the participants view their own experiences with mathematics generally positively and those of others, mainly their students, predominantly negatively.

Characteristics of mathematics

One last aspect, which is represented indirectly in many pictures, particularly in the picture by P1 who argues that each of the small images stands for one characteristic or aspect of mathematics, is its nature. When asked to describe the nature of mathematics the use of adjectives is predominant and while the participants were not directly asked to do so, many of them used numerous adjectives when talking about mathematics, for example: mathematics is useful, explaining, precise, organising, abstract but also hidden, playful, reliable or contradictory. The one feature, which was named most often and in each interview at least once, can be summarised with the adjective fundamental. It includes statements like “I think, yes, maths is like always included” (P3) or “It is always and everywhere” (P4). This is one aspect which seems central to the belief of the interviewed teachers, but which cannot easily be reconciled with any of the three perspectives described in the used scheme.

Overall, a number of additional aspects of mathematics, such as its close relationship with language, how it is experienced in school and other everyday situations as well as the connected affective issues gain more clarity in a verbal exchange than in visual representations. Furthermore, it seems that they are better suited to provide insight into dynamic aspects of beliefs, namely their development or how they influence teaching practices. The combined results of the visual and verbal descriptions will briefly be discussed in the next paragraph before some concluding remarks are presented.

Discussion

Many characteristic features of mathematical beliefs and other issues prominently discussed in mathematics education can be recognised in the beliefs of the five adult education teachers presented in this study. Among them the relevance of affective issues (Evans, 2000), the invisibility of mathematics (Wedege, 2010) and findings described in many other studies such as the early formation of beliefs, or their influence on an individual’s behaviour. One aspect which is completely absent is the issue of gender: Lim (1999) has found that mathematics is generally perceived to be a male domain and Pehkonen (1994) has identified gender differences as one area of belief research which is
well documented – however, it has not been an issue in the data used for this paper. In the next paragraphs, two aspects of the findings will be discussed, namely how the described beliefs fit into Ernest’s categories and methodological issues.

**Instrumental, Platonist or problem solving views?**

On one hand, it seems easy to allocate specific views of mathematics to the participants. Both their pictures as well as the interviews illustrate the relevance of the application of mathematics in the course of life – one aspect of the instrumental view – as well as the importance of autonomous mathematical activities – one key aspect of the problem solving view. Both these aspects can be explained with the context in which they work and their identity: They see themselves as numeracy teachers and the issue of autonomous applications in real life, in specific contexts, is a key aspect of numeracy. On the other hand, there are also some issues, which seem to be unique to these five individuals, among them the relevance of language when discussing mathematics. Potential explanations for this aspect are on one hand the informant’s background – all of them also work as German as a second language teacher – on the other hand their training: In their education as numeracy teachers, comparing language and mathematics was a prominent theme (oral information by the respective course leader).

Two other dominant aspects of the described mathematical beliefs include firstly the fact that the participants see mathematics as being divided into what they know and are able to do and the rest – an aspect that is not reflected in either Rolka’s and Halverscheid’s (2011) or Ernest’s (1989) original presentation of the three views. Again, this can partially be explained by the teachers’ identity as well as their experiences: they see themselves as numeracy teachers and not mathematicians therefore needing only specific knowledge in the former field. Furthermore, during their education they all have experienced that there are issues in mathematics that they do not understand. One could argue that this division of mathematics into what they understand and are able to do, that is above all numeracy, and the rest, namely “abstract mathematics”, is not only based on their experiences but also allows them to see themselves as competent numeracy teachers. The second aspect is that the participants see mathematics as something fundamental and universal and in this function they provide it with a trait that goes beyond the strict instrumentality of specific procedures, namely that mathematics per se explains and organises the world. One could argue that this characteristic is constructivist rather than instrumental, however the notion of usefulness is still strongly linked to this function of explaining and organising the world, therefore the relevance of the instrumental view for these adult education teachers is justified.

**Methodological issues for future research**

Overall, it can be said that using pictures to explore adult education teachers’ beliefs has worked very well. Many of the participants commented positively upon the task of creating the picture and were engaged in the research process. Furthermore, data collected from the pictures and interviews have proven to be somewhat complementary – two positive aspects of visual methodologies as they are also identified by Rose (2012). The complementarity of issues raised has also been reflected in the elaboration of the codes, where it can be seen that certain codes predominantly occur in the visual respectively verbal data (for example time and money respectively language). However, looking at the diversity and richness of the pictures presented and the classification reached according to the three views of mathematics, a sense of inadequacy remains. The benefits of working with visual data seem to vanish if one of the main results is a categorisation that hardly goes beyond what could also be attained by using questionnaires. The obtained results therefore not only underline the relevance of

the question raised by Halverscheid and Rolka (2007) whether the identified categories describe the works extensively, but point to the more fundamental question of whether these categories which focus on one aspect of beliefs are adequate to analyse the richness of visual data. Particularly if beliefs are understood in the broad sense of world views taking into account affective as well as cognitive aspects, a more encompassing analysis which allows capturing these diverse components of beliefs is needed.

Kress and van Leeuwen (2006) argue that verbal and visual communication both have their specific possibilities and limitations in constructing meaning and in the shift towards a new visual literacy the corresponding abilities of reading visual communication are essential. They present a system of categories which can be used to critically analyse images and which could be a starting point for a more fundamental and inclusive analysis of the pictures presented here. For example, the layout of images: While Rolka and Halverscheid (2011) reduce this aspect to the issue of connectedness (point 1a in Table 1), Kress and van Leeuwen (2001) suggest various types of narrative and conceptual representations of different types of layout – an aspect which could enrich the presented analysis. Moreover, as the created images were discussed extensively, a multimodal perspective taking the specificities of and interaction between the verbal and visual data into account as described by the same authors (Kress & van Leeuwen, 2001) could be even better suited for a more in depth analysis of the presented data. Such an approach could most likely help to address some of the challenges encountered when using the scheme developed by Rolka and Halverscheid (2011), namely that adults’ perspectives of mathematics seem to be somewhat richer (for example including less mathematical objects, but more characteristics of mathematics) and are therefore sometimes more difficult to capture with the provided characteristics only. Or the specific difficulty, which these authors also encountered and which became even more prominent in the analysis of pictures created by adults, namely that of separating and identifying the extent of each of the three perspectives in mixed world views. As mentioned before, it has proven to be particularly challenging to differentiate between the aspect of application of mathematics in everyday life and autonomous mathematical activities. Once again, the question that Rolka and her colleague (Halverscheid & Rolka, 2007) ask might need to be reformulated, namely that using visual data is not best suited to estimate the extent of each of the three perspectives, but rather how they are related.

Furthermore, it would be interesting to explore, how the perspectives relate to the division of mathematics into what the participants can do and the rest, as it has been described above. As Rolka and Halverscheid (2011) have observed an overwhelming dominance of the instrumentalist view amongst younger students, a move towards more autonomous mathematical activities might also be explained with increasing life experience. Another emerging question in this context is what factors facilitate a change from an instrumental use to an autonomous use of mathematics.

In short: the performed analysis has proven a valuable starting point for exploring adult education teachers’ beliefs, but other more suitable analytic methods are needed in order to find answers to some of the questions raised or formulate alternative questions.

Conclusion

When taking stock of the experience of using pictures to explore mathematical beliefs of adult education teachers, the overall assessment is a positive one. Furthermore, combining visual and verbal data (data triangulation) has proven to be beneficial as the two sets not only confirmed the centrality of particular themes, therefore validating each other; they also complemented each other, as some issues only emerged in one of the two sets, indicating that data triangulation also helped to improve the quality as the two sets enriched each other thematically. These benefits gained from data triangulation could be exploited even more, if triangulation was also applied to the methods of
analysis. More specifically, if a particular visual method of analysis was used or if content analysis was adapted to reflect the specificities of both the visual and verbal data. Each of them has their characteristics and unique qualities that need to be respected and taken into consideration in the analytic process.

References


Annex: Interview questions

List of questions used for talking about the creation and content of the picture. While the first question was always the same, the order of the following questions was adapted depending on how the interview developed.

1. You received the written task and what happened then?
2. Why have you decided to use this mode of presentation?
3. How is mathematics presented in your picture?
4. What is the connection between the elements of your picture?
5. Are there aspects of mathematics that you wanted to present but could not do so?
6. Is there anything you would like to add to what we have said?
Abstract

In this paper we review and compare language policy in relation to adult numeracy education in Wales and New Zealand with respect to the Māori and Welsh languages in the latest stage of our international comparative study of adult numeracy education. While much has been written about the relationship between language and literacy, the relationship between language and numeracy - especially adult numeracy - has been less explored, especially from a policy perspective, despite evidence of the importance of language for learning. We seek to shed light on the policy context in which adult numeracy education is set in Wales and New Zealand with respect to these languages, viewed from a critical linguistic human rights perspective.

Key words: numbers, language policies, ethnomathematics

Introduction

In both Wales and New Zealand policies are in place to raise levels of adult numeracy. Both countries have also developed measures to revitalise the Welsh (Cymraeg or y Gymraeg) and Māori (Te Reo Māori) languages respectively and afford them some protection from the language spoken by the majority of the population: English; sizeable numbers of people in both countries speak other languages.

In this paper we seek to shed light on the policy context in which adult numeracy education is set in Wales and New Zealand with respect to these languages. We begin by setting out our argument, from a critical linguistic human rights perspective, on why language matters – or should matter - to adult numeracy educators. We then give a brief review of research on language in relation to mathematics education, and ethnomathematics before setting the scene with a brief language-focused description of the current legal contexts, demographics, principal policy drivers, strategies and policies on language, education and adult numeracy in Wales and New Zealand. Finally, we compare current policies and strategies with respect to language and adult numeracy education.

Why should language matter to adult numeracy educators?

Language is important in relation to adult numeracy education because, in a world where, as Barwell, Barton and Setati (2007, p. 113) point out, “Multilingualism is no longer an extraordinary case”, the language in which mathematics (or numeracy) is learned and practised has a bearing on learning. They identify “three good reasons for focusing on multilingual issues in mathematics education” which we summarise as follows:

27 In this paper we use ‘Te Reo Māori’ or ‘Te Reo’ (literally: ‘the Māori language’ or ‘the language’) and ‘Welsh’, respectively, to refer to these languages.

1. Increasing movement of populations across international borders.
2. Widespread demand for access to English internationally, whether or not this is desirable or promoted.
3. The rise of minority and indigenous peoples’ movements, usually incorporating a strong educational focus with immersion and bilingual settings on the agenda, as the means to political and economic emancipation and cultural renaissance. (Richard Barwell et al., 2007, p. 114)

We concur; Barwell, Barton and Setati’s third reason is particularly pertinent to this paper since Welsh and Te Reo Māori, the indigenous languages of Wales and New Zealand respectively, are the focus of this paper.

We start from the position that language rights are human rights. As François Grin states:

being a native Welsh speaker in Cardiff or a Māori speaker in Auckland (instead of a native speaker of English) cannot, in a liberal society, be construed as a failing for which one should have to atone through a lifetime of denial of one’s identity, culture and language. (Grin, 2005, p. 455)

Accordingly, we approach our exploration of language policy and adult numeracy education in Wales and New Zealand from a critical linguistic human rights perspective, echoing Stephen May’s argument for a more nuanced sociolinguistic and wider socio-political approach to the issues of language, inequality and social justice with which minority language rights are centrally concerned (May, 2005, p. 339). While a full exposition of our perspective is outside the scope of this paper, we are broadly aligned with May’s and Grin’s positions in their works cited here and mindful of the United Nations’ Declaration on the Rights of Indigenous Peoples (United Nations, 2007) to which both the United Kingdom and New Zealand are committed. We characterise our perspective as ‘critical linguistic human rights’ because a linguistic human rights approach per se “is a necessary but far from sufficient argument for advocating the protection and promotion of minority languages and/or of linguistic diversity” (Grin, 2005, p. 458). Ultimately we are interested in the practical and pedagogical implications of language policy for adult numeracy teaching and learning in situations of linguistic diversity and a critical approach allows us to consider these.

By ‘language policy’ we mean:

a systematic, rational, theory-based effort at the societal level to modify the linguistic environment with a view to increasing aggregate welfare. It is typically conducted by official bodies or their surrogates and aimed at part or all of the population living under their jurisdiction. (Grin, 1996, p. 31)

We turn next to look at research on language in relation to mathematics education, including work to explicate the ‘mathematics register’ (Meaney, 2006), and ethnomathematics, in order to outline the ‘state of play’ in these fields as this may be relevant to our study.

Research on language and ethnomathematics in relation to mathematics education

The role of language in mathematics learning

There is growing recognition from around the world that language (and bilingualism/multilingualism) plays a key role in mathematics teaching and learning (R. Barwell, 2003).

Research on Gaeilgeoirí learners (students who learn through the medium of Irish) in transition from learning mathematics through Gaeilge (Irish) to learning it through English at the third level “highlights that mathematical understanding is influenced by language and […] the students’ cultural background and experiences” (Ni Riordáin & O'Donoghue, 2008, p. 248).

Findings from a larger study of the Irish context by Ni Riordáin & O'Donoghue are consistent with those found in bilingual contexts in other countries:
Studies in these contexts [also] found that students learning through the medium of English (their second language of learning) experienced problems with syntax, semantics, and mathematics vocabulary in the English mathematics register, with language playing a key role in their mathematical performance. (Ni Riordáin & O'Donoghue, 2011, p. 62)

A study of EAL students studying mathematics in English-medium classes at secondary school and university in New Zealand found that:

EAL students suffer a disadvantage in mathematics learning due to language difficulties. [...] Prepositions and word order were key features causing problems at all levels. So also were logical structures such as implication, conditionals, and negation, both at senior secondary and third year university levels. (Neville-Barton & Barton, 2005, pp. 13-14)

Similarly, a study of English-Chinese language differences by Galligan (2001, p. 112) found “large differences in orthography, syntax/semantics, and phonetics” which “may have consequences in the processing of mathematical text”. Ni Riordáin (2013, p. 6) has also examined the differences between the Irish and English languages and points out the difficulties of how to interpret “whether differences between the languages have a differential impact on cognitive processing”.

The mathematics register

Yore, Pimm and Tuan (2007, p. 599) discuss the “importance of general cognitive and metacognitive abilities [...] and discipline-specific language” for both scientific literacy and mathematical literacy. They emphasize the importance of “not overlook[ing] or underemphasiz[ing] the fundamental literacy component of mathematical and scientific literacy for all students”. This ‘fundamental literacy component’ for mathematics, the ‘mathematics register’ of a language, “includes both the terminology and grammatical constructions which occur repeatedly when discussing mathematics” (Meaney, 2006, p. 39). Yore, Pimm and Tuan (2007, pp. 565-566) stress that “natural language is only a starting point toward acquiring the disciplinary discourses or languages of mathematics and science”, that it is essential to engage with the “three-language problems of moving from home language to school language and onto scientific and mathematical language” to become “mathematical and scientific literate”. For English as an additional language (EAL) students there is the complication of a further language.

In New Zealand, the development of a Māori mathematics register (Tikanga reo tātai) has been described by Barton, Fairhall and Trinick (1997, p. 3). They describe a “self-conscious process of mathematics discourse production [...] highlight[ing] both the complexity and the multiple directions of language evolution” (Barton et al., 1997, p. 8).

Ethnomathematics

The ‘father of ethnomathematics’, Ubiratan D’Ambrosio, has defined ethnomathematics as “the maths practised among cultural groups such as national-tribal societies, labour groups, children of a certain age bracket, professional classes and so on” (Ubiratan D’Ambrosio, 1985, p. 45) and later as “the arts or techniques developed by different cultures to explain, to understand, to cope with their environment” (Ubiratan D’Ambrosio, 1992, p. 1184).

The inclusion of ethnomathematical perspectives into the mathematics education of indigenous students is often described as being politically essential and culturally, linguistically and pedagogically beneficial (see, for example, Powell & Frankenstein, 1997). A New Zealand study is pertinent here: Colleen McMurphy-Pilkington explored Māori women’s mathematical thinking in marae28 kitchens. She explored the “complex mathematical thinking and reasoning skills” that Māori women have constructed outside of school and “embedded in their everyday cultural practices”

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28 Marae: an area of land where the Wharenui (meeting house) sits – the community focal point.
Coben, D., & Miller-Reilly, B. (2014). Numbers talk—words count: Language policy and adult numeracy education in Wales and New Zealand. (McMurchy-Pilkington, 1995, p. 21). She argued that despite policies that have contrived to alienate Māori girls from mathematics over 150 years, Māori women have been a driving force behind Māori educational initiatives (McMurchy-Pilkington, 1995, p. 7).

More recently, the Māori Adult Learners (Te Pakeke Hei Ākonga29) project aimed to capture the perspectives of learners, tutors and providers on how language, literacy and numeracy in foundation learning programmes can be optimised for adult Māori learners. It was found that the “PTEs30 and iwi31 providers expect to deliver more than literacy and numeracy skills; they aim to celebrate the Māori identity of their learners and usually teach Māori tikanga32 and sometimes Māori language as well” (McMurchy-Pilkington, 2009 p.1).

The findings with regard to adult numeracy education and Te Reo Māori are encouraging:

The Māori learners felt their tutors were teaching them and their needs rather than a set curriculum. This was in contrast to their school days. They acknowledged that they were learning more than numeracy and literacy. They were learning social skills (how to get along with other people), survival skills, how to study more effectively, cultural skills and knowledge […], work employment skills, self-confidence, te reo Māori (in some instances), self-respect and respect for others. Their learning was more interactive, it related to everyday life, and in maths it was more hands-on. Their tutors explained and clarified things and made learning fun. (McMurchy-Pilkington 2009, p.2)

However, ethnomathematical approaches alone may not be enough. As Meaney, Fairhall and Trinick (2008) found, cultural practices, including ethnomathematical ones, cannot be separated from the language in which they were developed. Hence, changing the language or the linguistic register in which practices are discussed will have an impact on how the practices are perceived by students and could result in a loss in the fundamental values that would normally accompany the practices. They conclude that without proper consideration of this issue many of the benefits associated with using ethnomathematical approaches may be nullified.

We turn now to consider the demographic and policy contexts in Wales and New Zealand in order to situate our discussion of language policy in these countries in relation to adult numeracy education.

Wales

Status of the Welsh language in Wales

Welsh is the oldest language in Britain, dating back possibly 4000 years. Early in the ninth century, when Wales enjoyed a cultural and political autonomy that lasted until the Norman invasions in 1066, the Latin alphabet was adapted for writing Welsh and Welsh literature emerged33. In more recent centuries there has been a long history of the suppression of the Welsh language in Wales in favour of English. Following the Laws in Wales Acts of 1535 to 1542, Wales was treated as part of England; English was the only language of the courts and all use of Welsh was banned from public office.

Literacy began to spread throughout Wales in the 18th century, greatly aided by the circulating schools established by the preacher Griffith Jones. He devised an efficient three-month system to teach children and adults to read in their mother tongue using religious texts. The language taught was usually Welsh, although English was used in areas with an English-speaking majority. ALMost half

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29 [https://akoaotearoa.ac.nz/community/recommended-resources-ako-aotearoa/resources/pages/te-paceke-hei-%C4%81konga-%C4%81ori-adult-learner](https://akoaotearoa.ac.nz/community/recommended-resources-ako-aotearoa/resources/pages/te-paceke-hei-%C4%81konga-%C4%81ori-adult-learner)
30 PTEs are Private Training Establishments.
31 Iwi: the largest everyday social units in Māori society, analogous to that of tribe or clan. Māori who know their iwi connections typically value them highly and take pride in knowing their genealogy.
33 [http://www.bbc.co.uk/wales/history/sites/themes/language.shtml](http://www.bbc.co.uk/wales/history/sites/themes/language.shtml)
the population had attended these schools by the time Jones died in 1771 and Wales became one of the few European countries to have a literate majority.\footnote{http://www.bbc.co.uk/wales/history/sites/themes/society/language_literacy.shtml}

While there were very few Welsh national institutions in 1850, in 1896 the Central Welsh Board was established to inspect grammar schools and a separate Welsh Department of the Board of Education was established in 1907. Although speaking Welsh in schools was not illegal, it had no government support and was actively discouraged; the medium of instruction was English and pupils could be punished for speaking Welsh until as late as the 1930s. Nevertheless, the BBC’s Welsh service began introducing some Welsh-language radio programming in 1937; Welsh was allowed in the courts from 1942; and Welsh-medium education was authorised in 1944. The Welsh Language Act 1967 legitimised the use of Welsh in the courts and in 1988 the Welsh Language Board was established to advise the British Secretary of State for Wales on language issues. From the 1990s, legislation required equal treatment of the Welsh and English languages in Wales: The Welsh Language Act 1993; The Government of Wales Act 1998; The Welsh Language Measure 2011; and The National Assembly for Wales (Official Languages) Act 2012. Under this legislation: public bodies prepare and implement a Welsh Language Scheme; local councils and the Welsh Government use Welsh as an official language, with official literature in Welsh and English; and the Welsh language is visible in public. Welsh language media are important instruments of language revitalization; these comprise: a Welsh language TV station (S4C) and a radio station: BBC Radio Cymru; a weekly national paper, magazines and regional monthly papers. This is important because the availability of broadcast media, especially television, in the minority language strengthens other language revitalisation measures, as Grin and Vaillancourt (1998, p. 114) point out.

Through a process of devolution within the UK, the Government of Wales Act 1998 created the National Assembly for Wales which determined how the UK government’s budget for Wales is spent and administered. Education is a devolved power under this legislation. More recently, the Government of Wales Act 2006 created the Welsh Assembly Government (the executive), separate from the National Assembly for Wales (the legislature).

\textbf{Welsh language speakers}

Wales has a diverse population with 78 languages spoken in 2006.\footnote{http://www.museumwales.ac.uk/en/2680/}. In 2011, 19 percent of usual residents aged 3 or more could speak Welsh, a reduction from 21 percent in 2001, despite an increase in the total population (3.06 million in 2011). The population with no Welsh language skills increased between 2001 and 2011. Welsh is now a minority language in the Welsh-language heartlands of Carmarthenshire and Ceredigion and the proportion of Welsh speakers has also dropped in Gwynedd and Anglesey, mainly due to inward-migration by non-Welsh speakers (in 2011 26 percent of the population was born outside Wales). However, there are more Welsh speakers aged 3 to 14 and 20 to 44 years but fewer in other age groups\footnote{http://www.ons.gov.uk/ons/rel/census/2011-census-analysis/language-in-england-and-wales-2011/index.html} (ONS, 2013).

\textbf{The Welsh language in schools}

The Welsh Assembly’s strategy, The Learning Country, set out a ten-year vision and associated actions to transform education and lifelong learning in post-devolution Wales (Welsh Assembly, 2001). Welsh-medium schools were included in the strategy and the government’s Welsh-Medium Education Strategy was published in 2010 with a vision to have an education and training system that responds in a planned way to the growing demand for Welsh-medium education (Welsh Assembly Government, 2010, p. 4). In English-medium schools Welsh is taught as a second or additional


The Welsh Assembly Government’s literacy and numeracy strategy: Words Talk – Numbers Count

Post-devolution, the Welsh Government’s commitment to raising standards in literacy and numeracy has been expressed in a series of reports with an emphasis on basic skills in work. These include Skills that Work for Wales (Welsh Assembly Government, 2008), the first annual report of the Wales Employment and Skills Board (2009) and the Employer Pledge37, awarded to employers who support staff with essential skills needs. The government’s second Basic Skills Strategy, Words Talk – Numbers Count (National Assembly for Wales, 2005), covers 2005 to 2010 and takes forward the agenda of The Learning Country (Welsh Assembly, 2001). Words Talk – Numbers Count covers all ages, and includes the aim that “the number of adults with poor basic skills should be diminished significantly” (National Assembly for Wales, 2005, p. 6). From 2007 the National Assembly for Wales (since 2011, the Welsh Government) has promoted Wales as a “bilingual and multicultural nation” but “there has been less of a strategic emphasis on the development of basic skills in the medium of Welsh” (Miller & Lewis, 2011, p. 6).

Adult numeracy in Wales

Adult numeracy in Wales has been measured in a series of national and international surveys in recent years. All four countries of the UK took part in the second round of the International Adult Literacy Survey (IALS) in 1996; England, Scotland and Wales took part as one jurisdiction (Carey, Low, & Hansbro, 1997) and Northern Ireland was assessed separately (Sweeney, Morgan, & Donnelly, 1998)38. The UK did not take part in the successor to IALS, the Adult Literacy and Lifeskills (ALL) survey. Instead, the National Survey of Adult Skills in Wales 2010 (Miller & Lewis, 2011) assessed literacy and numeracy skills of adults aged 16 to 6539 through the medium of English and the literacy (but not numeracy) skills of Welsh-speaking adults through the medium of Welsh. The 2010 Survey replicated similar surveys undertaken in 2004 (BMRB, 2004; BSA, 2004).

The 2010 survey found that progress on numeracy was slower than literacy, with 50 percent of respondents assessed at Level 1 or above, three percentage points higher than in 2004 but five percentage points below the Strategy target of at least 55 percent to achieve at least Level 1 numeracy by 2010. Assessment results for Welsh literacy declined between 2004 and 2010, from 67 to 63 percent at Level 1. The report notes that “The gap between literacy and numeracy assessment levels also widened, so that four times as many people were classified at Entry Level for numeracy than for literacy in 2010 and some 918,000 working age adults across Wales were estimated to have numeracy skills below Level 1” (Miller & Lewis, 2011, p. 9). Numeracy levels were higher amongst the employed and those with greater household income, higher qualifications and amongst the older age groups. The survey also revealed a substantial gender gap in numeracy: 60 percent of women and 41 percent of men were assessed at Entry level; and 29 percent of men were assessed at Level 2 or above, as compared to 13 percent of women (Miller & Lewis, 2011, p. 10).

England and Northern Ireland (but not Wales or Scotland) have taken part in the successor to the ALL survey, the Programme for the International Assessment of Adult Competencies (PIAAC) (OECD, 2013).

38 IALS surveyed ‘quantitative literacy’ rather than ‘numeracy’.
39 The survey used the latest available mid-year population estimate from the Office for National Statistics at the point the survey was carried out in 2009 and was 1,927,000 (Llywodraeth Cymru/Welsh Government, personal communication, 7 February, 2014).
Aotearoa\textsuperscript{40} New Zealand

The precise date of the first human settlement in New Zealand is debated, but current understanding is that Māori arrived in the 13th century. From 1642, when Abel Tasman named the country New Zealand, Māori had increasing contact with European and other seafarers and then with settlers, the latter mainly from the British Isles. The Treaty of Waitangi\textsuperscript{41} (1840) is the nation’s founding document, setting out the terms of a political compact between Māori and the British Crown. Following the Treaty, from 1841 to 1907 New Zealand was termed a British colony, then, from 1907, a Dominion of the British Empire and in 1931 became a founder-member of the British Commonwealth\textsuperscript{42}. In 1986 residual British legislative powers ended and New Zealand became formally (rather than just de facto) self-governing. Until the ‘Māori Renaissance’ of the 1980s, New Zealand government policies favoured the Pākehā\textsuperscript{43} majority. Since then biculturalism has been emphasised, based, since 1992, on Treaty of Waitangi claims and settlements.

Languages spoken in New Zealand

New Zealand has three official languages: English; Te Reo Māori; and New Zealand Sign Language. New Zealand is one of the world’s most super-diverse societies, with 160 languages spoken (Spoonley & Bedford, 2012). Despite its linguistic diversity, 76.6 percent of New Zealanders continue to be monolingual in English (NZHRC, 2008).

A proposed national languages policy for New Zealand

2013 marked the 21st anniversary of the publication of the Ministry of Education report Aotearoa: Speaking for ourselves (Waite, 1992), widely understood to be a precursor to a national languages policy (East, Shackleford, & Spence, 2007; Holmes, 1997; Spence, 2004). However, while various language initiatives (outlined below) have emerged, so far there is no such policy. Meanwhile, independently of government, the New Zealand Human Rights Commission (NZHRC, 2010) has proposed a national languages policy, recently summarised in priorities for action (quoted in RSNZ, 2013, p.3).

Te Reo Māori in New Zealand

Use of Te Reo Māori in New Zealand was actively suppressed and discouraged in favour of English until the later half of the 20th century (NZHRC, 2012, p. 3). The Māori Language Act 1987 brought Te Reo Māori into the public policy domain in New Zealand and established the Māori Language Commission to promote and support the growth of the Māori language. A 1991 Amendment to the Act expanded the range of legal settings in which Te Reo could be used. As in Wales, the broadcast media are important instruments of language revitalization. There are two TV channels (Māori Television and Te Reo) and there are Māori language programmes on mainstream TV and Māori radio stations. The promotion of Te Reo has resulted in the public acceptance of the use of some Māori language and protocol as a part of New Zealand culture. For example, by 2011 most government agencies had Māori and English names and traditional Māori welcome and farewell ceremonies are often performed at official functions.

Numbers of Te Reo Māori speakers in New Zealand

The most recent New Zealand Census for which figures are available (2006) showed a total population of 4,027,947, with Māori at 15.4 percent. Māori were counted in two ways: by ‘ethnicity’

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\textsuperscript{40} Aotearoa is the Māori name for New Zealand; in this paper we use the country’s official name: New Zealand.

\textsuperscript{41} http://www.nzhistory.net.nz/politics/treaty-of-waitangi

\textsuperscript{42} In 1949 the British Commonwealth was re-named the Commonwealth of Nations.

\textsuperscript{43} Pākehā refers to non-Māori New Zealanders, primarily those of European descent.

(i.e., cultural affiliation: 15 percent) and ‘descent’ (i.e., ancestry: 18 percent)\textsuperscript{44}. The figures for those of Māori descent are rising: in 2006 they were up 26 percent from 1991. The Māori population has a predominantly young demographic profile: in 2006, 35 percent of people of Māori descent were under 15 years old, while only 4 percent were 65 or over (Statistics New Zealand, 2007b). The Census shows that Te Reo is spoken by 4 percent of the New Zealand population and English is spoken by 96 percent; all adult Māori speakers can also speak English. Amongst the Māori population, 25 percent of those aged 15 to 64 and 49 percent of those aged 65 or over could hold a conversation in Te Reo Māori. However, there is a decline in the use of the language by those aged under 15: of these, 17 percent could hold a conversation in Te Reo Māori in 2006, compared with 20 percent in 2001 (Statistics New Zealand, 2007a).

However, the Survey on the Health of the Māori Language in 2006 (Research New Zealand, 2007) shows significant increases in Māori adults’ proficiency in Te Reo. Speakers of the language are up 8 percent, readers of it up 10 percent, writers up 11 percent and the numbers of those who can listen with understanding are up 9 percent, compared with the 2001 survey (Statistics New Zealand, 2002). This increase comes alongside progress in re-establishing intergenerational language transmission, with more Māori adults speaking Te Reo Māori to children in their homes and in community domains. The greatest increases have been recorded in the higher proficiency levels, which have more than doubled in the 15-24 and 25-34 year age groups. More young people now have some degree of speaking proficiency, with increases of 13 percent, 16 percent and 10 percent across the 15-24, 25-34 and 35-44 year age groups respectively (Research New Zealand, 2007).

**Te Reo Māori in schools**

By the 1830s Māori were attending mission schools in large numbers and becoming literate in English and Māori\textsuperscript{45}. By the early 1860s Pākehā were in the majority and English became the dominant language. Te Reo became confined to Māori communities and was suppressed in schools (including government-funded Native Schools), either formally or informally, in the name of assimilation with the wider community.

Since the mid-1980s the Māori Renaissance has led to the emergence of different levels of Māori language and cultural immersion in education: ‘Māori-medium’ schools; ‘Māori language in English medium’ schools; and ‘no Māori language in education’. ‘Māori-medium’ schooling comprises kōhanga reo (pre-school); kura kaupapa Māori (primary school); and wharekura (secondary school) wherein students are taught the curriculum in the Māori language for at least 51 percent of the time. In ‘Māori language in English-medium’ schools students learn Māori as an additional language, or are taught the curriculum in the Māori language for up to 50 percent of the time. Thirdly, ‘no Māori language in education’ ranges from an introduction to the Māori language via Taha Māori\textsuperscript{46} to no involvement in Māori language education at any level. In addition, whare wānanga\textsuperscript{47} provide Māori Tertiary options and most of the major universities and technical institutes teach Te Reo Māori as a language subject\textsuperscript{48}. In principle, parents can send their children either to an English-medium school or to a Māori bilingual or immersion school but in practice many parents have no local access to Māori-medium programmes.

\textsuperscript{44} Intermarriage between Māori and non-Māori in New Zealand has been commonplace since early colonial times.

\textsuperscript{45} Missionaries first transcribed the Māori language in 1814 and the written language was systematised by 1820.

\textsuperscript{46} Taha Māori means ‘the Māori perspective’, in this context, this entails the use in teaching of simple Māori words, greetings or songs.

\textsuperscript{47} Whare wānanga: ‘house of learning’ or ‘house of teaching’ (referring to higher learning or teaching).

\textsuperscript{48} http://www.maorilanguage.info/mao_lang_faq.html.

Māori students’ outcomes of schooling in Mathematics

The New Zealand Ministry of Education’s Best Evidence Synthesis (BES) for mathematics, Effective Pedagogy in Pāngarau/Mathematics, paints a disturbing picture of low achievement in mathematics by Māori students, with one in three leaving school without any formal qualifications: “the harsh reality is that average achievement, as shown in PISA and other mathematics assessments (e.g., the National Education Monitoring Project), is lower for Māori and Pasifika49” (Anthony & Walshaw, 2007, p. 9).

Recent efforts to improve this situation with respect to Māori include Te Poutama Tau project (Trinick & Keegan, 2007) which aimed: to develop the discipline to support Māori-medium mathematics; to raise Māori student achievement in mathematics by improving the professional capability of teachers; and to continue the revitalisation of Te Reo Māori. The authors found that 11 year-old pupils performed significantly above the national norms for Māori-medium schools (Trinick & Keegan, 2007, p. 20).

Adult numeracy, literacy and language in New Zealand

In the ALL survey New Zealand adults consistently scored average on all four scales50 of the survey. The main variation in the literacy and numeracy skills of 25 to 65 year olds was due to three key factors: completed education; language background; and computer use. People whose first language was English had a considerable advantage, especially in English literacy, but also in numeracy tested in English. Non-first language speakers of English were less disadvantaged if their main home language was English (Lane, 2010, p. 1). Interestingly, when ethnic identification was examined as a secondary factor for English first-language speakers, “an advantage for Europeans and a disadvantage for Māori and Pasifika, especially in numeracy, [was found] within this language subgroup” (Lane, 2010, p. 4). New Zealand is taking part in the second round of PIAAC, the successor survey to ALL, with results due in 2016.

New Zealand’s strategies, policies and goals with regard to Te Reo Māori and Māori students

New Zealand has instituted various strategies, policies and goals with regard to Māori students and Te Reo Māori; these are outlined below.

The Māori Language Strategy 2003

The Māori Language Strategy 2003 set out five goals to be achieved by 2028: the majority of Māori will be able to speak Māori to some extent and proficiency levels in speaking, listening to, reading and writing Māori will increase; Māori language use will be increased at marae, within Māori households and other targeted domains; all Māori and other New Zealanders will have enhanced access to high-quality Māori language education; iwi, hapū51 and local communities will be the leading parties in ensuring local-level language revitalisation; iwi dialects of the Māori language will be supported; the Māori language will be valued by all New Zealanders and there will be a common awareness of the need to protect the language (Ministry of Māori Development, 2003). In 2011 Te Pūni Kōkiri, the successor to the Ministry of Māori Development, published a Review of the Māori Language Sector and the Māori Language Strategy (Te Pūni Kōkiri, 2011). A proposed national Māori Language Strategy (Te Puni Kōkiri, 2013) was released in December 2013 with public

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49 Pasifika refers to people of Pacific Nations heritage.

50 The ALL survey measured prose literacy, document literacy, numeracy and problem solving.

51 Hapū: A named division of a Māori iwi (tribe) consisting of a number of whānau (extended families); membership is determined by genealogical descent.
consultation in February 2014. The Strategy proposes strengthening the focus on whānau\textsuperscript{52}, hapū and iwi and consolidating Māori leadership.

**Ka Hikitia**

Ka Hikitia is the New Zealand Ministry of Education’s (2008, 2013) strategy for Māori achieving educational success as Māori, currently being refreshed for the period to 2017. In the first stage of the Ka Hikitia strategy, from 2008 to 2012, Māori language in education was identified as one of four areas in which coordinated activity would have most impact (Ministry of Education, 2008, p. 24).

**Adult literacy, language, and numeracy education policy in New Zealand**

There has been a strong development of adult literacy, language, and numeracy education policy in ‘foundation learning’ in New Zealand, consistently in literacy, although numeracy and language appear and disappear in official policy documents. For example, More Than Words, the policy document that launched the New Zealand Adult Literacy Strategy in 2001, is silent on numeracy but does include “the opportunity to achieve literacy in English and Te Reo Māori” (Walker et al., 2001, p. 3).

The subsequent Literacy, Language and Numeracy Action Plan 2008–2012 (TEC, 2008) includes both language and numeracy, as the title suggests. However, Te Reo Māori is not mentioned and language is subsumed within literacy (TEC, 2008, p. 7).

Two years later, Getting Results in Literacy and Numeracy (TEC, 2010) provided an update on what had been achieved since the Action Plan and outlined the next steps for the tertiary education sector. The main focus is on literacy and numeracy, not language.

The title of the most recent document associated with New Zealand’s adult literacy and numeracy policy, the Adult Literacy and Numeracy Implementation Strategy (TEC, 2012), reflects the focus on literacy and numeracy but once more language is not included. Te Reo Māori is mentioned, but only weakly, in the New Zealand adult Learning Progressions in listening, speaking, reading and writing in New Zealand English (introduced in 2005 and a key element in the New Zealand adult literacy and numeracy infrastructure)\textsuperscript{53}.

The current Tertiary Education Strategy 2010–2015 (TES) specifically includes Te Reo Māori: “tertiary education plays a major part in promoting the revitalisation of te reo Māori” (New Zealand Office of the Minister for Tertiary Education, 2010, p. 7). At the same time, TES Priority 4 is “improving the literacy, language and numeracy and skills outcomes from levels one to three study” (New Zealand Office of the Minister for Tertiary Education, 2010, p. 10) and the Tertiary Education Commission’s (TEC’s) priority groups are Māori, Pasifika and Youth learners.

The TEC’s operational approach and implementation of the government’s Draft Framework for Māori Learners, Tū Māia e te Ākonga 2013-2016, is informed by the Tū Māia Working Group\textsuperscript{54}. This Group advises the TEC and shares best practice in the tertiary sector to ensure that Māori enjoy success as Māori in tertiary education, particularly at higher levels.

**Te Reo Māori in adult numeracy education practice and provision in New Zealand**

Foundation programmes in tertiary education are provided by universities, polytechnics, whānanga, private training establishments (PTEs) and iwi providers. There is targeted government

\textsuperscript{52} Whānau: extended family.

\textsuperscript{53} http://www.literacyandnumeracyforadults.com/resources/354991

funding for ‘embedded’ (i.e., integrated) literacy and numeracy provision at Levels 1 to 3 of the National Qualifications Framework but, as noted above, Te Reo Māori barely features.

Against this background, the Māori Adult Learners (Te Pakeke Hei Ākonga) project aimed to capture the perspectives of learners, tutors and providers on how language, literacy and numeracy in foundation learning programmes can be optimised for adult Māori learners (McMurchy-Pilkington, 2009). Findings from this project are discussed earlier in this paper in the Ethnomathematics section.

Comparing New Zealand and Wales

As we have seen, New Zealand and Wales have similar-sized populations in which the majority of people speak English, a minority speak Te Reo Māori or Welsh (albeit a larger minority in Wales than in New Zealand) and adult members of these linguistic minorities generally also speak English. Both countries have a history of the suppression of their native languages by successive British governments, followed by relatively recent attempts at language revitalisation, including through education, with varying but limited success to date.

In both countries the native language is a powerful symbol of a resurgent national, cultural and/or ethnic identity. The main policy driver in this respect in Wales is devolution, with the Welsh language an important outward and visible sign of increased independence within the UK. In New Zealand, the main policy driver is biculturalism (Māori and Pākehā), with the revitalisation of Te Reo Māori strongly bound up with issues of ethnicity and culture, played out against the backdrop of post-colonial redress for Māori through Treaty of Waitangi settlements. This is happening at the same time as New Zealand is becoming increasingly linguistically (and ethnically and culturally) diverse.

Both countries are liberal democracies, currently governed by coalitions of political parties. Rata (2011) warns that institutionalising ethnicity in New Zealand is leading to the re-racialisation of society, thereby subverting the claim to universalism upon which liberal democracies are based. It is notable that debates around language and culture in Wales have largely abjured issues of ethnicity (although perhaps language is a proxy for ethnicity for some) and there is no equivalent in Wales to the emphasis in New Zealand on Māori kaupapa and tikanga (Māori world view and protocols).

At the level of policy, Wales’ language policy is enshrined in law, while New Zealand has no formal language policy. Nonetheless, the revitalisation of the minority language is a live issue in both countries. In both countries, also, education in the native language is available as an additional language and (though to varying extents) Welsh-medium and Māori-medium education are available in compulsory schooling.

From the late twentieth century there is also evidence of similar levels of numeracy amongst adults of working age, similar concern by both governments to raise levels of numeracy and literacy for economic and social reasons and similar government responses in terms of the creation of an infrastructure to support adult literacy and numeracy learning and achievement, together with associated research and professional development. As a result, adult numeracy education in both New Zealand and Wales is widely available. However, in both countries it appears to be conducted ALMost exclusively through the medium of English. This requires some explanation, given the efforts to revitalise Welsh and Te Reo Māori outlined above and the “growing recognition that language (and bilingualism/multilingualism) plays a key role in mathematics teaching and learning” noted by Ní Riordáin and O'Donoghue (2011, p. 45). It may simply be that adult numeracy tutors are thin on the ground in both countries, with Welsh-speaking or Māori-speaking bilingual tutors especially rare. If so, this bespeaks the need for tutor training and professional development – in language and adult numeracy pedagogy - to fill the gap. However, that is unlikely to happen without a clear policy direction.
The absence of a robust link between language policy and adult numeracy education indicates the need for further policy development, alongside research and development focusing on language issues in relation to both existing adult numeracy learners and those outside provision; for some in either camp the language of instruction may be a barrier rather than a tool for learning.

**A way forward? Policy evaluation from a critical linguistic human rights perspective**

Since the adoption of the United Nations’ (1992) *Declaration on the Rights of Persons Belonging to National or Ethnic, Religious and Linguistic Minorities*, states must positively engage in the protection of minorities rather than just refrain from discrimination. Grin (2004) points out the need for fairness and presents a framework for evaluating the monetary and non-monetary costs and benefits of minority language policy, including important social non-monetary effects, from a critical linguistic human rights perspective. Beneficial social non-monetary effects include “harmonious community relations or the positive value placed on diversity in its own right” and “long term benefits such as building capability, competitiveness and reducing costs”, while social non-monetary costs include the unused skills of speakers of non-majority languages (Royal Society of New Zealand, 2013, pp. 3-4, citing Grin, 2004). While a full policy analysis along Grin’s lines is beyond the scope of this paper, the findings of the Māori Adult Learners project, outlined above, indicate beneficial social non-monetary effects of adult literacy and numeracy education, with some inclusion of Te Reo, tikanga and kaupapa Māori and a whānau atmosphere, all of which were valued by Māori learners. It behoves us as educators not to squander the unused and undeveloped numeracy skills, knowledge and understanding of speakers of non-majority languages.

Finally, Stephen May (2005, 2011) looks forward to ways in which minority languages may be reconstituted as instrumentally useful, rather than simply as ‘carriers’ of identity. He hopes that minority language rights will continue to develop a more nuanced sociolinguistic and wider socio-political approach to the issues of language, inequality and social justice with which it is centrally concerned.

We echo May’s hope and share his and Grin’s critical linguistic human rights perspective. We believe May is right to emphasise the practical advantages of implementing minority language rights within nation-states (May, 2005, p. 327). In further work we plan to explore what these advantages (and any disadvantages) may be (and for whom) with respect to adult numeracy education and how these rights might be articulated within relevant policy frameworks in linguistically diverse societies. We see minority languages as something to celebrate rather than just accommodate in adult numeracy education. Language is too important for the language dimensions of adult numeracy learning to be ignored in policy, teaching and the organisation of provision. Numbers and words are both important in adult numeracy teaching and learning. To invert the title of the adult literacy and numeracy strategy in Wales: numbers talk and words count.

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From Standards-Led to Market-Driven: A Critical Moment for Adult Numeracy Teacher Trainers *

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Abstract

There has been a shift in the training of numeracy teachers in England away from a highly regulated 'standards-based' approach to teacher training towards one that seeks to engage employer groups and stakeholders in determining the training needs of teachers in further education. This shift has taken place within the context of rapid reform to numeracy and mathematics curricula for post-16 learners. The planned curriculum changes have again highlighted the shortage of qualified numeracy teachers needed to implement national policy initiatives, and has brought numeracy teacher training onto the policy agenda once again. This paper uses Bernstein's notions of vertical teacher knowledge and horizontal teacher knowledge to consider how trainee teachers may be supported to bridge the gap between their own mathematical knowledge and their classroom practice as numeracy teachers. It also draws on Shulman's seven types of teacher knowledge to make these connections. Recommendations made relate to the entry criteria for adult numeracy teachers, allowing 'time and space' to reflect with other trainees rather than 'immersion in practice', the benefits of practitioner-led enquiry to develop innovative pedagogies, and enhanced links between further education and school-based mathematics and between further education and higher education.

Key words: numeracy, teachers training, standards-based approach

Introduction and policy context for adult numeracy teacher training in England

The Moser report (DfEE, 1999) signalled the introduction of the ‘skills for life’ policy in England with a commitment to raise the literacy and numeracy skills of adults. This policy initiative was introduced in the context of a largely casualised teaching workforce where literacy and numeracy teachers often existed on the margins of further education and were sometimes perceived as lacking the subject or occupational expertise often associated with teachers of academic or vocational subjects (Lucas, 2007). The introduction of ‘subject specifications for teachers of adult literacy and numeracy’ (DfES/FENTO, 2002) sought to address this by ensuring “that all new teachers [of literacy and numeracy] are equipped with the appropriate knowledge, understanding and personal skills in their subject, in order to put them on a par with teachers in any other subject” (Lucas, 2007, p.127).

The drive to raise the subject knowledge of literacy and numeracy teachers in England through the introduction of the DfES/FENTO (2002) subject specifications was to some extent subsumed within the wider ‘equipping our teachers for the future’ initiative (DfES, 2004) that sought to raise the subject knowledge of all teachers in further education. This was partly driven by a critical Ofsted report (2003) into the initial training of further education teachers that found little systematic development of the specific skills and understanding needed for effective subject specialist teaching and that the lack of this specialist dimension to be “a major shortcoming in the present system of FE teacher training” (Ofsted, 2003, p.23).

The DfES/FENTO (2002) ‘subject specifications for teachers of literacy and numeracy’ were replaced in 2007 by 'new overarching professional standards for teachers, tutors and trainers in the

lifelong learning sector’ (LLUK, 2007a) and an application of those standards for specialist teachers of adult numeracy (LLUK, 2007b). These new professional standards were followed by a qualification framework, workforce regulations and the imposition of highly prescriptive learning outcomes that sought to regulate the competencies trainee teachers were expected to demonstrate during initial teacher training. Nasta (in Lawy and Tedder, 2009, p.56) described this policy model as driven by a “linear notion that the standards must be specified first, then regulations and qualifications must be developed that incorporate the standards, and only at the final stage is a curriculum and assessment model to be developed that will form the basis of what trainees actually experience”.

Two research projects were carried out by the National Research and Development Centre (NRDC) into the DfES/FENTO (2002) ‘subject specifications for teachers of numeracy and literacy’. The earlier of these studies (Lucas et al., 2004) was based on nine universities that piloted the subject specifications alongside their initial teacher training courses whilst the later study (Lucas et al., 2006) drew upon a larger sample of mostly in-service courses delivered by both universities and colleges. The key foci of these research projects included an exploration of how the subject specifications were being translated and re-contextualised into teaching practice; different approaches taken to delivering the subject specifications; and the balance to be struck between subject specific knowledge, pedagogic knowledge and practical teaching skills (Lucas, 2007). The two NRDC projects led to a number of peer-reviewed publications by the researchers involved in the projects (Lucas, Loo and McDonald, 2006; Lucas, 2007; Loo, 2007a; Loo, 2007b). These discussed issues relating to the increased subject knowledge of numeracy (and other ‘skills for life’) teachers and the relationship of that increased subject knowledge to classroom teaching practice using Bernstein’s (2000) notions of vertical teacher knowledge and horizontal teacher knowledge.

Whilst a body of literature began to emerge specific to adult numeracy teacher training as a result of the two NRDC studies (Lucas et al., 2004; Lucas et al., 2006), this literature did not explicitly take account of the more developed debates on the nature of subject knowledge needed for teaching mathematics in schools (e.g. Ball and Bass, 2003; Davis and Simmt, 2006; Ball, Thames and Phelps, 2008; Hodgen, 2011). It is appropriate in considering subject knowledge for teaching adult numeracy to engage with the wider debate of subject knowledge for teaching mathematics in schools, particularly given the research that has taken place into the longer-established subject knowledge enhancement courses (formerly called mathematics enhancement courses) that are by universities to prospective trainee mathematics teachers for secondary schools (e.g. Adler and Davis, 2006; Askew, 2008; Stevenson, 2008; Adler et al., 2009).

The change of government in the UK in 2010 resulted in a shift of educational policy on teacher professionalism away from centralised government-control through a standards-based and regulatory system towards one that afforded greater autonomy to employers to determine the professional qualifications their teaching workforce needed to respond to the needs of the learners and employers they seek to serve. The Lingfield review of teacher professionalism in further education (BIS, 2012, p.5) did confirm the need for specialist pre-service or early in-service teacher training for “lecturers in the foundation skills of literacy and numeracy”, albeit within the context of the revocation of the statutory regulations for teacher qualifications in further education. What Lingfield did not attempt to do was define what constitutes foundation skills in numeracy (whether it includes functional mathematics for 14 to 19 year-olds or GCSE mathematics, for example) or the specific outcomes trainee teachers should be expected to demonstrate during initial teacher training.

This article seeks to develop Bernstein's notions of vertical teacher knowledge and horizontal teacher knowledge found in the literature relating to adult numeracy teacher training in England by comparing it with Shulman's seven categories of teacher knowledge found in the literature from the more established subject knowledge enhancement courses offered by universities for intending mathematics teachers in secondary schools. Bernstein and Shulman's theoretical models will be used
to analyse post-hoc three teacher training activities drawn from courses designed to meet the subject knowledge requirements of the DfES/Fento (2002) subject specifications for adult numeracy teachers.

Throughout this article the term ‘numeracy’ is used to distinguish the curriculum taught to post-16 learners in vocational contexts from ‘mathematics’ as the curriculum taught as a compulsory subject in schools. Similarly ‘numeracy teachers’ refers to those teachers qualified or training as specialist teachers of adult numeracy and ‘mathematics teachers’ to those qualified or training as specialist teachers of mathematics in secondary schools. The use of these terms to distinguish between curricula and job roles does not imply that such a simplistic division between numeracy and mathematics exists. Indeed, as will be seen in the later section critical moment in a changing policy context, the labels numeracy and mathematics can be used to signal the ideological perspectives of policy-makers and as such be subject to different interpretations. For a flavour of the debate on the use of the terms numeracy and mathematics see the papers presented by Kaye in earlier conference proceedings of this journal (Kaye, 2002; Kaye 2010).

**Subject specifications for adult numeracy teachers - Bernstein's vertical teacher knowledge and horizontal teacher knowledge**

The two NRDC studies (Lucas et al., 2004; Lucas et al., 2006) into pilot courses designed to meet the requirements of the FENTO ‘subject specifications for teachers of numeracy and literacy’ identified three different types of participant on the courses studied. These included very experienced practitioners who also held management posts and staff training roles in colleges; practicing teachers with some classroom teaching experience; and new entrants to teaching with little teaching experience. Each group had different expectations from the course with the most experienced wanting “a high level of theoretical content that would … provide them with a synoptic perspective on their specialism” (Lucas, Loo and McDonald, 2006, p.341) whilst the newer entrants to teaching wanted an emphasis on practical teaching to prepare them for teaching practice. Lucas, Loo and McDonald (2006) applied Bernstein’s notions of horizontal teacher knowledge and vertical teacher knowledge to understand the distinction between theoretical and practical knowledge for teachers and ways in which the courses attempted to bridge these two types of knowledge through what Bernstein called ‘re-contextualisation’.

An examination of the FENTO subject specification for adult numeracy (DfES/FENTO, 2002) shows that it consisted primarily of Bernstein’s ‘vertical knowledge’ separated into the sections of number and numeric operations, geometry and spatial awareness, statistics, and working with algebra. It was primarily ‘vertical knowledge’ in the sense that the specification required an academic or theoretical understanding of the content that was independent of context or experience. A closer inspection of the elements listed in the specification revealed that most of them approximated to topics that might be found on the first year of a course in GCE Advanced Level mathematics (level 3 on the English National Qualifications Framework) whilst other topics were identifiable from the content required for higher level tier of GCSE mathematics syllabi (level 2 on the English National Qualifications Framework). The specifications immediately raised the questions of (i) how the courses can be justified as being at level 4 on the national qualifications framework (equivalent to the first year of undergraduate study) when the content was clearly a repetition of level 3 study, and (ii) how all the elements listed in the specifications can be covered in a course of one-year part-time duration.

The first of these two questions relating to academic level was the simplest to answer. In the case of the experienced practitioners seeking a theoretical and synoptic perspective of mathematics this ‘level 4-ness’ could be justified as being demonstrated through the adoption of a connectionist approach to mathematics that emphasised relational understanding over procedural understanding (Skemp, 1976; Askew, 1997). For new entrants to teaching it was the requirement for 60 hours of
practical experience in teaching adult numeracy that were seen to bring the ‘level 4-ness’. In both cases there were significant challenges for numeracy teacher trainers supporting trainees in the process of re-contextualising vertical teacher knowledge of mathematical content into horizontal teacher knowledge of classroom practice in teaching adult numeracy.

The second of the two questions posed more difficulties for course designers with different approaches taken by awarding bodies and universities to the problem of achieving coverage of the specifications within the learning hours available. Lucas (2007) identified that whilst national awarding bodies adopted a ‘standards-based approach’ that emphasised ‘coverage’ and ‘mapping’ in the competency tradition, universities were more innovative in a ‘knowledge-based approach’ where they chose which elements of the specifications to emphasise and in what depth to explore them.

Three examples, one from a course that I delivered at Thames Valley University, another from a course delivered by LLU+ at London South Bank University reported in the proceedings of the 13th annual international conference of Adults Learning Mathematics (Stone and Griffiths, 2006), and a third from one of the NRDC pilot studies (Lucas et al., 2004; Lucas et al., 2006) illustrate ways in which universities developed innovative ‘knowledge-based approaches’ towards the DfES/FENTO (2002) subject specifications:

**Example 1: Thames Valley University**

One element of the DfES/FENTO (2002) subject specification within the statistics section required knowledge of discrete probability distributions. The direct contact-time available to the trainer to teach this topic was a single session of four hours duration, albeit with the expectation that trainees would engage in self-directed study to further their knowledge outside of the taught session. There were several problems with this. Discrete probability distributions include rectangular, binomial and Poisson distributions. Each of these constitutes a topic in its own right worthy of more than four hours of direct contact-time. Furthermore, knowledge of discrete probability distributions does not easily translate to strategies for teaching adult numeracy learners. Interestingly, coverage of the normal distribution was not required by the DfES/FENTO (2002) subject specifications since this is a continuous rather than discrete probability distribution, even though an understanding of the normal distribution is arguably more relevant to teachers than the discrete probability distributions due to its usefulness in interpreting assessment results for large populations, understanding IQ scores, and so on.

The trainer made the decision in planning the session to teach both the continuous probability distribution (normal) and the discrete probability distributions (rectangular, binomial and Poisson) within the four hour session. Being aware of the impossibility of teaching such a range of mathematical knowledge within four hours the trainer elected to see the content as a vehicle towards meeting an overarching course aim rather than specific content to be covered. The overarching aims of the trainer were (i) to provide trainees with the opportunity to carry out self-study in pairs on an area of mathematics unfamiliar to them and then teach that concept to the rest of the group, (ii) appreciate the uses of mathematical modelling (e.g. the normal distribution to interpret IQ scores and the Poisson distribution to predict volcanic activity), and (iii) to make links with own practice as teachers of adult numeracy.

**Example 2: LLU+ at London South Bank University**

Stone and Griffiths (2006, p.148-149), in reflecting upon their experiences as numeracy teacher trainers at LLU+, argued that:

Making teachers ‘do some hard sums’ and giving them some background information on personal and social factors affecting learning was not really equipping them to teach their subject. … Clearly,
something was missing. At LLU+ the feedback from our own teacher training programmes was that while the course sessions were fun and participants were exposed to [an] imaginative variety of teaching methods, they did not feel they were learning as much as they would have liked that would be useful to them in the numeracy classroom. To this end, we began enriching our programmes on offer with opportunities to explore mathematics and numeracy at a basic level and to discuss and evaluate ways to teach it.

This extract appears to indicate a similar orientation to the trainer in example 1 where a commitment to overarching course aims allowed the subject specifications to be interpreted creatively. In the case of the two trainers at LLU+ the overarching course aims appeared to include learning as fun, modelling variety in teaching methods, valuing the ‘student voice’, and ensuring relevance of activities to participants’ professional practice.

**Example 3: Broken keys activity**

Loo (2007) describes an activity used by one of the institutions in the NRDC studies called ‘broken keys’. This involved trainees creating problems for others in the group to solve using mathematical functions. These were then linked to word cards and picture cards to illustrate the links between algebraic symbolism and real life. Finally the trainees were encouraged to reflect on how the approaches could be applied to the teaching of topics from the Adult Numeracy Core Curriculum (DfES, 2001).

Whilst the starting point to the ‘broken keys’ activity was drawn from the ‘working with algebra’ section of the subject specifications a commitment on behalf of the trainers to overarching course aims such as modelling the Standards Unit approaches of learners creating problems, multiple representations and encouraging discussion (Swan, 2005) can arguably be inferred from the teaching approach described.

**Subject knowledge enhancement courses for schoolteachers in secondary mathematics - Shulman's seven major categories of teacher knowledge**

Subject knowledge enhancement courses (previously known as mathematics enhancement courses) are well-established in many English universities offering Post-Graduate Certificate in Education (PGCE) courses for intending mathematics teachers in secondary schools (Sheffield Hallam University, 2013). These courses are usually offered as short part-time courses to graduates who have already been offered a place on secondary mathematics PGCE courses. They are designed to meet the needs of new entrants to teaching whose undergraduate degree is not in mathematics but in a related subject such as engineering or finance. Since such courses are more established and theorised than those developed to the DfES/FENTO (2002) subject specifications that are the subject of this article it is worth considering what lessons can be learnt from them, and whether those lessons are transferable to adult numeracy teacher training.

Shulman (1986), in developing a theoretical model for teacher knowledge that can be applied to mathematics (and adult numeracy) teacher training, defined the seven major categories of teacher knowledge shown in figure 1. The first four of these categories related to generic teaching skills and these were the mainstay of teacher education programmes at the time. These four categories were seen as relevant to all teachers irrespective of the subject-specific context of their teaching. Shulman acknowledged the crucial importance of these four categories for teaching but went on to propose three further categories that he termed content knowledge, curriculum knowledge and pedagogical content knowledge.

‘Content knowledge’ includes knowledge of the subject to be taught and how it is organised, including an understanding of which concepts are central to the discipline and which are peripheral (Ball, Thames and Phelps, 2008). This type of knowledge can be related to the expectations of the

most experienced practitioners in Lucas, Loo and McDonald’s (2006) study of pilot DfES/FENTO courses who wanted a high level of theoretical content to provide them with a synoptic view of their specialism.

‘Curriculum knowledge’ relates to knowledge of the full range of courses available to teach particular subjects and topics at a particular level, including the range of instructional materials available (Ball, Thames and Phelps, 2008). It also includes ‘lateral curriculum knowledge’ (what is being taught to learners in other subject areas) and ‘vertical curriculum knowledge’ (what has been taught in the subject in previous years, and what will be taught in subsequent years).

Shulman’s final category of ‘pedagogical content knowledge’ sought to define that specific knowledge about a subject that is unique to teachers of the subject. It includes an awareness of what makes particular topics conceptually easy or difficult for learners to understand; the most useful analogies, illustrations, examples, explanations and demonstrations that can be used to support learning whilst remaining consistent to the integrity of the subject matter; and common conceptions and misconceptions of particular topics typically held by learners at different ages or ability levels (Ball, Thames and Phelps, 2008). Interestingly, Shulman’s approach was quite different to that of subject specifications and prescribed learning outcomes adopted by FENTO and its successor bodies in that he “did not seek to build a list or catalogue of what teachers need to know in any particular subject area” but instead “sought to provide a conceptual orientation and a set of analytic distinctions that would focus the attention of the research and policy communities on the nature and types of knowledge needed for teaching a subject” (Ball, Thames and Phelps, 2008, p.392).

By analysing Shulman's categorisation of different types of teacher knowledge it becomes apparent that his content knowledge related most closely to Bernstein's vertical teacher knowledge whilst Shulman's curriculum knowledge and pedagogical content knowledge are more akin to Bernstein's horizontal teacher knowledge.

![Figure 1. Shulman’s major categories of teacher knowledge](image-url)

There are currently two dominant views on the subject knowledge that mathematics teachers in secondary schools need to know to effectively teach their subject (Bell, Thames and Phelps, 2008). The first view is that they need to know whatever mathematics is in the curriculum at the level they are intending to teach plus some additional years of further study at a higher level of mathematics. The second view is that they need to know the mathematics in the curriculum at the level they are intending to teach, but that this should be a ‘deep understanding’ incorporating aspects of Shulman’s
‘pedagogical content knowledge’ (Shulman, 1986). The notion of deep understanding in mathematics is evident in the literature in a number of guises. Ma (1999), for example, refers to ‘profound understanding of fundamental mathematics’ whilst Adler and Davis (2006) use ‘understanding mathematics in depth’ to describe their conceptualisations of subject pedagogical knowledge.

**Bringing together the theories of Bernstein and Shulman**

Bernstein’s notion of the re-contextualisation of vertical teacher knowledge into horizontal teacher knowledge applied by Loo (2007a; 2007b) to adult numeracy teacher training and Shulman’s seven categories of teacher knowledge applied to secondary mathematics teacher training (Ball and Bass, 2003; Davis and Simmt, 2006; Ball, Thames and Phelps, 2008; Hodgen, 2011) can be brought together by considering the three examples of teacher training activities discussed earlier.

In example 1 the teaching of discrete probability distributions was discussed. Knowledge of discrete probability distributions (rectangular, binomial and Poisson) fits comfortably within Bernstein's vertical teacher knowledge in that it provides teachers with a synoptic view of their specialism. The re-contextualising of that vertical teacher knowledge into horizontal teacher knowledge is more problematic since the pedagogical techniques adopted of peer-led teaching and mathematical modelling could have been achieved more effectively through studying a numeracy concept drawn from the curriculum that trainees were being trained to teach, rather than through an unfamiliar mathematical topic that trainees themselves experienced as conceptually difficult. It could be argued, for example, that it would be more beneficial for teacher trainers to model the use of a ‘washing line’ strung across the classroom to order the probability of events occurring on a scale of 0 to 1 rather than being required to teach discrete probability distributions in the tradition of Bernstein's vertical teacher knowledge as a proxy for Shulman's pedagogical content knowledge.

In example 2, discussed earlier, the difficulties teacher trainers experienced in supporting trainees to re-contextualise Bernstein's vertical teacher knowledge into horizontal teacher knowledge was even starker. In this case the phrase 'do some hard sums' was contrasted negatively with what teacher trainers saw as necessary to equip trainees to teach adult numeracy effectively. Their response was to enrich the programmes (presumably by adding what they considered to be more relevant pedagogical content knowledge) to the content prescribed by the subject specification. In this case it could be argued that the trainers pedagogical content knowledge replaced, or at least marginalised, the vertical teacher knowledge found in the subject specification in such a way as to obviate the need for the re-contextualisation by trainees of different types of teacher knowledge.

The broken keys activity described earlier in activity 3 resonates with the first example in that mathematical functions do not feature in the adult numeracy core curriculum (DfES, 2001). Nevertheless they appear to have been used with some success to introduce Shulman's pedagogical content knowledge by proxy through the use of Standards Unit (Swan, 2005) approaches to teaching mathematical functions. In spite of the apparent success of this approach it could again be argued that using the algebraic notation of functions unfamiliar to trainees adds an unhelpful layer of conceptual difficulty that clouds the more pressing concern of how to effectively teach the basic algebraic concepts found in the adult numeracy core curriculum (DfES, 2001).

**Critical moment in a changing policy context**

In recent times teaching has been practiced within a rapidly changing policy context (Ecclestone, 2008; Earley et al., 2012). This has led to changes in the way that the teaching role and teacher professionalism has been conceptualised, along with related changes within teacher training itself. It is within this context that a 'critical moment' for adult numeracy teacher training may emerge.
Current government policy in England raises the expectation that all school-leavers without the GCSE mathematics pass expected of sixteen year-olds should be required to retake the full GCSE in mathematics if they progress to full-time further education (DfE, 2013). Additionally, those school leavers progressing to full-time further education who have already achieved the GCSE mathematics pass expected of school-leavers should be required to continue to study mathematics to a higher level rather than being allowed to discontinue mathematics at age 16 as previously (ACME, 2012). Such an approach is seen by policy-makers as promoting the more rigorous and academic study of mathematics rather than the development of numeracy skills for vocational learners through qualifications such as adult numeracy and functional mathematics. Such curriculum reforms are seen by policy-makers as ensuring the UK can compete with leading industrialised nations (Vorderman, 2011).

Recent policy initiatives in teacher training for schools have included encouraging high-achieving graduates to enter teaching through targetted bursaries and to encourage school-centred initial teacher training (SCITT) consortia to provide teacher training as an alternative to more traditional university-led provision (DfE, 2010; DfE, 2011). Such an approach to teacher training assumes that the acquisition of subject content knowledge at a high level should be attained prior to entering teacher training, and that the practical skills of teaching itself are acquired as a ‘craft’ by working alongside practicing teachers. The speech by the Secretary of State for Education to the National College (Gove, 2010) expressed the view that "Teachers grow as professionals by allowing their work to be observed by other professionals, and by observing the very best in their field …" and that "teachers … improve their craft by learning from others while also deepening their academic knowledge" (my emphasis). The dichotomy between teaching as a craft and teaching as a profession was challenged by Kirk (2011) who argued that whilst teaching generates substantial personal craft knowledge, often in the form of tacit knowledge, it also required engagement with a broader type of knowledge that "… implies a professional duty to keep in touch with the literature of teaching and learning, and indeed to contribute to it as a way of raising the level of public and professional debate on teaching and learning" (Kirk, 2011).

Similar tensions have been experienced in the training of further education teachers to those found for schoolteachers. The Lingfield Report (2012) recommended the revoking of the regulatory framework for teachers in further education and called for new qualifications for teacher training to be developed by an employer-led ‘guild’. However, Lingfield (2012, p.33) also called for a strong professional identity for further education teachers underpinned by increased autonomy to develop innovative pedagogies specific to the vocational focus that is unique to further education. Such practitioner-led enquiry hinted at by Lingfield (2012) is not new to further education. Previous initiatives have included the practitioner-led research initiative (NRDC) and the teacher enquiry funded projects (NCETM). Such initiatives were consistent with Hoyles’ (1975) notion of extended professionalism and sit comfortably with emerging measures of professional esteem such as chartered mathematics teacher status and chartered status for further education teachers. In reflecting upon such initiatives, however, it is necessary to sound a cautionary note concerning the culture within the further education sector that can mitigate against such initiatives. The using research to enhance professionalism in further education project (Economic and Social Research Project) identified that whilst practitioner research had a significant role to play in shaping the professional identities of those teachers that engaged in it, the benefits were often undermined by managerialist cultures within colleges where short-term gains, such as compliance with national policy agendas, hindered practitioners from asking more fundamental and critical questions about their practice (Goodrham, 2008).

The reforms to the post-16 mathematics curriculum described earlier in this section are a case in point where the shortage of qualified mathematics teachers to deliver the policy initiative has led to

the launch of a government-subsidised six-day training programme intended to "further develop the skills of those currently teaching functional skills, preparing them to teach GCSE maths" (Education and Training Foundation, 2013). Such a quick-fix approach to numeracy training appears unlikely to provide teachers with the space or time to gain Bernstein's vertical teacher knowledge and re-contextualise it into horizontal teacher knowledge, nor to acquire those aspects of Shulman's subject pedagogical knowledge critical for effective teaching of numeracy to 'second-chance' learners in further education. Regional training programmes promoted as up-skilling teachers of numeracy by "enhance[ing] their knowledge so that they can teach GCSE effectively" (EMCETT, 2013) is likely to lower the status of numeracy teachers and undermine the gains made through the introduction of specialist teacher training for adult numeracy teaching rather than raise the quality of numeracy teaching. The ambitious targets set to engage post-16 learners in the study of mathematics up to the age of eighteen is laudable, as is the intention to enhance the subject knowledge of teachers so that they can effectively meet the challenges of the new curriculum. These targets and intentions need to be matched by a strategy for recruiting high quality graduates into teaching mathematics and then providing specialist teacher training courses to support them to re-contextualise their own knowledge of mathematics into effective numeracy pedagogies for further education. Similarly, experienced teachers of vocational subjects cannot be expected to retrain to teach GCSE mathematics without first being provided with the opportunities to increase their own mathematical knowledge to the standards that would be required for teaching in any other curriculum area.

Conclusions and recommendations

Mathematics subject knowledge should be a prerequisite for new entrants to numeracy teaching, whether for new entrants to teaching or for experienced teachers retraining to teach numeracy from other curriculum areas, in the same way that the best graduates and those with substantial vocational experience are sought as teachers for other academic and vocational subjects. Whilst it is unlikely that a consensus can be reached amongst the mathematics community on the detail of the content and level necessary, it is nevertheless important for the status of numeracy that minimum entry criteria be developed. These criteria should be credible when compared with entry requirements for teaching in other academic and vocational areas of further education.

Numeracy teachers should be given opportunities to build upon and extend their own mathematical knowledge and subject pedagogical knowledge throughout their careers, including at Masters level. They should be given support, time and space to develop innovative numeracy pedagogies related to the particular vocational contexts and specialist settings they encounter within further education. Supporting practitioner-led enquiry holds much promise as an effective form of continuous professional development for numeracy teachers.

Whilst acknowledging the benefits of observing the best teachers to learn the 'craft of teaching', it is also necessary to allow teachers the time and space to reflect on their professional learning with other trainee teachers. Such an approach is more likely to develop the critical skills to adapt to the fast-changing and policy-driven culture of further education than immersion in practice. The benefits gained from the subject specialist teacher training in adult numeracy from 2002 need to be maintained and strengthened if the challenges of post-16 curriculum reform are to be met.

Opportunities for developing links between further education and school-based mathematics and between further education and higher education should be grasped. These links can be beneficial both to share effective practice in teaching mathematics and to identify the nature of numeracy pedagogies specific to the contexts and learners in further education.

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NEW PIAAC RESULTS: CARE IS NEEDED IN READING REPORTS OF INTERNATIONAL SURVEYS *

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Abstract
Results from the Survey of Adult Skills, also known as PIAAC (Programme for the International Assessment of Adult Competencies), were recently made available for 24 participating countries. PIAAC involves several developments in relation to the earlier international “adult skills” surveys (IALS in the 1990s and ALL in the 2000s), notably the use of computer administration of the survey. In this paper, I focus on understanding these studies, by considering conceptual issues, methodological validity of research design and execution, and presentation of results. I consider several of the sample items for numeracy published by OECD (2012). And I discuss illustrative results from Australia made available in February 2013, by the Australian Bureau of Statistics. The paper shows when and how to be sceptical when reading international survey reports. It also opens up questions concerning the relevance of the results, and the other types of research that may be needed, in different national and local contexts.

Key words: adult skills, international assessment, and mathematics

Introduction
From October 2013, results from PIAAC (Programme for the International Assessment of Adult Competencies) for 24 participating countries have been available (OECD, 2013a, 2013b). PIAAC aims to provide information as an international comparative survey, successor to IALS (during the 1990s) and ALL (2000s), and it has many similarities with national studies, such as Skills for Life in the UK. Unlike the school level surveys (TIMSS, PISA), which gain access to “captive populations” in schools, PIAAC needs to use a combination of household survey and educational testing methodologies. It involves developments from the adult earlier studies, in several ways.

The first round covers a greater range of countries (24, two thirds of which are EU members, with the rest from North America, East Asia and Australia) – though all are advanced industrial economies. It focuses on three domains or “competencies” – Literacy, Numeracy, and now Problem Solving in Technology Rich Environments (PSTRE). It uses computer administration, which has a number of consequences, in particular allowing adaptive routing of respondents (see Section 3), and making the survey results available more quickly and more accessibly. In addition, PIAAC has implemented a number of methodological and fieldwork improvements, for example, tighter specification and regulation of sampling and fieldwork standards than in previous international surveys (OECD, 2013b, pp. 47-61). PIAAC is designed to be repeated, in order to build up time series data for participating countries. This longitudinal aspect would aim to facilitate the study over time of the correlations of the performance outcomes with relevant social or attitudinal variables.

In Section 2 I sketch international the policy context, including the conception of Lifelong Learning (LLL) promoted by the survey’s sponsor, the OECD (Organisation for Economic Cooperation and Development). In Section 3, I describe the survey aims, and the underlying
conception of numeracy. In Section 4, I consider how this conception is deployed in the measurement process, and other aspects of methodological validity that need to be considered for international performance surveys. I also focus on the need to consider the way that the survey results are reported, since this crucially affects the way “the findings” are perceived by various categories of readers. In Section 5, I discuss some illustrative results from Australia, and in Section 6, I return to focus on the effects of international surveys like PIAAC on the developing educational policy context worldwide.

The international policy context

Educational policy is currently being developed on a world-wide scale, with supranational organisations acting as key agencies for change. Increasing globalisation and competitive economic environments are leading national governments to seek competitive advantage – which is “frequently defined in terms of the quality of national education and training systems judged according to international standards” (Brown, Halsey, Lauder & Wells, 1997, pp. 7-8). Results from surveys like PIAAC (and PISA) seek to provide measures of a country’s progress according to international standards.

The idea of Lifelong Learning (LLL) is central to the conceptualisation of adult numeracy (and literacy). In international policy debates, LLL has been much contested, e.g. between “humanistic” (learning for the whole person) and “economistic” (human capital) approaches (Evans, Wedege, & Yasukawa, 2013). In this connection, it is important to consider work done both within the UNESCO programmes (e.g. Guadalupe, 2013), and by the OECD.

Here I focus on the OECD, PIAAC’s sponsor. OECD’s view of LLL aims to promote the development of knowledge and competencies enabling each citizen to actively participate in various spheres of globalised social and economic life. It also promotes a broad view of the context of learning, and a weakening of the distinction between formal and informal education. At the same time, it emphasises the citizen’s need to acquire and update a range of abilities, attitudes, knowledge and qualifications over the life-course, and hence the individual learner’s responsibility for their own education (e.g. Walker, 2009). Some of the consequences of these commitments will be discussed below; see also Tsatsaroni & Evans (2013).

The European Union (EU) is working closely with OECD on PIAAC. For supra-national institutions like the EU, the area of Lifelong Learning provides a domain where they can make a legitimate policy intervention, since, in a globalised world, a focus on labour mobility makes LLL a supra-national concern. This provides a basis for OECD’s and EU’s actions, leading to the promotion of the “skills and competencies agenda”, in all sectors of education and training (Grek, 2010). More generally, the OECD and the EU are disseminating ideas and practices that strongly influence national policy making around the world. These include the promotion of expertise in creating comparable datasets, and new forms of “soft governance” of national educational systems, encompassing the production and dissemination of knowledge, and of comparative data such as educational and social indicators, and peer reviews involving country and thematic reviews. These practices allow countries to measure the relative success of their education systems and to shift policy orientations accordingly, while increasingly facilitating the role of these supra-national organisations themselves to be “governing by data” (Ozga, 2009). Overall, one of the effects of international studies like PISA and PIAAC is to contribute to a “comparative turn” in educational policy-making and to a “scientific approach” to political decision-making (Grek, 2010).

The PIAAC Survey

PIAAC’s main objectives were presented by Andreas Schleicher (2008) of the Education Directorate at OECD – as helping the participating countries to:
• Identify and measure differences between individuals and across countries in key competencies.
• Relate measures of skills based on these competencies to a range of economic and social outcomes relevant to participating countries, including individual outcomes such as labour market participation and earnings, or participation in further learning and education, and aggregate outcomes such as economic growth, or increasing social equity in the labour market.
• Assess the performance of education and training systems, and clarify which policy measures might lead to enhancing competencies through the formal educational system – or in the work-place, through incentives addressed at the general population, etc. (pp. 2-3).

The PIAAC objectives thus appear to comprise a “human capital” approach, coupled with social concerns (Evans, Wedege & Yasukawa, 2013).

In the framework used by OECD, literacy, numeracy and problem-solving in technology rich environments are the three competencies which PIAAC aims to measure. In the OECD’s approach, competencies are internal mental structures (i.e. abilities, capacities or dispositions embedded in the individual […] . Although cognitive skills and the knowledge base are critical elements, it is important not to restrict attention to these components of a competence, but to include other aspects such as motivation and value orientation [PIAAC Numeracy Expert Group, 2009, p. 10]). Numeracy is defined for the purposes of designing the items for PIAAC as: ‘The ability to access, use, interpret, and communicate mathematical information and ideas, in order to engage in and manage the mathematical demands of a range of situations in adult life’ (PIAAC Numeracy Expert Group, 2009, p. 20ff).

This is put forward as a basis for conceptualising mathematical thinking in context. However, in order to produce measures of numeracy, the idea of numerate behaviour is put forward, that is:

The way a person’s numeracy is manifested in the face of situations or contexts which have mathematical elements or carry information of a quantitative nature. […] inferences about a person’s numeracy are possible through analysis of performance on assessment tasks designed to elicit numerate behaviour. (PIAAC Numeracy Expert Group, 2009, p.10)

This led to specifying the following dimensions of “numerate behaviour” that can be used to guide the construction of assessment tasks:

• Context (four types): everyday (or personal), work, society and community, further learning
• Response (to mathematical task - three main types): identify / locate / access (information); act on / use; interpret / evaluate.
• Mathematical content (four main types): quantity and number, dimension and shape, pattern and relationships, data and chance
• Representations (of mathematical / statistical information): e.g. in text, tables, and/or graphs 55.

Each item can be categorised on these four dimensions, along with its estimated difficulty.

PIAAC also aims to produce affective and other contextual data that can be related to the respondent’s performance. This includes demographic and attitudinal information in a Background Questionnaire (BQ), and self-report indicators on the respondent’s use of, and need for, job-related skills at work; see OECD (2013b) for the BQ’s conceptual framework, and CSO, Ireland (2013) for a copy of the BQ.

55 Literacy and PS-TRE items are characterised by a similar, though not identical, set of dimensions (OECD, 2013b, pp. 21-34).
Each country interviewed at least 5000 adults, normally 16-65 years of age. PIAAC’s default method of survey administration is by laptop computer, although paper-based testing was used in IALS / ALL (and PISA up to now). This facilitates the use of adaptive routing, which estimates the “skill level” of the respondent from a few initial responses, and then administers more appropriate items (in terms of difficulty) throughout the rest of the interview.

Understanding PIAAC’s conceptual framework and methodology

In seeking to understand PIAAC and other adult skills surveys and their results, I consider how the interpretation of such studies needs to be related to their conceptual bases and methodological decisions, as well as choices about presentation and reporting and arguments about the range of applicability of the findings (Tsatsaroni & Evans, 2013; Hamilton & Barton, 2000; Radical Statistics Education Group, 1982 / 2012).

Generally, surveys rely on aspects of the research design, responding to reasonably well-understood criteria of validity, to enhance and to monitor the measurement and sampling procedures. It is important for literacy and numeracy researchers, teachers and policy makers to be able to consider these, when the results of a survey are presented and discussed. Here I consider the likely effects of certain design features of the survey, and their realisation in the field, in terms of the following aspects of validity:

- The content validity of the definitions of numeracy and numerate behaviour (“types” or categories of items, as described above)
- The measurement validity of the items presented, including the administration and scoring procedures (“qualities” of items)
- The reliability of the measurement procedures
- The external validity, or representativeness, for the national population of interest, of the results produced from the sample

(See Evans, 1983, for a more detailed discussion)

Content validity

I am using the term content validity in this paper to refer to the extent to which a measure represents all aspects of a given concept, as it is defined. The definition of numeracy used by PIAAC (and, earlier, ALL) is based on the four dimensions of numerate behaviour stipulated above. Each item can be categorised on these four dimensions, and the proportion of items falling into each category can be controlled over the whole scale, so as to make the operational definition of numerate behaviour more explicit, and the content validity of the overall set of items more open to scrutiny. In PIAAC numeracy, the proportion of items falling into each category of mathematical content, context, and response is controlled (OECD, 2013b, p.28). This allows test designers to stipulate the proportions of the items that are from each type of each key dimension, and from different levels of difficulty – for example, the proportion of “data and chance” items of medium difficulty.

However, in an international survey, this can provide only a general, transnational definition, and one needs to question how well it “fits” adults’ lives in any particular country. For example, the four types of context (everyday / personal, work, society and community, further learning) can be specified only in a rather general way – they may or may not represent the repertoire of actual specific social

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56 Respondents are presented with initial computer-based tasks; anyone uncomfortable with these takes an alternative pencil-and-paper version of the main tests.
57 These levels of difficulty are estimated by Item Response Modelling procedures; see subsection 4.5 below.
practices or social contexts in which any particular respondent might engage, in his/her life. Thus we need to examine a set of items that a particular sample member might be asked to respond to.

Measurement validity

What I call here “measurement validity” refers to the extent to which the responses to the set of items administered to a respondent actually capture what the conceptualisation of numeracy specifies; this will depend on the actual range of items used. As with most large-scale educational assessments, the full set of the items used is not made public, while the survey is on-going\textsuperscript{58}. Nevertheless, four illustrative items are presented on several websites (e.g. CSO, Ireland, 2013), and in the Appendix.

This sample of four PIAAC or “PIAAC-like” numeracy items were published to represent the more than 50 that might potentially be presented to any PIAAC respondent (OECD, 2012). Like any sample, of course, these four items cannot represent the full range of combinations of content, context, responses required, and difficulty levels. Nevertheless, it may be useful to consider them here, since they give some specificity to the more general characterisation of numeracy in the survey discussed in the previous subsection. For two of the items, the mathematical contents are framed by Everyday/Personal or Work contexts; for the other two, Society and community contexts\textsuperscript{59}. They appear to combine realistic images of the problem at hand with school-like test rubrics, providing the questions that need to be answered, presumably by applying the correct mathematical procedures. Thus these items represent a hybrid type of task.

In any particular country, we need to ask how well these sorts of tasks – such as making precise calculations (as in sample item 3), making precise readings from the appropriate scale (as in item 2), or detecting changes in a time series graph (as item1) – might represent adults’ social practices and everyday lives in that country. We should also ask whether tasks such as these would tap or encourage what we would consider as mathematical thinking about potentially challenging tasks. Sample item 4 certainly appears to represent a more challenging task for most adults in many of the countries surveyed by PIAAC in the current round.

Measurement validity also requires procedures designed for the administration of the survey to be standardised in advance across all countries, e.g. design specifications of the laptops and software to be used, and rules for access to calculators and other aids\textsuperscript{60}. As with any survey, full appreciation of the validity of procedures requires assurance of how these procedures are followed in the field; see OECD (2013b, pp. 47-61). This is even more crucial when results are compared across countries using different fieldwork teams.

External validity

External validity includes the representativeness of the sample for the population of interest; thus, the 5000 or more adults (usually aged 16-65) selected for the sample in each country need to represent the population of that country. We can scrutinise, for any participating country, the sample design and other key aspects, such as the incentives offered to those selected for the sample, in order to encourage agreement to be a respondent. Again, judgments about the effectiveness of these procedures depend partly on knowledge of actual field practices.

However, it is important to realise that any result from such a sample, whether the mean score for a country, or a difference (e.g. by gender) in percentages of items correct, is only an estimate for the corresponding population value (namely, the mean, or the size of the difference in percentages), for

\textsuperscript{58} Round 2, including a further 9 countries, is now underway.

\textsuperscript{59} The overall distribution of numeracy items included by contexts was: Everyday / Personal – 45%, Work – 23%, Society – 25% and Further learning – 7% (OECD, 2013b, p.28).

\textsuperscript{60} Respondents in the first round of PIAAC, completed in 2011-12, were supplied with hand held calculators and rulers with metric and imperial scales, for use during the interview.
the whole country. Of course, we would like to know about the population value – but this is not possible with certainty, since we only “know” about a subsample. So virtually every numerical result that we produce with a sample survey cannot be considered exact, but should have a “tolerance”, a margin of error, on either side of the sample-based estimate\(^{61}\). Thus, if we consider the PIAAC Numeracy results from OECD (2013a), we would find that the first four countries are: Japan (288) … Finland (282) … Netherlands and Belgium (280)

This appears as a clear ranking – before we realise that a 95% confidence interval for the country score for Finland would be approximately 280 to 284, and for Netherlands and Belgium, approximately 278 to 282: thus these countries have overlapping confidence intervals, and so their performances are not really able to be differentiated\(^{62}\).

Similarly, the differences between the Netherlands and Belgium and the next three ranked countries (the Scandinavians) are not “statistically significant”, again because of the variation that we must always expect in results based only on samples. So what appeared to be a neat ranking of the top 7 dissolves into Japan at the top, followed by a group of six countries, within which one cannot really differentiate performance on the PIAACC Numeracy survey (OECD, 2013a, pp. 79-80).

Reliability

The comparability of test administration across countries and across interviewers, and especially assuring the use of the same standards and practices in marking, has been a problem with past international surveys. Computer presentation and marking of test items can be expected to help greatly with reliability (assurance that the survey will produce the same or very close results, if it were to be repeated, using the same procedures). But it may tend to undermine content validity, if it reduces the range of types of question that can be asked; for example, it is difficult to construct an item which can validly assess a respondent’s reasons for his/her answer, when the item is computer-marked. This trade-off between content / measurement validity and reliability is a well-known dilemma in research design.

Further, the strengthening of reliability may lead to concerns about loss of another aspect of external validity, namely ecological validity, i.e. whether the setting of the research is representative of those to which one wishes to generalise the results. For example, the on-screen presentation of tasks may not be representative of the settings in which respondents normally carry out tasks involving numeracy, and so may not facilitate their “typical” thinking and behaviour responses\(^{63}\). Again, similar dilemmas arise for much educational assessment.

Beyond methodology: variations in interpretation and reporting

This discussion of several aspects of the validity of the survey shows the importance of sound research design – and also of the way field work is accomplished. However, a number of key issues in interpreting the uses and effects of the survey go beyond the technical issues around methodological validity (Radical Statistics Education Group, 1982 / 2012). They include the way that the survey’s measured scores are interpreted / reconceptualised in presentations and reports of various interested parties. This aspect is of course not under the complete control of the survey’s sponsors: for example, the media and certain national interests have often offered conflicting interpretations

\(^{61}\)The margin of error depends on the degree of “confidence” desired in the estimate, but is normally 2 standard errors for a 95% confidence interval.

\(^{62}\)The confidence intervals produced here are only approximate for the sake of illustration: I have estimated the margin of error for country scores based on an inspection of Figure 2.6a (OECD, 2013a, p.80), and have used the idea of countries “with overlapping confidence intervals”, instead of the broadly equivalent idea of countries “differing by an amount which is not statistically significant”.

\(^{63}\)And this may disadvantage some groups of respondents more than others, e.g. older ones more than younger. (I am indebted to one of the anonymous referees for this suggestion.)
Evans, J. (2014). New PIAAC results: Care is needed in reading reports of international surveys.

(“spin”) of results of international surveys. These processes require an understanding of the policy context and the ideological debates that surround the reception of results in a particular country, as well as the global education policy discourse.

Several examples can be given of the need for care and scepticism about the reporting and interpretation of these results; see e.g. EERJ (2012), on the way that PISA results have been reported and used, and in particular, Carvalho on the “plasticity of knowledge” (2012, pp. 180-83). One problem is that an adult’s performance on one of the subtests such as numeracy cannot simply be expressed as the proportion correct – since adaptive routing means that respondents were presented with different sets of items, some “harder”, and some “easier”. So Item Response Modelling is used to (“psychometrically”) estimate a standardised score (e.g. for PIAAC: scores 0-500, mean 250, standard deviation 50). Then, the numerical score is usually related to one of five general “levels” of literacy or numeracy to make it meaningful; see OECD (2013b, pp. 69-70).

Now, this may well be more informative than simply reporting the percentage of adults in a country that are categorised as “literate” or not, as was formerly done. But as in other national and international surveys, there is debate about use of a simple and one-dimensional characterisation of an adult’s numeracy. For example, Gillespie (2004) referring to the first UK Skills for Life survey (done using a similar methodology to PIAAC) notes: “The findings confirm that for many, being ‘at a given level’ is not meaningful for the individual, as levels embody predetermined assumptions about progression and relative difficulty” (p. 1). Part of this scepticism flows from the finding that many adults have different spiky profiles, due to distinctive life experiences (Gillespie, 2004, pp. 4-6). Thus, some adults may find items of type A (say, “data and chance”) more difficult than type B items (e.g. “dimension and shape”) – and others find the opposite.

Similarly, some policy-makers attempt to stipulate “the minimum level of numeracy needed to cope with the demands of adult life” in their particular country. But this notion too is questionable, since such generalising claims group together adults with different work, family and social situations, and different literacy / numeracy demands on them; see Black & Yasukawa’s (2013) discussion of current debates in Australia.

These sorts of concerns about validity and interpretation are shared by users of all surveys which include assessments, especially those that aim to make comparisons across countries, or over time. Nevertheless, such concerns must be assessed for any survey, where results aim to inform policy or practice.

Some illustrative results for PIAAC from Australia

A summary of the methodology and results from Australia was made available in February 2013, by the survey contractor, the Australian Bureau of Statistics (ABS, 2013). This illustrated the sorts of results that were made available in each of the participating countries in October 2013. Here I give three examples.
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Figure 1. Overall results from PIAAC for Literacy and Numeracy: Australia, 2013
Source: ABS (2013)

Figure 1 allows us to read off the proportions of Australian adults at different skills levels. Approximately 44% (7.3 million) of Australians aged 15 to 74 years had literacy skills at Levels 1 and 2, a further 39% (6.4 million) at Level 3 and 17% (2.7 million) at Levels 4/5. For the numeracy scale, approximately 55% (8.9 million) Australians were assessed at Levels 1 and 2, 32% (5.3 million) at Level 3 and 13% (2.1 million) at Level 4/5. One could also compare literacy and numeracy levels for subgroups, e.g. residents of different Australian states (using other data). For example, the Australian Capital Territory recorded the highest proportion of adults at Level 4/5 (23%) numeracy. We can also ask about gender differences, of interest in much earlier research; see Figure 2.

Figure 2. Proportion at each PIAAC numeracy level, by sex: Australia 2013. Source: ABS (2013)

In Figure 2, there appears to be little difference in the proportion of males and females at each level of the numeracy scale. However, a higher proportion of males (17%) attained scores at Levels 4/5, compared with females (9%), as seen from the graph.

We can look at age differences too, over the age group surveyed in Australia: 15-74 (a wider age range than required by PIAAC protocols); see Figure 3.
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The data suggest that proportions of people at Level 1 are highest among the oldest age groups (people aged 60 years and older), and lowest in the younger age and middle-aged groups (people aged 20 to 49 years) for numeracy skills.

**Discussion: Possible effects of international surveys and “countervailing forces”**

In previous sections we have described the developing role of a globally promoted type of pedagogic discourse promoted by transnational organisations, which asserts adults’ need for certain rather generic skills, and individual countries’ needs to assess these in a comparative way. Basil Bernstein’s analysis (2000) of the structuring of pedagogic institutions and discourses and his focus on changing forms of educational knowledge and practices, along with related work (e.g. Moore with Jones, 2007), can illuminate and critique shifts in the mode of governance of educational policy, in which international surveys like PIAAC are used (by a number of policy actors) to play a role (Tsatsaroni & Evans, 2013).

The international studies of adults, like IALS and PIAAC, have no systematically thought out curriculum associated with them (unlike TIMSS and PISA). Yet the existence of such a “curriculum” is arguably implied in the definition of numeracy (see Section 3 above) and the use of existing classifications of mathematical content. Tsatsaroni and Evans (2013) originally predicted that there was “a strong possibility that PIAAC could reinforce this type of pedagogic discourse, and the surveys could tend to work as an exemplary curriculum type which indirectly prescribes what knowledge the adult populations in all societies should value, strive to acquire, and demonstrate” (emphasis added). In the event, Christine Pinsent-Johnson’s more recent paper (2013) on adult literacy shows that this “possibility” has already materialised in the Essential Skills in Canada, “a competency-based compendium of employment related ‘learning outcomes’ that integrates [international testing] constructs”. Ontario, Canada’s largest province, has recently begun to use a new curriculum that was put together using these constructs: “A hypothetical and abstracted literacy devised for large-scale testing has been transposed into a pedagogy that is distinct from schooling and academic literacy practices, and disconnected from personal, community and work literacy practices” (Pinsent-Johnson, 2013, p.2).

There are a number of possible effects of such performance surveys, which may represent high
stakes for adults and the countries involved. An obvious negative effect is the pathologising of countries which do not “perform” to standards – not necessarily by the survey’s sponsors, but by sections of the media, political parties, and new educational agencies, such as national assessment bodies. (cf. “PISA shock”, discussed in EERJ, 2012).

The emerging discourse supported by international surveys may also have effects on teachers’, learners’, researchers’ and citizens’ ways of understanding adult literacy and numeracy. Knowledge can come to be seen as generic skills, flowing from a decontextualised imagining of the adult’s everyday practices. To the extent that different social groupings and different countries embrace such ideas, they may have restricted access to the countervailing principles of thinking that disciplinary or professional forms of knowledge can provide.

Now, “disciplinary knowledge” can also be understood as “powerful (mathematical) knowledge” (Young, 2010), or as “big ideas” in mathematics education (Lerman, Murphy & Winbourne, 2013) – that is, as ideas that have rich applicability in a range of fields. One example of a big idea in mathematics / statistics that was illustrated several times at the ALM-20 conference is the idea of conditional probability. This idea occurs under many guises: as having the right denominator for your proportions, in arithmetic; or in reporting research results (e.g. percentage of items correct) for the appropriate population; or in appreciating the difference between the probability of testing positive for x, given that you have disease x – and the probability of having disease x, given that you test positive for x, which is vital in understanding medical test results (Gigerenzer, 2003; O’Hagan, 2012.) However, for big ideas to be fully appreciated by learners, a coherent curriculum for adults’ mathematics is necessary.

As for positive effects, we must investigate whether international surveys afford opportunities for further research. One can relate performance scores to demographic and attitudinal data from the Background Questionnaire, and/or further information available on numeracy related practices and “use of skills” at work; see OECD (2013a, pp. 101-140) for such analysis, at the international level. These studies may also provide a context for certain types of national studies, or local qualitative studies, to supplement or to probe Background Questionnaire results; for example to investigate why residents of the Australian Capital Territory might have recorded the highest proportion of adults at Level 4/5 for numeracy (23%) (See above). There are also some examples of use of results from earlier international surveys, e.g. PISA and TIMSS, to study wider educational and social questions (see Tsatsaroni & Evans, 2013).

Resources for researching additional interesting questions suggested by the preliminary results are now more accessible than before. OECD makes available, on their website, datasets from PIAAC – and software for data analysis–for research purposes. (See http://www.oecd.org/site/piaac/#d.en.221854).

In the international adult numeracy community, we can look to alternative research programmes to assert the value of alternative conceptions of educational knowledge, and to critique developments in adult educational policy issues, including literacy and numeracy. From within adult numeracy, or what can be called adults’ mathematics education (Evans et al., 2013) – we can illustrate ways to challenge the currently dominant ideas of numeracy and adult skills. For example, Diana Coben and colleagues have challenged the conventional “deficit” characterisation of practising adults’ (nurses’) numeracy, and argued that the high-stakes testing programmes used have often deployed instruments which lacked reliability, validity, and authenticity (Coben, 2000). Hoyles, Noss, Kent & Bakker (2010) go beyond a narrow definition of numeracy to develop a richer conception of “Techno-mathematical Literacies” (TmLs), informed by the affordances, flexibilities and demands of information technologies, and document its use by middle ranking UK professionals, in decision-making in specific workplaces. Mullen & Evans (2010) describe demands on citizens’ numerate

And lifelong learning more generally (Evans, Wedege & Yasukawa, 2013).
thinking and learning, emphasising the social supports made available (by government and other institutions), in coping with the 2009 currency conversion to the euro in the Slovak Republic. Gelsa Knijnik and her colleagues (e.g. Knijnik, 2007) describe work with the Landless Movement in Brazil, facilitating their learning to recognise, to compare, and to choose appropriately from academic and/or “local” knowledges, in carrying out their everyday practices. The proposals of Knijnik and colleagues and Hoyles et al. are clearly moving towards the formulation of alternative, coherent curricula based on the big ideas that their researches are pointing towards, and helping to develop. Coben and her colleagues are working to develop alternative methods of assessment for professional practitioners.

Powerful knowledges of these kinds can empower on a broader social basis, through knowledge located in the disciplines, professional practice, or other established practices of adults’ “lived experience”. The aim of educational researchers must be to support the development of potentially powerful knowledge (Young, 2010), like numeracy and literacy, and to prevent their being reduced to narrow competencies.

To summarise, it seems clear that PIAAC and other international surveys will be key background features in educational policy discussions and educational research for the foreseeable future. These surveys will have a range of effects, some of which will be a focus of struggle involving their transnational sponsors, countries and their citizens. PIAAC itself includes a complex set of measures, and offers the opportunity to relate them in a range of ways. Like all studies, because of its conception and its methodology, it tends to highlight and to emphasise particular aspects of the world it surveys – such as a generic conception of numeracy and literacy, and the use of measures understood as comparable across a globalised world – and to play down others. It is therefore essential for all those interested in adult numeracy and literacy to read its results carefully and sceptically.

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Evans, J. (2014). New PIAAC results: Care is needed in reading reports of international surveys.


Appendix. Sample Items from Current Round of PIAAC (2011-2013)

Numeracy – Sample Item 1
This sample item (of difficulty level 3) focuses on the following aspects of the numeracy construct:

<table>
<thead>
<tr>
<th>Content</th>
<th>Data and change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>Interpret, evaluate</td>
</tr>
<tr>
<td>Context</td>
<td>Community and society</td>
</tr>
</tbody>
</table>

Respondents are asked to respond by clicking on one or more of the time periods provided in the left pane on the screen.


Numeracy – Sample Item 2
This sample item (of difficulty level 3) focuses on the following aspects of the numeracy construct:

<table>
<thead>
<tr>
<th>Content</th>
<th>Dimension and shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>Act upon, use (estimate)</td>
</tr>
<tr>
<td>Context</td>
<td>Every day or work</td>
</tr>
</tbody>
</table>

Respondents are asked to type in a numerical response based on the graphic provided.

Correct Response: Any value between 77.7 and 78.3
Evans, J. (2014). New PIAAC results: Care is needed in reading reports of international surveys.

**Numeracy – Sample Item 3**

This third item (of difficulty level 1) in the set focuses on the following aspects of the numeracy construct:

<table>
<thead>
<tr>
<th>Content</th>
<th>Dimension and shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>Act upon, use (measure)</td>
</tr>
<tr>
<td>Context</td>
<td>Every day or work</td>
</tr>
</tbody>
</table>

Respondents are asked to type in a numerical response based on the graphic provided.

**Correct Response:** Any value between -4 and -5

**Numeracy – Sample Item 4**

This sample item (of difficulty level 4) focuses on the following aspects of the numeracy construct:

<table>
<thead>
<tr>
<th>Content</th>
<th>Quantity and Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>Act upon, use (compute)</td>
</tr>
<tr>
<td>Context</td>
<td>Community and society</td>
</tr>
</tbody>
</table>

**Wind Power Stations**

In 2005, the Swedish government closed the last nuclear reactor at the Barsebäck power plant. The reactor had been generating an average energy output of 3,572 GWh of electrical energy per year.

Work continues in Sweden on installing large offshore wind farms using wind power stations. Each wind power station produces about 6,000 MWh of electrical energy per year.

**For your information:**

<table>
<thead>
<tr>
<th>Electrical energy units</th>
<th>Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kWh</td>
<td>1,000 Wh</td>
</tr>
<tr>
<td>1 MWh</td>
<td>1,000,000 Wh</td>
</tr>
<tr>
<td>1 GWh</td>
<td>1,000,000,000 Wh</td>
</tr>
</tbody>
</table>

**Correct Response:** One of the three values (no values between): 595, 596 or 600.

*Source:* CSO, Ireland (2013)
IMPLICATIONS OF SOCIAL PRACTICE THEORY FOR THE DEVELOPMENT OF A NUMERACY PROGRAMME FOR THE GUSILAY PEOPLE GROUP IN SENEGAL *

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SIL, Dakar, Senegal

Abstract
In this article, I present research on some traditional numeracy practices of the Gusilay people group in Senegal and make recommendations for developing a numeracy programme for women. Based on a strong foundation of traditional knowledge and practices, the programme will aim to meet felt needs of women who are faced with new numeracy related challenges due to changes in society. My research is placed in the framework of social practice theory, which emphasizes the fact that numeracy is not a set of skills that are learned and used in isolation, but rather practices that happen in context and vary with it. After a brief outline of social practice theory and the methodology I have chosen for my research, I analyze my findings from that perspective and suggest some practical implications for developing a numeracy programme for Gusilay women.

Key words: adult numeracy; social practice; ethnography; Africa

Introduction
In my work as coordinator for adult literacy programmes in several Senegalese languages I am often asked by literacy class participants why we do not offer a numeracy programme. Many learners, especially women, feel the need for acquiring more numeracy skills. For example, some women sell charcoal or cookies, but have no idea how to fix the selling price. Teaching numeracy to women within the context of a literacy programme will increase their understanding of basic mathematical concepts, strengthen their ability to mathematize and give them skills and confidence to better face numeracy related challenges. I decided to review relevant literature and to research traditional numeracy practices of one people group, the Gusilay, in order to be better equipped to help meet these felt needs. I set out to investigate the following questions: What are the felt needs of Gusilay women in the area of numeracy? What are some of their traditional numeracy practices?

Literature tells me that each society develops mathematical ideas in a different way due to various factors, based on the needs of the group (Zaslavsky, 1999). In order to build a curriculum for a numeracy programme that is designed specifically for the target group, relating to their cultural values, practices and needs, a thorough analysis of the situation, including linguistic and social research into existing numeracy practices and felt needs is required (Dalbéra, 1990). Moreover, basing the curriculum on traditional practices and beginning with what adults already know should build motivation, help learners overcome their fears of not being able to learn numeracy and enable them “to develop their ability to cope with their problems themselves” (p. 11).

This article begins with a brief summary of social practice theory and the methodology I have chosen, followed by some background information on the Gusilay people group in Senegal, their number system and a description of my participant observations of three numeracy “events” (Heath, 1983) from harvesting rice to cooking, and selling vegetables. A discussion of the implications of my findings, from a social practice theory point of view, leads to various suggestions for the development of a numeracy programme for Gusilay women. This time could be seen as a critical
moment in adult mathematics for the Gusilay people group, when important questions are raised that will influence the development of a relevant numeracy programme.

Social practice theory

Developed in the context of literacy (Barton & Hamilton 1998; Gee, 1990; Street, 1984;), social practice theory emphasizes the fact that literacy practices are embedded in broader social and cultural practices and are influenced by the context in which they happen. Moreover, the purposes and meanings a reader brings to the text vary. Literacy is therefore not just a set of mechanical skills that, once acquired, can be used in other situations. Street criticized what he termed the “autonomous” view of literacy, which “works from the assumption that literacy in itself – autonomously – will have effects on other social and cognitive practices”, and suggests that “in practice literacy varies from one context to another and from one culture to another and so, therefore, do the effects of the different literacies in different conditions.” (2003, p. 77).

Even more so than literacy, mathematics had for a long time been viewed as decontextualised and value-free, an abstract code with unlimited power of transfer. This idea was challenged through research in the 1980s (Carraher, Carraher & Schliemann, 1985; Lave, 1988; Saxe 1991), which led Lave and Wenger (1991) to propose the concept of “situated learning”, viewing learning as a social process that happens in a specific context and involves relationships, motivation and values.

The implications of social practice theory for numeracy have been researched and discussed (Baker, 2009; Baker, Street & Tomlin, 2008; Evans, Wedge & Yasukawa, 2013; Tett, Hamilton & Hillier, 2006;). Baker (2009) adapted social practice theory to numeracy, emphasizing the fact that “numeracies”, like “literacies” vary with the social context and have different associated uses and meanings. According to him, mathematics as social practice implies “being aware that mathematics takes place in contexts with values, beliefs and social relations” (p. 6) and using a constructivist approach that “takes a broad vision of learners’ funds of knowledge for mathematics”, including not only skills, but also “processes of engaging with mathematics” and relationships etc. (p. 7).

Tett, Hamilton & Hillier (2006) point out various implications for practice regarding the curriculum, learning, teaching as facilitating and supporting rather than transmitting information, the roles of curriculum managers and other key programme personnel. They appreciate the fact that a social practice view provides a framework that even allows a numeracy programme itself to be analysed and understood as a set of numeracy practices. According to the authors, a social practice perspective on numeracy “is not just meant to be descriptive but engaged – it changes the situation it analyses by articulating new understandings and learners and teachers to actively ‘take hold’ of adult literacy, numeracy and language and shape it for their own purposes” (p. 13).

Evans, Wedge & Yasukawa, with regards to social justice issues, point out the fact that adult mathematics education that starts with learners’ numeracy practices and therefore with different social situations, means that there is a tension between affirming learners’ roots and “the generalizing views of mathematics that smooth out these differences” (2013, p. 225). In the context of a numeracy programme for Gusilay women, this could mean that even though the numeracy programme helps women to be more efficient in their traditional activities as market vendors, it enables them at the same time to run a shop or eventually become a financial consultant, which are male dominated domains.

Methodology

There are several reasons for my choosing social practice theory as the framework for my research. My review of literature on social practice theory (Papen, 2005; Street, Baker & Tomlin, 2008) and on numeracy practices in non-Western countries and ethnomathematics (D’Ambrosio, 2001; Gebre et al.

2009; Nabi, Maddox, 2001; Rogers & Street, 2009) have made me aware of the importance of context. Moreover, in my opinion, social practice theory matches the holistic worldview that is characteristic of Senegalese society, one of many cultures that “value contextual understanding rather than decontextualization and objectivity” (Ascher, 1991, p. 6). Another rationale for taking into account the insights of social practice theory is provided by adult education theory, emphasizing the wealth of knowledge and experience adults bring to the classroom and the importance of relevance to daily life (Knowles, Holton III & Swanson, 1998).

An ethnographic approach, commonly used in anthropological research, seemed by far the most suitable method for studying numeracy as social practice, observing and describing numeracy practices in the context in which they occur. During a total of four weeks of research in the town of Thionck-Essyl, between October 2011 and January 2012, I participated in various numeracy events. The research tools I used were participant observation, unstructured discussions and visual methods, especially photographs and where possible artefacts. I made an effort to choose people without school experience, but found that some of them had formal schooling.

Numeracy practices of the Gusilay ethnic group in Senegal

Background information

The Gusilay live in Thionck-Essyl, a town with a population of about 15,000 inhabitants, situated in the Casamance region in the south of Senegal. Traditionally, they have been agriculturalists, mainly growing rice but also millet and peanuts. Preparing the rice fields, before and at the beginning of the rainy season, is men’s work. Sowing, transplanting and harvesting traditionally is women’s work, with women often working together. Each married woman automatically joins an age group when she gets married. Women of the same age group, who got married during the same period in the same part of town, often do activities together. Moreover, women frequently organise themselves by forming associations, often with the goal of earning money, e.g. by harvesting other people’s rice fields as a group. Most women work hard every day, with highlights in the hardships of life being celebrations that include singing and dancing. Relationships are characterized by solidarity and much teasing and laughter.

Overall, less than 40% of Senegalese women over the age of 15 are estimated to be literate (UNESCO, 2012). Many younger Gusilay women have gone to school for a few years. The language of instruction there is French, a language not understood by most children when they enter school, and repetition and drop-out rates in Senegal are high. The Gusilay are motivated to learn to read and write in their language and especially to become more proficient in the area of numeracy since life has changed drastically in recent decades. There are many new numeracy related challenges women have to face nowadays. Whilst growing rice is still the occupation of many inhabitants of Thionck-Essyl, an increasing number of women run small businesses to meet the needs of growing family expenses. Money is used in more domains, as can be seen with payment for school equipment and electricity bills, since the town recently got electrified.

Banks attract a growing number of clients. New technologies like cell phones, scales, calculators or computers are introduced. With these changes comes a need for acquiring more and different skills and knowledge. In conversations with members of our partner organisations and also through questioning women in the literacy classes I coordinate, I found that women’s main goal in wanting to learn numeracy is improving the financial situation of their families. Areas of special interest that were mentioned were learning to count and calculate better, dealing with money and calculate profit, understanding written documents (e.g. bank statements or children’s health records), keeping track of family expenses and knowing how to weigh in order to sell in bigger quantities or in income generating projects like soap making.
The Gusilay number system

Whilst an in-depth discussion of the number system is beyond the scope of this article, I will mention some basic facts that I consider most relevant for the development of a numeracy programme. Here is an excerpt of Yashina’s (2011) list of the main cardinal numbers in Gusilay.

<table>
<thead>
<tr>
<th>Number</th>
<th>Gusilay Term</th>
<th>English Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>yanur</td>
<td>10 guñen (lit. ‘hands’)</td>
</tr>
<tr>
<td>2</td>
<td>siruba</td>
<td>15 guñen gaat (lit. ‘hands foot’)</td>
</tr>
<tr>
<td>3</td>
<td>sìfàajir</td>
<td>20 gafaakan (lit. ‘the end of a person’)</td>
</tr>
<tr>
<td>4</td>
<td>sibaaqir</td>
<td>30 gafaakan n’guñen</td>
</tr>
<tr>
<td>5</td>
<td>futok</td>
<td>40 gafan gùrbua*</td>
</tr>
<tr>
<td>6</td>
<td>futok n’yanur</td>
<td>60 gafan gùfaajir</td>
</tr>
<tr>
<td>7</td>
<td>futok n’siruba</td>
<td>80 gafan gubaagir</td>
</tr>
<tr>
<td>8</td>
<td>futok n’siifàajir</td>
<td>100 eceme</td>
</tr>
<tr>
<td>9</td>
<td>futok n’sibaaqir</td>
<td>1,000 éwuli</td>
</tr>
</tbody>
</table>

There are distinct number words for the numbers 1 to 5, 10, 15, 20, 100 and 1000. All other numbers are mathematical calculations. Number words get long as numbers get higher. 100 and 1000 are loanwords from a dominant language in the area. There are two traditional bases, 5 and 20, and a more recent one, 10 (Kané, 1987). Vocabulary for new concepts like ‘plus’, ‘minus’, ‘tens’, ‘hundreds’ or ‘book-keeping’ would need to be developed, ideally based on traditional concepts. For example, there is the expression ‘gassaŋar’ that might be used to explain the concept of units and tens: Traditionally, the fruit of a certain pALM tree is cut, one or two bunches per tree, and put into piles of ten on the ground. For example, you will say that you have five ‘gassaŋar’, five piles of ten.

There is a difference between numbers in general and numbers in the context of money. Calculating with money in Gusilay is based on the ‘ékori’, with 1 ‘ékori’ equalling 5 F CFA. Therefore when numbers are used in the context of money, the value is actually five times as much as the word itself (e.g., 25 F CFA is called ‘futok’ [five, understood 5 ‘ékori’], even though the print on the coin says 25). There are various proverbs that contain numbers and riddles, for example: “I have two children and two adults. They have gone fishing and caught three fish. Each of them has got one fish.” (Solution: Son, father and grandfather).

Participant observation of various numeracy practices

Working in the rice field

Since it was harvest time, I spent a day doing participant observation on harvesting rice. Here is an account of my observations. I join seven women, who belong to the same age group, to harvest a ‘ñikin’ (rice field) that belongs to one of them. We walk on small paths for about an hour, the women carrying baskets with water, knives, some food and rolled-up strips of leaf from a certain tree that are used for binding the sheaves. After a quick breakfast of rice and curdled milk we start cutting the rice. The women work in rows, each one cutting the rice at the bottom of the stem with a knife.

The woman beside me shows me how to hold the rice I have cut, with the stems in the pALM of my hand and the leaf outside my thumb. From time to time I tear off the leaves. The women talk whilst working, mainly about their work for the next few weeks. Each stem is cut by hand with a knife, the length being assessed by visual judgment, maybe 20-30 cm according to my guesses. When

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65 Gafan’ is a contraction of ‘gafaakan’. ‘Siruba’ becomes ‘gùrbua’, since it adapts to the noun ‘gafan’, Gusilay being a noun class language where attributes, including numerals, change according to the noun they define.
66 773 is ‘siceme futok siruba guñen gafak bugan gufaajir guñen siifàajir’.
67 Franc de la communauté africaine.
a ‘galiten’ (handful) of rice is cut, it is laid on the ground on top of a row. The ‘galiten’ do not seem to be of a definite size.

One woman tells me: “You lay it down so that your hand does not get tired because the rice is too heavy”. One of the women binds the ‘galiten’ together into an ‘ekok’ (sheaf). She wraps a strip around the first ‘galiten’, then adds the next one, pushing down hard and wrapping the strip tightly. When asked how many ‘galiten’ make up the ‘ekok’ she is binding, the woman does not know the answer. My colleague has counted: There are ten ‘galiten’. She wonders whether it is the length of the strip that decides the size of the ‘ekok’. One of my informants tells me later that in the past sheaves used to be much smaller. We finish the ‘ñikin’ in about two hours, having harvested eight sheaves of rice.

Each woman brings her own rice for lunch, whilst the owner of the rice field has to contribute the fish. She also pays 1,000 CFA and gives two sheaves of rice to the association they all belong to. The women tell me that women’s associations can be hired to work on anybody’s field, but then the price is higher. Reflecting on my participant observation, I realized that the main strategy used in working in the rice field is estimation and approximation by visual judgment. The length of the rice stems, the measure of ‘handfuls’ of rice as well as the size of a sheaf are all determined by visual judgment based on experience. I am told that visual judgment is also used in sowing and transplanting, e.g. for determining the distance between individual seeds and between the seedlings when transplanted to the rice field into three lines on each row. Estimation seems to be a much more useful skill in this society than measuring with exactness.

The women I observed are of the same age group and at the same time organised in an association, together with other women. There are clear regulations as to the contributions of each person involved. As a newcomer, I joined in the activity, learned by doing and was shown how to do it correctly by one of the women.

**Cooking the daily rice dish**

I spend a day with Khady, my host. We cook a dish called ‘etoj ekaama’, rice with a sauce of ground peanuts and manioc leaves. Khady is 35 years old and is pregnant with her eighth child. She lives in the same house with her husband, a second wife and their children. The kitchen is a square house made out of dried earth, with a roof and several small rooms. We sit in the little square porch area on little stools while cooking. When I ask Khady at what time she starts cooking, she says, “It does not matter when exactly”. The children come home from school between 1 and 1.30pm, and the food should be ready shortly after. Khady tells me that she has a cell phone that she could consult to check the time. Around 10 am - I check my watch - Khady sends a boy to the market with money and instructions as to what he should buy. I see him come back with six packets of peanuts, a hot pepper, a piece of dried fish, four green bitter tomatoes, four stock cubes, a piece of dried sea snail and a packet of small beans. Khady must have calculated the amount of money she needed to give him in advance. She has been to school and speaks some French.

We pick a bucket full of manioc leaves in a nearby garden. Another boy is sent with 200 CFA to have them shredded at a mill. We could have pounded them ourselves, but I am told that this would take too long. These days Khady buys three sacks of rice per month, all at once, since her own rice is already finished and the harvest on her rice fields has not yet started. She tells me that she uses three nescafé tins of rice per meal. I know from another informant that in the past, woven baskets were used in the kitchen, ‘gáfankum’ for storing rice and ‘funip’ for storing peanuts or salt, but nowadays empty nescafé tins have replaced the baskets for measuring rice.

Having crushed the peanuts in a small mortar, several handfuls at a time, we sieve them through a strainer with fairly big holes and afterwards one with a finer mesh. The rice is first steamed, on a

strainer on top of a pot of boiling water, with a cloth ribbon wrapped around the gap between the pot and the lid to seal it. Khady takes a handful of salt from a big mustard jar and puts it on top of the rice. Then she dumps the rice into the boiling water. She says she just knows how much water to put into the pot and how long she needs to let the rice steam and then boil. Then she puts the cooked rice aside, adds more charcoal to the fire and puts on a new pot, about 1/3 full with water, for the ‘etoj’ sauce. She washes the green tomatoes in a bucket of water, takes the stems off and puts them into the boiling water. Two of Khady’s smaller children sit with us, and the baby is on her back. A chicken runs on top of the roof beams from time to time, and dirt falls on me. We chase it away several times.

The boy comes back with the ground manioc leaves; they now cover only maybe 5 cm of the bucket. Khady puts them into the boiling water. She washes the dried fish and the piece of snail and adds it. Then she puts the peanut powder into the now green water. From time to time she stirs the sauce with a big metal spoon. I notice that she lets it simmer for at least two hours. Finally Khady adds the hot pepper, the stock cubes and two spoonfuls of shrimp powder, which she takes from a big mustard jar. Her daughter Awa, who has just come back from school, is putting the rice onto two platters, when Khady suddenly realises that she has forgotten to add the beans. Awa crushes them, using pestle and mortar, and Khady puts them into the sauce and lets it boil for another 30 minutes or so according to my reckoning.

Reflecting on my observations, it struck me that my way of categorising is different from the traditional Gusilay way. ‘Time’, for example, is numerical information for me, whilst for a Gusilay, it might be in the category of ‘the way relationships are used’ or ‘duration of an activity’. Traditionally, numbers have not played a big role in many mathematical concepts in Africa (Zaslavsky, 1999).

Moreover, I realised that women all over the world cook using estimation and approximation, techniques honed through experience. And certainly women all over the world, and specifically in Senegal, are not aware of how much mathematical knowledge is applied when cooking. The amounts of water or salt are assessed by estimation and approximation, as is the time needed for cooking. Strategic planning is involved in deciding what ingredients to buy for the daily meal or how many bags of rice to purchase per month. Many of these strategies are applied largely unconsciously due to daily routine and experience.

Measuring capacity is based on the body, e.g. a handful, or on varying containers, e.g. spoonful, bucketful and various pots. Khady knows from experience what size cooking pots and platters to use. There is no interrelated system for measuring capacity. Some of the strategies include the use of number. Mental calculation skills were put into practice as Khady decided how much money to give to the boy to buy ingredients at the market. Khady knows money, and she knew how much money to give to the boy to go shopping, so she must have some mental calculation skills. I did not ask her where she learned those. Her assessing the value of time versus money when sending the boy to the mill is an example of numeracy being linked to values. It might be interesting to find out whether her appreciating time over money was influenced by my presence.

Selling condiments at the market

The market place of Thionck-Essyl is a big square of roughly 40 x 40 m, bordered by mango trees. About 20-25 women vendors sit on small wooden stools or plastic buckets under the trees, some with wooden tables on which their goods are displayed, some with plastic mats on the ground. I join them for several days to observe them and learn from them.

The president of the market, an elderly lady named Mariama Sambou, sits on a bucket behind her goods, which are laid out on a big plastic sheet on the ground. She tells me that she has never gone to school and has traded for 30 years. This reminds me of Bhola’s emphasizing the fact that “oral numeracy” (1994, p. 89) is a cognitive process unrelated to the learning of reading and writing.
Mariama tells me that she has never taken a pen to calculate, but does it all mentally. She tells me that she prefers to not make errors, because it is she herself who has a problem if she does, and that she makes fewer mistakes than others who write.

Mariama sells slices of cabbage, carrots cut in halves, manioc, dried fish, fresh hot peppers, onions, hot dried pepper, tomato paste in little plastic bags, stock cubes and other ingredients that women need for their daily cooking. Women buy these each day in small quantities, which is why the market vendors can make a profit by selling their goods in small quantities. The market women chat with each other and their clients. A young woman with a baby on her back buys a pile of onions and hands Mariama a coin. Mariama asks her neighbour to exchange the coin into smaller ones; having small coins is a challenge in Senegal.

Mariama sells three kinds of dried fish: ‘con’, ‘bërr’ and ‘dëggërbbopp’. She tells me that she bought 1 kg of ‘con’ for 600 CFA; 1 kg equals six fish. She cuts each fish into three pieces and sells the piece for 50 CFA. This is how her mental calculation works: She takes two fish, which makes six pieces in total. Again two, that makes 12 pieces; again two, that makes 18 pieces. She sells 12 pieces at 50 CFA each, which makes 600 CFA, then the six that are left: 300 CFA, so she sold for a total of 900 CFA. I reflect on the fact that multiple additions seem much slower and more complicated than multiplications. She takes off the 600 CFA and sees that she has a profit of “only 300 CFA”, as she says. For the ‘bërr’, she paid 1,500 CFA for 1 kg. She sells a piece for 100 CFA. There are 18 pieces in 1 kg. She sells for a total of 1,800 CFA and knows that she again has a profit of 300 CFA.

She bought 1 kg ‘dëggërbbopp’ for 800 CFA. 15 fish weigh 1 kg. First she sorts the fish. She sells the big ones for 100 CFA, the middle ones for 75 CFA and the small ones for 50 CFA. She gives me an example:

She sells five fish at 100 CFA, which makes 500 CFA. She has ten fish left. Then she sells four fish at 75 CFA. For this she calculates in her head “75 times 2 makes 150, and again 75 times 2 makes 150, so the total is 300 CFA”. She has six small ones left, which she will sell for 50 CFA. She calculates with five. If she sells five, she gets 250 CFA. The last one makes 50 CFA, so the total is 300 CFA. Five for 500 CFA and four for 300 CFA makes 800 CFA. She knows that that is the price she bought them for. “So I know that my profit is identical with the six little fish, that is 300 CFA”, she says. It strikes me that she does not add up all the income and then deduct her cost, but states that her profit is identical with the fish that are left, a concrete object rather than an abstract number.

Mariama also explains how she calculates the profit she makes from selling onions. She buys a 25 kg bag of onions for 7,500 CFA in the nearby town of Bignona. She pays 200 CFA for the transport of the bag and 900 CFA for herself. She calculates only one way transport expenses into the cost of the onions, and the return trip she will calculate with the other goods she bought. When she gets home, she first weighs the sack with the scales she owns. Sometimes there are 26 or 27 kg in a bag. She weighs per kg and then counts how many onions there are in 1 kg. She gives me an example: There are eight onions per kg. She wants to sell the kg at 500 CFA. If they are all the same size, she sells one for 75 CFA. She puts the onions in groups of four, which makes 300 CFA per group. She knows that she can sell the kg for 600 CFA if she sells the onions one by one or per group. If she sells them by kg, she will have 500 CFA only for the kg. She earns 100 CFA more per kg if she sells one by one. Afterwards she thinks some more about the bag. She takes 20 kg. Each kg she will sell for 500 CFA, so 500 times 20 makes 10,000 CFA for 20 kg. The rest is 5 kg × 500 = 2,500 CFA. The total is 12,500 CFA. She takes off the 7,500 CFA that she spent on buying the bag. Then she takes off the transport cost of 1,100 CFA, which leaves her with a profit of 3,900 CFA. If she sells each onion separately, she has more profit, between 5,000 CFA and 6,000 CFA total.
Mariama puts the money she earns in her bank account. I ask how she reads the bank statements. For each payment, she gets a receipt, and her children will read the amount for her. Sometimes she checks and looks at all the receipts and calculates in her head.

Reflecting on my observations, I realize that market vendors frequently buy by weight and sell by number. This might be the case because people buy small quantities of vegetables, which are not easily weighed in units of 100 g or so. Bigger scale trade uses international measurement systems, e.g. some goods like fish and rice are mostly sold using scales.

Mariama is an expert at mental calculation. She seems to know a lot of calculations by heart, e.g. multiples of 5, which is 25 CFA in the context of money. I have noticed that many food items cost 25 CFA. Strategies I observed include regrouping of concrete objects, counting, and mental calculation strategies of decomposition and repeated grouping. She has a fairly good knowledge of addition, subtraction and some multiplication, but sometimes used multiple additions rather than multiplication. Many women I know have limited or no mental calculation skills. I even talked with a young vendor who sells fresh fish at the common price, without knowing how to calculate well. Moreover, most women do not know how to read scales and have no notion of Western measurements of weight.

Implications of social practice theory for the development of a numeracy programme

Analysing my observations of traditional numeracy practices from a social practice viewpoint has led me to various suggestions for the development of a numeracy programme for women.

Choice of language

The logical conclusion for the choice of language in the class-room is the language used in everyday life. It is people’s first language in which they can express themselves best, and in which all the numeracy practices I observed happened. Meaney, Fairhill & Trinick emphasize the fact that “cultural practices including ethnomathematical ones cannot be separated from the language in which they were developed”, since the language used impacts how students perceive the practices (2008, pp. 62-63).

The Gusilay number system responds to the needs of society and has been developed and adapted to new demands. The challenges posed by the length of higher number words, the lack of vocabulary for new concepts and written calculations with numbers in the context of money will need to be addressed. Traditional concepts should be used where possible when developing new vocabulary, e.g. the expression ‘gassaŋar’ could be introduced to denote tens. In order to be immediately relevant, I propose that the programme begins with numbers in the context of buying and selling. Therefore the different value of numbers in the context of money will be discussed in the class, in order to avoid confusion. “25 CFA + 25 CFA = 50 CFA” will be written as “E 5 + E 5 = E 10”. This might need to be tested.

The language issue could lead to a discussion of values, goals and conflicts, since the younger women and children in Thionck-Essyl learn mathematics in school in French. Often local languages are viewed as inferior, and it might surprise some people to realise that they can say everything they need and want to express in their language.

Relationships and power relations

The issue of relationships needs to be addressed at various levels. A class constituted of women belonging to the same age group or association has the advantage of group dynamics, relationships and rules within the group matching traditional standards and being already established. The teacher should be a Gusilay woman, since women will feel less threatened and more inclined to trust another woman than a man. The choice and training of teachers should happen bearing in mind Street’s
observation, made in the context of literacy: “The way in which teachers or facilitators and their students interact is already a social practice that affects the nature of the literacy being learned and the ideas about literacy held by the participants, especially the new learners and their position in relations of power” (Street, 2003, p. 77). The group could be viewed as an already established “community of practice”, in the sense of being involved in “a more encompassing process of being active participants in the practices of social communities and constructing identities in relation to these communities” (Wenger, 1999, p. 4, emphasis in the original). Class activities will include discussions, role play, dancing and singing.

Another issue that needs to be addressed is the questions of who establishes the curriculum, who is responsible for developing and running the programme, and in which ways do teachers and learners participate in decision making, the governance of the class, etc.

Power relations are also influenced by the fact that attending a numeracy class empowers women by increasing their understanding of basic mathematical concepts and their ability to mathematize and by giving them skills and confidence to better face numeracy related challenges. As Mellin-Olsen put it, mathematics “is also a structure of thinking–tools appropriate for understanding, building or changing a society.” (1987, p. 17).

A strong foundation of traditional knowledge
The envisaged numeracy programme will aim at building on participants’ “funds of knowledge” (Moll, Neff & Gonzalez, 1992) rather than focussing on their deficits (Baker, 2009). Traditional numeracy practices have great value and will serve as a strong basis for an adult numeracy programme. Building on and giving value to these practices makes learners aware that they already know and use a lot of numeracy skills, strengthens their roots and self-esteem and increases their motivation for learning more. For example, discussing the numeracy skills used when cooking a meal will help women realise how much they know already. Making existing mental calculation strategies explicit and available to all learners will enable them to use a very practical skill that fits well into the context of a largely oral society. Other funds of knowledge in the larger sense include ways of categorising, traditional wisdom expressed in proverbs, games and riddles, and traditional ways of measuring time and capacity with their inherent values.

Baker encourages going “beyond a limited focus on number and also include concepts from shape, space, data, patterns, ways of thinking etc.” (2009, p. 14). The Reflect method, with its focus on development of maps, matrixes, calendars and diagrams that “represent local reality, systematise the existing knowledge of participants and promote the detailed analysis of local issues” (Archer and Cottingham, 1996, p. 5) represents a helpful approach.

Teaching numeracy as practices
Fourthly, the aim is to teach numeracy as practices rather than skill (Baker, 2009), which in turn encourages a teaching style of facilitating (Tett, Hamilton & Hillier, 2006). Baker (2009) suggests seeking to work from everyday practices towards formal numeracy practices and to be explicit when switching between the two. Gebre et al. (2009) emphasizes the importance of making numeracy taught and practiced in the classroom similar to real life in order to facilitate transfer.

Ideally an income generating project accompanies the numeracy teaching and learning, so that the women can practice their newly acquired knowledge and skills immediately. For example, the group could meet in their communal garden and learn how to weigh by weighing their harvested vegetables or calculate their profit when selling them. They could count and calculate in the context of selling their produce to their clients. The introduction of new forms of numeracy could include the teaching of written numeracy, introduced with challenges like writing income-expenditure lists, opening a bank
account and learning how to read the bank statements, reading children’s health booklets or the instructions for taking medicine.

“Discover, Discuss and Develop”

Finally, teaching and learning will be relevant to learners’ daily experiences, with discussion and reflection as important components of classroom practice. The approach “Discover, Discuss and Develop” (Gebre et al., 2009) could be used with the group. The teacher and learners, in this context all from the same ethnic group, identify together what people know about numeracy practices in the community, and the group then discusses the issues raised. The third step is to build on to the first two steps, for example by introducing new forms of numeracy according to what is relevant to the learners.

A discussion on differences in values and ways of classification of Gusilay and Western culture could be introduced with the question whether known strategies need to be replaced by new ones. I doubt that the strategy of estimation in cooking or in field work needs to be replaced by more precise measurements. In contrast, more precision is needed when weighing ingredients for making soap or taking medicine at specific times. The technique of estimation, traditionally not used in the context of numbers, could be discussed and maybe applied to the context of money in situations where exactness is not required, for example in estimating roughly whether the change received is correct.

Problems encountered in learners’ daily lives will form the basis of learning in the class room, with teachers using a problem-solving approach (Fordham, Holland & Millican, 1995). The use of different strategies to get to a solution is encouraged, discussed and taught explicitly (Ginsburg & Gal, 2000), since in everyday practices a variety of strategies and approaches are used also. Discussions with the whole group should foster the ability to analyse and reason rather than imitate and learn by heart. Investigation and cooperation will be encouraged by working on problems in pairs or small groups.

The class could organise a small project like buying, roasting and selling peanuts and plan, discuss the processes, results and challenges encountered as part of the learning experience. A presentation of the history of mathematics could serve to show learners that mathematics is by no means an import from the West, but has some of its roots in Africa.

Conclusion

My research on some numeracy practices of the Gusilay shows the existence of a variety of traditional practices, techniques, values and concepts. An analysis of my observations from a social practice theory viewpoint has led me to suggest five basic considerations for the development of a numeracy programme for women:

The first language of the participants, used in everyday numeracy practices, will be the language of instruction. Attention needs to be given to the issue of relationships, including power issues, on various levels including that of programme designers, teachers, classroom practice and the resulting changes of power relations as an outcome of the learning experience. The numeracy programme will attribute value to and build onto traditional knowledge. Discussing and making knowledge and techniques available to all learners will form the basis of the programme, at the same time increasing learners’ self-esteem and motivation by affirming their roots and identity. Numeracy will be taught as practices, with the teacher seeking to work from everyday practices towards formal numeracy practices. Finally, learning is facilitated through discovery, discussion and reflection. The goal of the numeracy programme is to see women grow in dignity and self-confidence, prospering by actively increasing their knowledge, using literacy, numeracy and language to meet their felt needs and to develop in areas that are important to them.

References


PROVOKING MATHEMATICAL THINKING: EXPERIENCES OF DOING REALISTIC MATHEMATICS TASKS WITH ADULT NUMERACY TEACHERS *

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Abstract
This action research project looks at what happened when a small group of adult numeracy teachers with widely different experiences of learning and teaching mathematics explored their own informal numeracy practices and undertook a series of collaborative mathematical tasks. Evidence from qualitative data collected during the enquiry suggests that realistic tasks can provoke a range of mathematical thinking and learning responses which allow us to identify ways in which procedural and conceptual thinking is being used, and to track learning journeys through different stages of problem-solving. Although more experienced numeracy teachers could move between and within their ‘real worlds’ and ‘maths worlds’ with intent and ease, others had less integrated experiences, often valuing perceived mathematical powers over their own intuitive powers, with mixed success.

Key words: mathematical thinking, action research, adult numeracy teachers, realistic, realisable, mathematisation, collaborative classroom, intra- and extra-mathematical.

Introduction
Historically, within the UK, adult numeracy teaching is a field that many people move into sideways, often from teaching other disciplines. The requirement for practitioners to have a set level of personal mathematics skills was introduced only relatively recently and it is not untypical to find teachers of numeracy who lack confidence in their own mathematical ability (Cara et al., 2010). Personal mathematics development is therefore an important component within many pre- and in-service adult numeracy teacher education programmes. Teachers are encouraged to develop their mathematical thinking throughout their training, both by participating in class activities and pursuing private study. As a tutor and course leader on such a programme, I have observed that when it comes to building a personal mathematics portfolio, many teachers exhibit fairly mechanistic and unreflective ways of working. This is true not only in terms of the approaches they adopt, but also the sorts of independent tasks they choose to undertake - often a surprisingly narrow diet of content-driven and competence-based exercises. The purpose of this research project was to explore how to better support adult numeracy teachers to develop and extend their own mathematical thinking. The rationale for this extends beyond the perceived need for adult numeracy teachers to ‘upskill’ and is based on the underlying assumption that developing teachers’ confidence, awareness and insight into their own mathematical thinking, will better equip them to develop and extend the mathematical thinking of their learners.

Method of enquiry
The classroom, tutor and teachers
The twelve teachers in the group participating in this enquiry were aged 25-55, from socially and ethnically diverse backgrounds and included two teachers whose first language was not English. They were all undertaking professional development in adult numeracy teaching and consistently
demonstrated high levels of motivation and engagement although their personal experiences of mathematics, both as teachers and learners varied tremendously.

Within the group, we had negotiated a shared sense of adult numeracy as involving more than basic mathematical skills, or the application of mathematics in everyday life but rather numeracy as a way of negotiating the world through mathematics, “not less than maths but more” (Johnston & Tout, cited in Coben, 2004, p3). In the course of working together during the year, we had tried to develop a co-operative and conjecturing classroom - a milieu that explicitly challenged deficit models of adult numeracy. This ethos was influenced by the idea of funds of knowledge describing the informal knowledge, skills and experiences that adult learners can draw on but may not be evidenced by formal qualifications (Moll et al., 1992; Baker, 2005), a concept that can be broadened to include interpersonal and metacognitive skills.

Responses to initial classroom probes into their mathematical thinking suggested that few of the teachers moved flexibly between different representational modes. The most mathematically experienced wanted to adopt a symbolic or algebraic response whenever possible, with few trying out more practical approaches. The least experienced saw this use of ‘formal’ mathematical methods as their ultimate goal, placing less value on other approaches. This apparent lack of variety on the teachers’ own mathematical journeys was often in contrast to the active learning and multi-sensory approaches they were developing to support mathematical thinking with their own learners. The initial focus of the enquiry was to explore how to provoke adult numeracy teachers to think and act less mechanistically as ‘doers’ of mathematics themselves.

Methodology

The enquiry adopted an action research approach based on the idea “that a practitioner is involved in analysing a situation, planning an alternative action, carrying out that action, and then evaluating the effects of what they have done” (Mason, 2002, p172). The research was broken down into three smaller cycles or phases of enquiry and reflection. These were undertaken over an eight week period in the final semester of the course.

All participants within the group were involved in research design tasks for about an hour a week in class with some out-of-class time required for auditing, self-reflection and write-ups. Although an essentially social constructivist perspective informed the research focus and the design of classroom interventions, the research methodology itself was mixed. Data collection from tutor field-notes and audio-recordings of semi-structured group discussions focussed on teachers’ interpretations and evaluations of tasks undertaken in and out of the classroom, suggestive of an ethnographic approach. Other sets of data, however, were generated from audio-recordings of pair discussions, stimulated recall interviews, written work and tutor observations which aimed to capture responses to paired and individual tasks. Though more typical of positivist methodologies, these provided rich qualitative data which allowed me as a practitioner researcher to experience more fully what happened as teachers engaged in tasks.

Mason (2002, p52) suggests that in researching one’s own practice, it is useful to differentiate between giving a brief-but-vivid “account of what was seen, heard, experienced” and analysing, explaining or “accounting-for” incidents. Accounts-of will be used to illustrate salient incidents and experiences, along with excerpts from edited transcripts of audio-recordings and examples of teacher responses to tasks. Data analysis will be through a mixture of event sampling using and adapting pre-specified categories from wider theoretical and empirical research, and accounting-for recurring phenomena using key constructs and frameworks which are reported within each of the three action research cycles.
This paper will now outline key findings from cycle 1 of the enquiry before going on to focus in particular on significant moments arising from data generated within naturally occurring peer-peer discourse between two pairs of teachers during the second and third cycle of the enquiry.

**Cycle 1 - Awareness raising**

Gattegno (1988, p167) highlights the importance of teachers sensitising themselves to their own behaviours, emotions, and awarenesses:

> Teachers need to make themselves vulnerable to the awareness of awareness, and to mathematicization, rather than to the historical content of mathematics. They need to give themselves an opportunity to experience their own creativity and when they are in contact with it, to turn to their students to give them the opportunity as well.

In considering what sorts of mathematical activities to use within this action research, I wanted tasks that would support teachers to take the initiative and become more fully engaged in their own mathematical thinking. Schoenfeld (1994) developed a broad and age-independent description of what learning to think mathematically means:

1. Developing a mathematical point of view – valuing the process of mathematisation and abstraction and having the predilection to apply them.
2. Developing competence with the tools of the trade and using these in the service of the goal of understanding structure – mathematical sense-making.

But what did mathematical thinking and mathematisation look like ‘outside formal mathematics classrooms’? Research has demonstrated that adults have access to many informal numeracy practices (Street, 1984; Nunes, Schliemann & Carraher, 1993a; Baker & Rhodes, 2007). The idea that teachers need to become aware of learners’ innate or natural powers to think mathematically (Mason and Johnston-Wilder, 2006) is echoed in a number of recent research reports (Swan, 2006; Swan and Swain, 2007). Indeed, much official discourse now actively encourages adult numeracy teachers to “build on the knowledge learners already have” (Swain et al., 2007, p. 7).

The belief in the importance of teachers’ recognising their own funds of knowledge and exploring innate mathematical sense-making powers themselves, provided the initial impetus for considering everyday contexts and numeracy in the task design. By exploring what we as adult numeracy practitioners noticed about our own numeracy practices, would any shared characteristics, prior knowledge or behaviours related to mathematical thinking emerge to inform the design of tasks for subsequent action research cycles, for both experienced and less experienced participants?

**Task design 1**

During the first week of the enquiry, teachers and tutors made diary notes about what they identified as their numeracy practices over the course of a ‘work-day’ and a ‘non-work day’. These were mostly handwritten on two large A3 diagrams resembling a clock face. A further record sheet was completed during the second week. This required us to identify and classify mathematical behaviours we noticed according to what Bishop (1988) identified as six universally occurring activities: counting, locating, measuring, designing, playing and explaining.

**Analysis**

Each week, findings were shared with peer partners. Subsequent whole group discussion were animated, as numerous and at times conflicting accounts-of and accounts-for were generated:
Accounts 1

The supermarket does all the price comparisons – I just read the labels.

We’re on a really tight budget so I’m working out stuff with money all the time.

I get the kids to help with the adding up when we’re in the supermarket.

I was quite shocked – I do more maths out of work than when I’m teaching.

It took ages to park this morning. Usually there are a few places left, but today it was practically deserted.

I didn’t realise how much time I spend in the car at the moment – there’s journey times, buying petrol, using maps and Google directions, speeds and signs, even working out the best lane to be in where all the road works are.

I’m totally addicted to Sudoku at the moment – my son and I try to see who can finish first.

Teacher and tutor accounting suggested that as well as becoming more sensitised to our own numeracy practices, we engaged in a diverse range of socially and culturally situated mathematical behaviours. Although some of us identified possible mathematical topics and themes related to particular situations or times, others discussed what they actually did. Many omitted or ignored things they did not consider mathematical but “just common sense”. This illustrates how difficult it is to design learning tasks tailored to each individual’s particular experiences.

Data from this part of the enquiry did however suggest some common characteristics of the group’s everyday numeracy practices which tended to involve purposeful activities which were often collaborative e.g. family activities involving playing, cooking, shopping or constructing. These were often linked to particular roles and could be dependent on and shaped by particular tools or realia e.g. maps, self-service checkouts, petrol pumps, Sat Navs. This is in line with findings from similar studies into everyday numeracy practices (Lave, 1988; Harris, 2000; FitzSimons, 2005). For example, in reviewing a range of empirical research some 20 years ago, Resnick (1987) noted that much activity outside classrooms is socially shared. She contrasted examples of shared knowledge and understanding, tool manipulation, contextualised reasoning and situation specific competencies from everyday numeracy practices with the sorts of individual knowledge and skills, abstraction, symbolic manipulation and generalised learning more likely to be experienced in many formal mathematics classrooms.

Implications from Cycle 1

This initial analysis suggested that the teachers’ informal numeracy practices could be drawn on more effectively by providing tasks which afforded:

- Opportunities for them to work together on problems.
- Access and use of cognitive tools.
- Direct engagement with objects and situations rather than purely symbolic thinking.
- Use of situation-specific competencies (adapted from Resnick, 1987).

However, the overall goal was to further develop and extend these teachers’ mathematical thinking; to build on existing knowledge and ensure those with little or less successful experience of learning maths were empowered to operate successfully within formal mathematics classrooms too. To this end, the framework above merely presented possible points of departure.

In terms of identifying an actual topic base for the mathematical tasks to be used in the next cycles of the research, I was particularly struck by the relatively infrequent use made of ‘standard’ measures or indeed measuring devices during awareness raising activities in Cycle 1. Discussions with teachers
revealed resonated experiences and generated additional complex, contingent and subjective strategies for measuring and estimating everyday phenomena:

**Accounts 2**

In the morning I know when the bath’s getting full … I can hear how long I’ve got to drink my coffee

I can estimate how much it’ll cost by how full the trolley is.

I know how much squash to add by the colour – not dilution ratios!

I measure how crowded a place is by how far I have to go to get to an uncrowded place.

Buying petrol has nothing to do with gallons or litres…

Don’t need an alarm clock… my dogs tell us when it’s time to get up.

**Cycle 2 - Plausible estimates**

Subsequent research and review of potential mathematical thinking tasks which could be adapted in accordance with the research focus and findings to date, uncovered a number of suitable open-ended tasks based on estimation and measure. A set of classroom assessment tasks (CATs) which had already been field-tested were chosen for cycle 2 of the research. These involved “Making plausible estimates” based on Fermi-type problems (Ridgeway and Swan, 2010).

**Task design 2**

Figure 1 details the task objectives presented to the whole group:

The aim of this task is to provide the opportunity for you to work with your partner to:

- Make sensible assumptions
- Develop a chain of reasoning
- Choose suitable units
- Communicate your assumptions and reasoning effectively to peers

**Extension:** Identify upper and lower bounds i.e. what range of values would you give in order to be pretty certain that you have included the true value being estimated?

**Figure 1. Plausible Estimations**

Tahta (1981) makes a useful distinction between inner and outer tasks which helps here to distinguish between the explicit outer task of finding a plausible estimate and the intended inner task which would allow both teachers and tutor to gain experience of what mathematical thinking and communicating might look, behave and feel like.

By building on a range of theoretical and empirical research, Goos et al. (2004, p100) identify five assumptions they argue are crucial to creating a culture and ‘community of mathematical inquiry’:

1. Mathematical thinking is an act of sense-making, and rests on the processes of specialising and generalising, conjecturing and justifying.
2. The processes on mathematical inquiry are accompanied by habits of individual reflection and self-monitoring.
3. Mathematical thinking develops through student scaffolding of the processes of enquiry.
4. Mathematical thinking can be generated and tested by students through participation in equal-status peer partnerships.

5. Interweaving of familiar and formal knowledge helps students to adopt conventions of mathematical communication.

Mindful of the desire to value and develop teachers’ informal and formal mathematical experiences, I found the first of these assumptions resonated strongly with the notion of accessing learners’ innate powers and the last two strongly influenced my decisions to conduct the plausible estimation sessions with particular peer partners, and to require teachers to present and justify their findings to the whole group. The focus of analysis within this cycle of the research also moved onto data generated by two pairs of teachers within the group who fulfilled certain contrasting characteristics related to previous experience of teaching and learning mathematics.

Teachers M and N were confident in using higher level mathematical skills, had studied mathematics at university level and each had at least five years’ experience of teaching mathematics to adult learners mainly within further education settings. They were given the ‘mummies’ task in Figure 2.

An unravelled roll of paper is 33 metres or 100 feet long.

Will one roll be enough to wrap a person up?

Figure 2. Mummies

Teachers R and S were less confident in their mathematics skills and knowledge, had no formal mathematics qualifications beyond a foundation level and had quite recently become involved in teaching adults numeracy within their respective work-based training organisations. They worked on the ‘briefcase of pennies’ task in Figure 3.

Suppose you filled a briefcase with one penny coins.

How much money would you have?

Figure 3. The briefcase of pennies

Before considering in more detail what unfolded as these teachers engaged with their plausible estimation tasks over the next two week period, it is important to outline further theoretical frameworks which significantly impacted on both the conduct and analysis of data from this second cycle of enquiry.

**Realistic maths and mathematisation**

The idea of relevance and realism within mathematics teaching is complex and contested. Many authentic mathematics and real problem solving approaches advocate settings and situations which
try to motivate and engage learners by using topics relevant to their immediate concerns. However, Swain et al. (2005) argue that is the quality of an individual’s engagement with a problem that makes math meaningful rather than its utility or everydayness. Others, like Cooper and Dunne (2004) highlight the hidden rules younger learners must negotiate when tackling contextualised word problems and how these can adversely impact on learners from different cultural or social backgrounds.

Realistic mathematics is a term which better describes the sorts of tasks adopted within this enquiry and relates to an approach developed by Freudenthal (1991) which accentuates the actual activity of doing mathematics and advocates the power of learners to make things real for themselves by using their imagination. Such realistic tasks require learners to mathematise subject matter from real or realisable situations and reinvent mathematical insights, knowledge and procedures in the course of “their own mathematical activity rather than from the traditional view of presenting mathematics to them as a ready-made system with general applicability” (Gravemeijer cited in Barnes, 2004, p5). These situations can include contextual problems or mathematically authentic contexts for learners where they experience the problem presented as relevant and real. Such a process- rather than content-driven approach was consistent with the research focus of developing more relational and creative mathematical thinking and built on earlier project findings. The ‘plausible estimation’ tasks are examples of such realistic tasks.

**Horizontal and vertical mathematisation**

Additionally, in responding to the challenge that both learners and teachers often experience in trying to distinguish between concepts and procedures in mathematical thinking, Treffers (1987) developed the idea of horizontal and vertical mathematisation within this realistic maths framework. According to Freudenthal (1991) horizontal mathematisation ‘leads from the world of life to the world of symbols’ (p.41), which Barnes (2004) suggests happens when learners use their informal strategies to describe and solve a contextual problem. On the other hand, vertical mathematisation occurs when the learners' informal strategies lead them to find a suitable algorithm or to solve the problem using mathematical language. For Freudenthal (1991), this is where ‘symbols are shaped, reshaped, and manipulated, mechanically, comprehendingly, reflectingly’ (p.41). For example, in the case of the ‘plausible estimation’ tasks, the process of establishing the important information required and using an informal strategy such as trial and improvement to arrive at an estimate would be horizontal mathematisation. Translating the problem into mathematical language through using symbols and later progressing to selecting an algorithm such as an equation could be considered vertical mathematisation, as it involves working with the problem on different levels. This framework will be used within the analysis of data generated during teacher work on the ‘plausible estimation’ tasks.

**Analysis**

When first presented with these Fermi-type problems, teachers responded with surprise and some uncertainty:

**Extract 1**

R: Make it pound coins and I might have a go.
S: How are we going to do this then?
R: Haven’t a clue.

This intrigue right at the start of the tasks worked effectively to harness teachers’ emotions. Teachers M and N worked flexibly between mainly iconic or visual and symbolic modes of representation. They modelled a human being as a cylinder, deciding this would be the most effective way of minimising surface area rather than use a collection of smaller cylinders; agreed symbolic formulae...
for this surface area; assigned variables and established a direct proportional relationship between foot length and height.

R and S initially worked in an iconic mode with mental images of their own bags and briefcases, before looking around the room for more immediate concrete items which approximated their mental image of the briefcase on the task sheet. They stayed in this enactive mode, using a ruler to measure an actual briefcase and the diameter and depth of a 1p coin. Cooper & Dunne (2004) might argue that this is an example of teachers not understanding conventions for estimating and rounding. However, taking time within this mode allowed R and S to feel confident in their estimates before moving on to iconic and symbolic approaches. M and N, in contrast showed throughout the task that they knew and understood ‘the rules’ of the mathematics classroom:

Extracts 2

M: We’ve worked to the nearest whole number throughout so we should use 2m for the height.

And later:

N: The task just wants us to decide yes or no, so we’ve done it. We don’t need to work out how much more paper we’d need.

Ironically, their numerical estimates were the weakest chain in their initial argument as they got caught up in the mathematical conventions and opted for a height of 2m rather than their original 1.8m. The extension task which M and N completed required them to establish upper and lower bounds and brought the idea of dimensions-of-possible-variation (Marton and Booth, 1997) into play. By considering the range-of-permissible-change (op cit) for the heights of adults and children, constraints on their first model were established and a new model created which would incorporate a baby’s particular body shape and size. This extension task had extended the teachers’ mathematical thinking by requiring them to look for invariance in the midst of change (op cit). Overall, M and N demonstrated sophistication in their relational understanding and worked together to integrate relevant real-life experiences as they engaged flexibly between horizontal and vertical mathematation (Treffers, 1987). The ease with which I was able to identify and analyse M and N’s responses to this task using the frameworks provided is also significant as it may provide an account of what I readily recognise and implicitly value as ‘mathematical thinking’.

R and S had a significantly different journey through the task. S began to mathematise vertically using an algorithmic procedure involving volume. She wanted to work out the volume of the case and then to divide by the volume of a single coin and remembered that $V = l \times w \times h$ “maybe”. R, on the other hand, began with horizontal mathematisation - drawing lines of pennies as he built up a sense of volume through layering. His approach required him to find out how many coins were needed to layer out the briefcase and he struggled to make sense of the approach adopted by S:

Extract 3

R: I’m just using a practical approach that I understand but S’s solution is more mathematical.

R’s implicit value judgment here about some sorts of mathematical thinking being more valuable than others resonates powerfully. Barnes (2004, p59) argues that using a formula does not necessarily imply better conceptual understanding and warns of the “danger of focusing too much on vertical mathematisation”. In fact, when R and S discovered that their initial results did not match, it was by using R’s horizontal mathematisation that they were able to establish that an error must have been made with S’s conversion rates. Indeed, R had a very solid conceptual understanding of volume whereas S had adopted vertical mathematisation mechanically but without Freudenthal’s (op cit) other two requirements: comprehension and reflection. This prevented her from spotting the common
misconception made in converting between units of volume. It was by reverting back to R’s layering approach that both were able to work out that $1 \text{cm}^3 = 10\text{mm} \times 10\text{mm} \times 10\text{mm}$ and come to an agreed plausible estimate. Having to articulate for the whole class their chains of reasoning, initial assumptions and ways of validating results helped both R and S strengthen their understanding of the general algorithms they had adopted, although more time to consider upper and lower bounds may have consolidated this further.

Although R and S were less confident in terms of their intra-mathematical skills, it is important to note that they brought a range of social, communication and meta-cognitive skills and experiences to the task process which allowed them to discuss, peer check and when necessary seek help from peers and tutor. They were tenacious, supportive of each other and prepared to take their time, progressing with small steps along repeated cycles of what Mason, Burton and Stacey (1985, p156) describe as “the helix of manipulating – getting a sense of – articulating” when thinking mathematically.

Both sets of teachers were provoked by the tasks to fall back on their own experiences and access a range of personal ‘everyday’ or extra-mathematical knowledge in diverse ways. M and N drew confidently on their experiences of child birth to establish estimates for the width of the head and the length of a new born baby. However, when asked how they might check their findings, neither M nor N wanted to try out their solutions. The intrinsic motivation and interest was in the intra-mathematical process – the accuracy of their final estimation all but redundant. M and N had quickly moved from the real world to their own mathematical world and intended to stay there. In contrast, when asked how they would check their estimate, R and S went straight back to extra-mathematical knowledge of their real world:

**Extract 4**

S: You’d not use volume at all – you’d empty the case and weigh them.

R: Just like they do in the bank.

This willingness (or not, in the case of teachers M and N) to re-engage with the real world scenario in order to evaluate not only the plausibility of the estimates found but the validity of the mathematisation process itself may have significant implications for the teachers’ own professional practice. Arguably, failing to reinterpret and validate mathematical results within real situations can result in leaving unrealistic modelling unexposed. For some learners this sort of uncritical mathematical thinking does nothing to close ‘the gap’ between real and maths worlds.

When asked whether the ‘Pennies in a Briefcase’ task had been useful, R and S responded:

**Extract 5**

S: Yes, it got us thinking – we had to use lots of different sort of maths.

R: We’d forgotten lots. I think I understand units of volume better now.

Although these 'Plausible Estimation' tasks required only a basic knowledge of geometry, numeric skills and units of measure, the teachers did engage in more relational and connected thinking. Misconceptions related to conversions of units, use of appropriate formulae and rounding errors were identified through self and peer monitoring and teachers seemed to develop a more intrinsic feeling for the plausibility of their estimates. The value of developing conceptual and procedural knowledge in tandem seemed clear to all participants, and some teachers were also able to reflect more confidently and critically on their chains of reasoning.

**Coding framework for plausible estimates**

A more analytical comparison of the mathematical thinking and specific problem solving strategies the two pairs of teachers adopted in moving from real worlds to their maths worlds and (sometimes)
vice-versa is difficult, not least because they were undertaking two different tasks. However, by adapting a framework devised by Arleback (2009), I was able to encode data from recordings of peer-peer discussions during the ‘Pennies in a briefcase’ and ‘Mummies’ tasks:

1. Reading: reading the task and getting an initial understanding of the task
2. Making model: simplifying and structuring the task and mathematising
3. Estimating: making estimates of a quantitative nature
4. Calculating: doing maths - performing calculations, solving equations, drawing diagrams
5. Validating: interpreting, verifying and validating results: calculations and the model itself
6. Summarising: summarising the findings and results in writing or orally

Figure 4. Mathematical behaviours during ‘plausible estimations’

Figure 4 aims to capture a macroscopic and fairly dynamic picture of how teachers were heard to move between different ‘behaviours’ during the audio-recordings of the first 30 minutes of paired work on these tasks. Coded activities are identified within blocks, representing approximately 30 second time intervals. A whole group tutor intervention (WGI) took place after 15 minutes, and tutor interventions (TI) for particular pairs are also identified. X indicates where teachers have explicitly used extra-mathematical knowledge and experiences in diverse ways as outlined earlier.

Interestingly, although R and S had divergent calculation strategies during their tasks, the actual mathematical behaviours displayed in the diagram were similarly categorised within this framework as was the modelling stage which did not differentiate between horizontal and vertical mathematisation.

**Implications from Cycle 2**

Although the main value of these diagrams to me as a practitioner comes from the actual process and challenge of coding and categorising the peer-peer discussions, they do also provide some triangulation of earlier observations on how and when extra-mathematical knowledge is used, some new insights into the timescale of comparative progress through the tasks by both pairs, the frequency with which the teachers validated results and the time taken to summarise findings in preparation for articulation to the whole group. Arleback (2009) noted similar phenomena with his learners and
observed that validation of results involved checking calculations, estimations and the initial model. However although both pairs of teachers here used articulation to summarise and peer validate their calculations, results and decision making processes throughout, M and N were more reluctant to ‘re-enter’ the messier real world once they had found a comfortable place of abstraction in their maths world.

**Cycle 3 Creating measures**

For the final cycle of the research, a second set of field-tested mathematical tasks were used. These aimed to prompt teachers “to evaluate an existing measure of an intuitive concept and then create and evaluate their own measure of this concept” (Ridgeway and Swan, 2010). A key component within this cycle would be the requirement for both pairs of teachers to test and evaluate any measures created back in the real world.

**Task design 3**

Requiring teachers to start from everyday concepts – steep-ness, sharp-ness, awkward-ness, compact-ness, crowded-ness and square-ness – to mathematise phenomena by creating their own measures seemed even more closely related to the experiences of awareness-raising in the first cycle of the enquiry and consistent with the sort of mathematisation and guided re-invention advocated by a realistic maths approach. As well as provoking mathematical thinking, I hoped these tasks would afford meaningful two-way connections between real and maths worlds.

Experiences during cycle two of the enquiry suggested that peer partners worked well together. This time however, I provided more scaffolding in the form of prompts in teachers’ work packs, so that tasks could be sustained and worked on independently. These included regular self-monitoring and reflection opportunities, consistent with the second and third assumption identified earlier as crucial to a community of mathematical inquiry (Goos et al., 2004). Teachers worked on these extended tasks in class each week for an hour over a three week period. Although they had individual work packs, pairs were expected to work collaboratively to reach a point where they would be able to go out on campus to test whether their measures actually worked. A written summary of findings ‘so far’ with commentaries, photographs and individual reflections on the creating measures process would provide evidence for teachers’ personal mathematics portfolios.

Before tasks were distributed, an introductory activity was undertaken to encourage teachers to consider themes, processes and specific features evoked by particular concepts:

- With your partner, take a few minutes to discuss what the concept of ‘sharp-ness’ means to you both.
- This might include thoughts, images, experiences, associations, special words or phrases, contexts or feelings.
- Use a concept map to record your initial responses.

*Figure 5. Example of introductory activity for ‘creating measures’ task*

When finally presented with their actual tasks, several teachers experienced what Mason & Johnston-Wilder (2006, p96) describe as “a contradiction of expectation” which they argue is a useful disturbance to provoke activity:

**Extract 6**

M: Oh, it’s nothing to do with pain or needles …
The actual ‘creating sharp-ness’ activity presented to teachers M and N is shown here:

**Figure 6. ‘Sharp-ness’ Activity 1 Warm-up**

Without measuring anything, put the four bends in order of "sharp-ness".

Explain your method clearly.

This first activity specifically invited teachers to engage with _iconic_ modes of representation. By inviting them to ‘look first, and act later’, I hoped that the teachers would use their own mental imagery and innate sense-making powers to identify similarities and differences between images, to specialise and generalise, order and classify and begin to become aware of some of the properties of the bends, or in the case of teachers R and S, the staircases which they might be able to explore later:

**Figure 7. ‘Steep-ness’ Activity 1 Warm-up**

Without measuring anything, put the staircases in order of "steep-ness".

Explain your method clearly.

Although these two dimensional images were less life-like than those used in the earlier ‘plausible estimation’ tasks, they were not conventionally mathematised to one-dimensional lines. Another feature of the classroom at the start of this third cycle of enquiry was the availability of mathematical equipment – tools for measuring, different sorts of paper including square, graph and dotty, calculators, counters, centicubes, etc. Indeed, all tasks required teachers to undertake some hands-on measurement, ensuring that everyone got involved at an _enactive_ level, quite literally manipulating, constructing and measuring particular properties of their task concepts. Nunes et al. (1993b) identify the significance of such _measuring_ tools in supporting mathematical reasoning in younger learners and increasingly adult learners are being re-introduced to the power of multi-sensory approaches to mathematical sense-making. These tasks required that my teachers did the same.
Figure 8 shows how the learning objectives for the ‘steep-ness’ task were introduced to teachers R and S:

**Objectives**

This problem gives you the chance to:

- criticise a given measure for the concept of "steep-ness"  
- invent your own ways of measuring this concept  
- examine the advantages and disadvantages of different methods.

*Figure 8. ‘Steep-ness’ Task objectives*

**Analysis**

In their initial discussions on the staircases, R and S identified a range of factors influencing their perceptions of steepness: personal preferences about heights and depths of steps, fitness and stamina, carrying shopping bags, going up or down, taking single or multiple steps, individual heights and builds, disabilities, indoor or outdoor steps, surfaces, ‘length’ of staircases. Their considerations were very much rooted in the social context of the staircase journeys – who, why, when, where, how often. Rather than a straightforward exercise in finding gradients, R and S were tackling a much more complex modeling task within the real-world scenario they had created.

M and N on the other hand again moved almost immediately to abstract mathematisation, exploring how they could use trigonometry to create a measure of ‘sharpness’, focusing solely on angles and width with no consideration of other contextual factors. When prompted, they were able to generate other variables: roads, lanes, vehicles, weather, surface, speed, visibility, gradient, etc. but the relevance of these only really became apparent to them when they went outside to test their new measure in the messier real world. Figure 9 provides a brief account-of their measure for ‘sharpness’:

*Figure 9. ‘Measures of sharpness’ invented by teachers M and N*

This may also convey some the unconscious assumptions and value judgements that I, as someone more comfortable within the abstract maths world of algebra myself, make about what mathematical thinking looks like. It certainly accounts-for some of my confidence that such realisable tasks can

provide effective points of departure for diverse groups of teachers to engage in doing, thinking and communicating mathematically and to recognise what this engagement entails.

Although data from this third cycle of the enquiry provided many other textured examples of ways in which the ‘creating measures’ tasks provoked teachers to engage in mathematical thinking, I will finish by focusing on one further incident that was particularly significant and indeed disturbing:

Extract

S: Before today I thought I could look at a slope and know how steep it was. But when you do the measurements, you realise it’s different. I’ll never decide about steepness by eye again.

What had happened for this teacher to conclude that her intuitive understanding and experience of steepness in the real world was wrong? Data from the audio-recording of S and R’s work and stimulated recall interviews suggest that S drew this puzzling conclusion as a result of some very ‘logical’ deduction:

Account 8

R and S measure the height and slope of staircases on campus.
Back in the classroom, they use Pythagoras to calculate length.
They produce scale drawings - ‘staircase triangles’.
They measure the angles.
The steepest staircase isn’t the one they thought it would be.
You can’t trust your eyes to measure steepness.
Do it by measuring in future!

Ironically, R and S had no need to use Pythagoras at all but had been so excited in “finally understanding how to do it” that they built it into what was otherwise a reasonable algorithmic approach to measuring steepness, believing their calculations would be more accurate if they only had to use two real-life measurements. However, rather than consider that they might have made a calculation error, S instantly gave up her own internal sense of what a reasonable result should look like, trusting to the “power of mathematics” and in particular, the power of formulae, over-riding the evidence of her own eyes. R who was much less critically engaged in the process, was happy to concur with S and seemed unconcerned that evidence from calculations totally contradicted his initial observations ‘by eye’.

This episode suggests that for S, the world of formal maths although exciting was still very external to her own internal world. It also suggests something about how she valued different sorts of knowledge – with formal mathematical powers at the top of the hierarchy and her own at the bottom. It took time, considerable peer checking and more experiences of measuring and testing staircases around the campus before S’s mathematical and personal worlds began to reintegrate. R and S may have recovered from this incident but it continues to resonate strongly with previous personal experiences.

If learners override extra-mathematical understanding, how can they develop their ability to judge whether their answers are sensible and how often do they leave classes not knowing any more how to do something that made sense to them at the start of the lesson? In the case of R and S, the incident actually provided a sort of dissonance that generated another very fruitful point of departure. However, in a short time-restrained session where curriculum and assessment demands may prevent teachers and learners taking the time to move within this horizontal phase of mathematisation to deal
constructively with misconceptions and bridge gaps between real and maths worlds, how damaging might this sort of mathematical experience be to learners’ self-confidence and self-concept?

While researching this phenomenon further, I found an article in which Meissner (2006) suggests that we have a number of internalised representations or micro-worlds which inform our subjective domains of experience. He identifies a reflective and subjective domain of experience (SDE) and argues that although both are important for flexible thinking one can often be more dominant over another, particularly when a new problem or conflict arises:

The individual prefers to ignore the conflict rather than modify the SDE or adopt another SDE. In mathematics education it is quite natural that an ‘analytical-logical’ behaviour remains dominant and that conflicting, common-sense experiences or spontaneous ideas get ignored. (Meissner, 2006, p3)

This is an interesting theoretical construct with which to try to understand why R seemed relatively unperturbed by cognitive dissonance, while S was so easily enticed to relinquish her own common sense experiences.

At this stage of the enquiry then, my initial disappointment that carefully selected and adapted mathematical tasks had resulted in some teachers dismissing rather than valuing their own intuitive mathematical powers, was tempered by the fact that engagement with these same tasks had generated phenomena that provided insight into another interesting and valuable point of departure related to how we move between and within our formal and informal, real and mathematical worlds.

**Summary discussion**

The initial focus of this action research project was to improve practice in supporting adult numeracy teachers develop and extend their own mathematical thinking. At each stage of this inductive process, as a participant observer I have collected, reflected on and evaluated data related to teachers’ responses to a series of research design tasks. In particular, using audio-recordings to reflect on classroom discourse during collaborative work on mathematical tasks and in oral presentations to peers generated evidence of rich, cyclical and non-linear problem solving and mathematical thinking processes. It was a real privilege to listen to teachers interacting together with energy, trust, humour, perseverance, intelligence and humanity.

During this enquiry, I hoped to gain insights into a group of adult numeracy teachers’ mathematical thinking but learned a great deal more about my own assumptions, beliefs, and expectations. In focusing on the quality of my own interventions and interactions with teachers, I need to recognise that I can be just as mechanistic and instrumental in supporting work on mathematical tasks as they can be in solving them. I also recognise, value and am more likely to favour mathematical thinking and behaviours which mirror my own formal mathematical experiences and interests and need to be fully conscious of this if I am to further develop my own inclusive practices in supporting teachers to develop mathematical thinking.

Teachers and tutors come to formal mathematics classrooms with funds of knowledge, which include diverse and contingent informal numeracy practices which are culturally and socially situated. These often go unrecognised, are not valued or are held subconsciously. Raising awareness of these through systematic reflection can provide valuable insights into hidden personal and interpersonal resources and propensities which can be harnessed or challenged to support teachers’ own mathematical thinking and, hopefully, their professional practice.

More enactive and iconic approaches can open up or close down possible lines of inquiry in unexpected ways. Similarly, tasks which specifically require teachers to take more time in manipulating and getting-a-sense of the mathematical structures of a problem, though often more time-consuming, are less likely to result in teachers adopting mechanistic or instrumental approaches.
Conclusion

What unfolded during this small-scale practitioner enquiry suggests that doing realistic mathematics tasks within a community of inquiry can provoke a range of mathematical thinking and learner responses. These allow us to identify ways in which procedural and conceptual thinking can be used within horizontal and vertical mathematisation, and how learner journeys can be tracked through different stages of problem solving. Such tasks can also provide meaningful starting points to teachers with varying levels of prior mathematical experience. However, teacher and tutor beliefs and assumptions about what constitutes mathematical behaviour can support or constrain the intent and ease of movement within and between their real and mathematical worlds, and vice versa. While teachers with more experience of mathematics could do this flexibly, despite preferences and predispositions to reside in more formal mathematical mental environments, others with less confidence or less well developed intra-mathematical knowledge and skills dismissed their own innate sense-making and extra-mathematical knowledge too readily, with mixed success.

Recommendations for future practice

Adult numeracy and mathematics teacher education courses need to support students to engage regularly in a variety of sustained, open-ended and realistic mathematical tasks, with further extended tasks signposted for independent study.

If teachers are to develop greater awareness of what mathematical thinking looks, feels and sounds like, more self and group reflection and evaluation tasks need to take place with explicit reflections on inner, outer and meta-tasks encouraged within personal maths portfolios and group discussions.

New mobile technologies are being used increasingly and naturalistically within sessions: listening to, watching and analysing targeted audio- and video-recordings of engagement in their own mathematical thinking tasks will support teachers to develop awareness of awareness further.

The key literature, frameworks and constructs which informed the context and conduct of this enquiry along with the specific mathematical tasks used could be shared and contribute to reading lists used on other adult numeracy teacher education courses.

Throughout this paper, there has been an underlying assumption that developing teachers’ confidence, awareness and insight into their own mathematical thinking, will better equip them to develop and extend the mathematical thinking of their learners. Adult numeracy teacher educators need to identify and value further opportunities for students to explicitly evidence and reflect on how they are using their own experiences of thinking and acting mathematically to inform their practice with learners.

References


INTEGRATING REAL-WORLD NUMERACY APPLICATIONS AND MODELLING INTO VOCATIONAL COURSES *

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Abstract
Practitioner research is in progress at a Further Education college to improve the motivation of vocational students for numeracy and problem solving. A framework proposed by Tang, Sui, & Wang (2003) has been adapted for use in courses. Five levels are identified for embedding numeracy applications and modelling into vocational studies: Extension; Special Subject; Investigation Report; Paper Discussion; and Mini Scientific Research. These levels represent a progression from applications set by the teacher, through increasing student involvement in the solution of real world problems, to totally independent project work. Case studies are presented of the incorporation of the five levels of application in engineering, construction, computing, and environmental science courses. In addition to student motivation, teaching staff observed that improvements have occurred in: use of specialised mathematical vocabulary; the combined use of numerical and algebraic methods in problem solving; and abstract reasoning, and a deeper level of understanding of the mathematics used in problem solving. A difficulty which has not yet been fully resolved is the reconciliation of a problem solving and project based approach to numeracy, and the requirement by some Examination Board numeracy syllabuses to assess specific mathematical methods.

Key words: numeracy, vocational education, modelling, applications, assessment

Introduction
This paper describes practitioner research which is being carried out by tutors of vocational courses at a Further Education College in Wales. Students often begin vocational courses with a poor experience of school mathematics and lack enthusiasm to improve their mathematical skills. However, they will need to develop numeracy and problem solving as an essential aspect of their vocational training, for example: in subjects such as engineering or construction. The aim of the current project is to develop a framework of learning strategies which will interest and motivate students. It is hoped to develop students' numeracy skills within their vocational areas; and to help them to gain transferrable skills in critical thinking, creativity, teamwork and collaboration, and learning self-direction.

School mathematics in Britain, as in many other countries, is designed around a bottom-up academic model. Pupils learn mathematical methods within distinct topic areas such as: number, algebra and geometry, then work on example applications still within these same topic areas. The intention of the developers of mathematics syllabuses seems that pupils will progress to study subjects at an advanced level, such as sciences, where they will be able to make good use of the mathematical techniques they have learned. Figure 1 highlights the components of this bottom up academic model in Britain.
This model can present problems for students who leave school at the age of 16 to study a practical vocational course. They may view mathematics as a series of unrelated topics, some of which seem to have no relevance to their chosen profession. Algebra, in particular, is seen by many school leavers as having very little practical everyday use.

Methodology

Students entering further education courses in engineering, construction, computing, and environmental science at post-16 age took part in questionnaire surveys. This allowed the researchers to better appreciate and understand the attitudes and abilities in numeracy developed by the students during their school education.

Clinical interviews (Ginsburg, 1981) were then carried out with a total of 12 students chosen from the range of courses. The students were asked to give a commentary on their reasoning whilst attempting to solve various mathematical problems. From an analysis of the interview transcripts, four particular difficulties were identified:

- Lack of specialised mathematical vocabulary. Students had difficulty describing features of graphs, equations and other mathematical entities.
- No strong connection between number and algebra in problem solving (Lee & Wheeler, 1989). Students made no attempt to understand relationships in formulae by substituting numerical values, and made no attempt to devise formulae to simplify the repetitive handling of numerical data.
- A preference for justification by concrete example. Students generally preferred to use manipulation and measurement of solid shapes to solve problems, rather than abstract mathematical reasoning.
- Misuse of standard algorithms which had been learned in a superficial manner without full understanding. Examples causing difficulty included formulae for areas and volumes, sides of triangles, and trigonometry.

It became evident that there was little to be gained by continuing to teach in a way which had already been unsuccessful for some students. A new approach was therefore attempted by teaching staff participating in the project, and forms the basis of this paper. Thought was given to the development of open ended and ill-defined numeracy problems to be presented to students which would realistically simulate work related tasks within the within their vocational areas.
A useful framework for introducing real world problems into mathematics teaching has been proposed by Tang, Sui, & Wang (2003) from work in China. Practitioner research during the current project has focussed on ways in which this framework could be successfully adapted for introduction into vocational courses at further education level. Five approaches are identified by Tang et al. for embedding numeracy applications and modelling: Extension; Special Subject; Investigation Report; Paper Discussion; and Mini Scientific Research. These approaches represent a progression from applications set by the teacher, through increasing student involvement in the solution of real world problems, to totally independent project work designed by students themselves.

At the end of an academic year, students were re-interviewed to investigate changes in their perceptions of numeracy, and to investigate the extent to which their abilities in problem solving had developed.

**Applying Numeracy**

A distinction is made by a number of researchers (Hoyles et al., 2000; Dingwall, 2000; Coben, 2000) between mathematics, which is taken to be a set of quantitative methods, and numeracy which has wider links with the real world. Numeracy need not be at an elementary level but might include, for example, the advanced mathematics used by engineers or scientists. Numeracy requires knowledge of the real world context in which the problem occurs. It is essentially a practical problem solving activity drawing upon appropriate mathematical techniques, and the results obtained often need to be communicated to others in a way which is useful for decision making. The relationship between mathematics and numeracy developed by this model is illustrated in Figure 2.

![Figure 2. Relationship between mathematics and numeracy](image)

The approach taken by teaching staff during the current project is to work downwards within vocational area to identify numeracy tasks undertaken by practitioners in everyday work. Tasks are analysed in collaboration with students, and solved using mathematical methods which might be familiar or which might need to be learned at this stage. Additionally, the work provides opportunities for consolidating mathematical knowledge in broader topic areas. This approach is illustrated in Figure 3.
Central to the numeracy approach which we are developing with our students is the MeE motivation model of Martin (2002) and Munns & Martin (2005), summarised in Figure 4:

The model focuses on the need to motivate students by presenting interesting learning activities, and the self-satisfaction that students can gain from engaging successfully with these activities. This can lead students to develop a personal engagement with the subject as a whole, through the enjoyment and sense of achievement which it provides, so that they become intrinsically motivated to develop skills and knowledge to a higher level.

Munns and Martin advocate the introduction of the most interesting work from the very start of a course, as a means of generating enthusiasm. Teachers may need to simplify tasks to ensure that students achieve a successful outcome and gain a sense of achievement. It is important that the students consider the tasks to be realistic, relevant and worthwhile.

During the current research activities, teaching staff realised that a number of interesting and motivating tasks might need to be presented, but they hoped that individual students would reach the point of engaging with the subject as a whole. From this stage on, the work of the teacher would become much easier. The value of the subject would be clear to the students and they would be motivated to extend their knowledge and skills through independent learning.
Naturally Occurring Numeracy

In a number of vocational areas, numeracy tasks occur quite naturally in everyday work. Two examples produced by colleagues are (a) curved work in carpentry, and (b) expedition planning, which are presented here:

Curved work in carpentry (Slaney, 2013)

Amongst the more advanced practical skills taught to carpentry students are methods for constructing curved door and window frames of various designs. Designs have to be produced as a bench template for cutting the timber components.

A challenge presented to students was to construct a gate in the form of a Tudor Arch, which traditionally has the geometrical design illustrated in Figure 5:

![Figure 5. Geometrical construction method for a Tudor arch](image)

Students investigated the construction method:

- Two circles of equal radius are drawn to set the width AB of the arch. Two arcs AE and BF of these circles form parts of the completed arch.
- A square is constructed, with the distance between the circle centres 1 and 2 as the length of each side,
- The mid point of the bottom edge of the square, CD, is used as a centre for constructing the upper arcs between E and F to complete the arch.

The group were interested to investigate the geometry of other traditional arch designs developed by masons and carpenters during different historical periods.

Expedition planning

Students who are training to become outdoor pursuits instructors are required to make reasonably accurate estimates of the time which expeditions will take over mountainous terrain as part of the procedure for safety planning. A mathematical formula known as Naismith’s Rule can be used for estimating journey time. This determines a time based on walking speed over flat ground, then adds extra time for the amount of ascent and descent necessary during the journey.

Students using Naismith’s Rule have found that the time calculations for expeditions in the mountainous area of North Wales are very inaccurate. This is due to wide variations in the time taken to cross different types of terrain. Walking speed is much slower across moorland, overgrown forest or wetland than along well constructed footpaths. Scrambling over rocks on mountainsides is particularly slow.
As a project, students have documented the actual times taken for the different stages of a number of expedition routes, and have related these to the nature of the terrain. They are attempting to develop a more accurate journey time formula to improve on Naismith’s Rule. This project is a good example of the application of the modelling cycle of Blum and Leiß (Keune & Henning, 2003).

The modelling cycle considers the manner in which a mathematical modelling problem can be conceptually divided into two domains – the real world domain, shown on the left in Figure 6, and the mathematical domain shown on the right.

The modelling cycle begins in the real world domain, where it is necessary to identify the factors which are important to the outcome of the model. The relationships between these factors are then assessed in descriptive terms. Modelling then moves to the mathematical domain, where the factors are expressed in terms of a formula and numerical examples are run to generate modelling predictions. These modelling predictions are then related back to the real world domain and checked against actual observations. If necessary, the modelling assumptions can be revised and the model re-run, until an acceptable solution is found.

A particular value of this project has been to help students make a connection between algebra and number, with these mathematical methods employed together effectively in problem solving. Students often have difficulty in constructing algebraic formulae from theoretical relationships between variables, or from the identification of patterns in observed data. We have found that the plotting of graphs can provide a helpful conceptual link between number and algebra.


It is valuable for numeracy tutors to make use of naturally occurring numeracy tasks, such as the carpentry work mentioned above which forms an essential component of the course syllabus. However, it is sometimes necessary for tutors to develop additional applications to broaden the mathematical and problem solving skills of vocational students. Many topics studied on vocational courses can, with imagination on the part of the tutor, provide opportunities for interesting and realistic numeracy problem solving.
Tang, Sui & Wang (2003) proposed a framework which we have adapted for use in vocational courses during this project. The original framework was intended to provide a practical structure in which mathematics students could apply their mathematical skills in realistic real world situations. Our approach is somewhat different, in that we have used the framework as a structure by which vocational students might investigate real world problems through the application of numeracy. Whilst the students of Tang et al. would be experienced in mathematical techniques but perhaps unfamiliar with their applications in the real world, our students would be familiar with the types of problems arising in vocational situations but might need to develop further mathematical skills to solve these. The overall aim in both cases is to develop practical numeracy problem solving skills, though from different starting points.

Five levels were identified by Tang et al. for incorporating applications and modelling into mathematics courses: (a) Extension, (b) Special Subject, (c) Investigation Report, (d) Paper Discussion, and (e) Mini Scientific Research. Examples of tasks illustrating each of these levels are presented below. The five levels represent a progression from applications set by the teacher, through increasing student involvement in the solution of real world problems, to totally independent project work designed by students themselves.

**Extension**

In this approach, students who have been studying a mathematical topic are presented with an ill-defined real world problem where they need to seek out additional data for its solution. As an example, consider the problem in Figure 7 which might be given at the end of a study of trigonometry. The problem cannot be solved without obtaining measurements.

**Figure 7. Example of an ill-defined problem**

In this case, the student should obtain actual data, or at least reasonable estimates, for the speed of rotation of the wheel, its diameter, and the height of the adjacent building. This might be found by use of the Internet. The student is then free to devise his/her own method for numerical, graphical or analytic solution of the problem.

An example solution produced by a student is shown in Figure 8. Trigonometry has been used to obtain a formula linking the height of a car above the ground, H, to the diameter of the wheel, the height of the central axel above the ground, and the angle of rotation θ. A graph was then plotted using a spreadsheet, and an estimate made of the time during which the car was above the height of the nearby building.
Figure 8. A possible graphical solution of the London Eye problem. The wheel has a diameter of 120m, and rotates in 30 minutes.

**Special Subject**

Students who have studied a vocational topic were given the opportunity to investigate the topic further through a quantitative project. This approach was used successfully with construction students who had been studying heat losses from buildings. After discussion of the insulating properties of different building components, students developed their own spreadsheets to determine the heat losses from a house. This allowed investigation of the effects of double glazing of windows, cavity insulation of walls, and insulation of the roof space, and gave a deeper understanding of the mathematics involved.

The model makes use of the dimensions of each wall of a room, and its construction material, to estimate heat losses. This heat loss is also dependent on the average temperature difference between the two sides of the wall. Heat losses are added for the floor and ceiling, to obtain total heat losses for the room. Allowance must also be made for heat loss through air ventilation in the room.

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Figure 9. House heat loss

**Investigation Report**

For this approach, students gather their own primary data through surveys, laboratory or fieldwork measurements, then process the data using appropriate mathematical methods. In this way, it is hoped to gain a clearer interpretation of the data and to obtain insights which were not initially obvious.
As an example, geography students investigating coastal processes measured pebbles which were being transported along a shingle spit by wave action. Results and analysis are presented in Figure 10. The chart on the left plots the average dimension of pebbles against position along the beach. The shingle spit originates at a cliff line at Friog on the left of the chart, and extends out into the estuary for a distance of approximately 1.5km, past Fairbourne to Barmouth Ferry.

![Figure 10. A comparison of field data and a theoretical model for pebble erosion](image)

It was seen that although a mixture of pebble sizes was present at each location visited, there was a reduction in mean size during transport along the shingle spit. Discussion between students and their tutor lead to a hypothesis that the rate of size reduction would be proportional to the actual pebble size — large pebbles would be eroded more easily by wave action than small pebbles.

A spreadsheet numerical model was developed for a constant percentage reduction in size for each distance unit, leading to the familiar negative exponential curve. The theoretical curve produced in the spreadsheet model to the right was seen to closely reflect the best fit curve through the actual field data, supporting the initial hypothesis connecting rate of erosion directly to pebble size.

**Paper Discussion**

The approach used here is to present students with an interesting and challenging vocational mathematics task, then provide resources from books, journal articles or the Internet which will allow the students to teach themselves the necessary quantitative techniques for solving the problem. This contrasts with the normal teaching approach in which the tutor provides instruction, and is intended to encourage students to develop as independent learners.

An example presented to computing students was to model an epidemic of a non-fatal illness such as influenza. Published articles were provided which explained the recurrence relations which form the Simple Epidemic Model (Keeling, 2001). The population is modelled as three groups:

- Susceptible: those who can catch the illness,
- Infected: those who have the illness, and could infect others, and
- Recovered: those who cannot catch the illness again and are no longer infectious to others.
In each time period, a number of people will catch the disease and move from the Susceptible to the Infected group. The number of persons infected will depend on the proportion of the population who are susceptible and infected, and come into contact. It will also depend on the infectiousness of the disease – a variable known as the Epidemiological Parameter.

In the time period, others will recover and move from the Infected to the Recovered group. This number will depend on the average time a patient takes to recover from the illness. Results from a run of the spreadsheet recurrence relation model are shown in Figure 11.

Figure 11. Results generated by students in running the Simple Epidemic model.

It is seen that the epidemic begins to decline when the number of recovered people in the population exceeds the number susceptible. This is due to the reducing likelihood of an infected person coming into contact with a susceptible person to spread the illness.

**Mini Scientific Research**

This approach represents the maximum level of student involvement in the planning, investigation and analysis of data for a substantial numeracy project related to their vocational area. An example of a project carried out by engineering students has been the investigation of the motion of a car when passing over a speed hump, in response to the springs and shock absorbers of the car suspension system. Results from a run of the spreadsheet model are shown in Figure 12.

Figure 12. Damped simple harmonic model for the motion of a car passing over a speed hump
The model was developed by the students as a recurrence relation for small time intervals. At the start of the time interval, the current vertical velocity and acceleration of the car body were known. Initially these are zero for steady motion along the road.

As the car climbs the speed hump, it transmits a vertical force to the car body. In the case of the spring component, this is dependant on the shortening of the spring according to Hooke’s Law. For the damper component, however, a reverse force is generated which is proportional to the vertical velocity of the damper piston. Vertical acceleration of the car body can then be modelled from the resultant force through the suspension system and the mass of the car body.

Students were able to compare the results of spreadsheet modelling with video film which they produced of the actual motion of cars passing over speed humps at different speeds.

**Evaluation**

The researcher conducted observations of students who were undertaking numeracy tasks, and examined the solutions students produced before interviewing participants about their experiences during the project and their broader attitudes towards numeracy and mathematics. The project is ongoing, but it is clear that higher levels of interest and motivation have been generated by the various tasks, and students’ confidence in using mathematical techniques has been improved. In particular, problems identified early in the year have been addressed to a significant extent:

- Use of specialised mathematical vocabulary is more evident,
- Numerical and algebraic methods were being combined in the solution of problems,
- Skills in abstract reasoning have improved, and
- A deeper level of understanding of the mathematics used in problem solving is evident.

A difficulty which has not yet been fully resolved is the reconciliation of a problem solving and project based approach to numeracy, and the requirement by some Examination Board syllabuses to assess specific mathematical methods. As an example, we might consider the Essential Skills Wales Application of Number qualification. From the description:

> The aim of the Application of Number standards is to encourage candidates to develop and demonstrate their skills in using number to tackle a task, activity or problem by collecting and interpreting information involving numbers, carrying out calculations, interpreting results and presenting findings. (WJEC, 2013)

this qualification appears to closely embrace a real-world problem solving approach to numeracy. However, closer examination of the assessment requirements presented in Figure 13 shows that a large number of particular mathematical methods must be demonstrated in the work submitted by candidates.

It is evident from this list that no single realistic real-world project, or even small number of projects, is likely to come anywhere near covering all the stated requirements. There is therefore a tendency for tutors to revert to the bottom-up model of teaching mathematical topics individually to cover the syllabus, and vocational applications become limited and unconvincing to students.

A compromise approach is to primarily employ real-world problem solving as a means of motivating students, but also allocate time at the end of each project session to provide broader coverage of related mathematical methods and topics. Students are made aware that this is necessary in order to meet assessment requirements. For example, after solving a graphical problem which is discovered to involve an exponential function, students may be introduced to other related functions...
such as powers, inverse powers and logarithms. After the use of trigonometry to creatively solve an ill defined circular motion problem, students might examine the use of trigonometric applications in other areas such as topographic surveying.

**IN ORDER TO SHOW THAT YOU ARE COMPETENT, YOU NEED TO**

- use powers and roots
- use compound measures
- use mental arithmetic involving numbers, simple fractions, and percentages
- work out missing angles and sides in right-angled triangles from known sides and angles
- calculate with sums of money in different currencies
- calculate, measure, record and compare time in different formats
- estimate, measure and compare dimensions and quantities using metric and, where appropriate, imperial units, and check the accuracy of estimates
- calculate within and between systems and make accurate comparisons
- draw 2-D representations of simple 3-D objects
- solve problems involving irregular 2-D shapes
- work out actual dimensions from scale drawings and scale quantities up and down
- work out proportional change

*Figure 13. Extract from the specification for Essential Skills Wales Application of Number*

**Further Development**

Creative problem solving can provide a structure for introducing new mathematical topics in a way which is motivating for students, demonstrates immediate relevance to vocational studies, and supports a deeper understanding of mathematical methods. As an example, a new approach has been used to introduce engineering students to calculus for the first time at the start of their course. Students are asked to estimate the volume of the centre cone of a jet engine (Fig.14):

*Figure 14. Volume calculation problem*
In discussions between the tutor and the student group, it was agreed that the volume could be estimated by dividing the cone into a series of cylinders, with volumes then calculated and totalled using a spreadsheet (fig.14):

\[
\text{volume} = \sum \pi r^2 t
\]

\[
\int_{0}^{0.5} \pi x^2 \, dx = \int_{0}^{0.5} \pi \left(\sqrt{x}\right)^2 \, dx = \pi \left[ \frac{1}{2} x^2 \right]_{0}^{0.5} = 0.125 \pi
\]

Figure 15. Solution to the volume calculation problem

Students were readily aware that the accuracy of the estimate would increase as the number of cylinders was increased, although in practice the number of cylinders would be limited by the capacity of the spreadsheet program. Integration was then introduced as an alternative quick and easy method of finding the total volume of an infinite number of infinitely thin cylinders – effectively providing the exact answer to the problem. The group were suitably impressed by the power of mathematics, and the effort that can be saved by applying appropriate mathematical methods.

Overall, the development of numeracy through problem solving in vocational areas, either by naturally occurring applications or use of the framework of Tang et al. (2003), is seen as an effective way of increasing student motivation and creativity.

Conclusion

This project has examined approaches to improving the numeracy and problem solving skills of students in engineering, construction, computing, and environmental science courses at a further education college. It has been evident to the teaching staff that student motivation is critical to developing numeracy. Principal factors affecting student motivation were found to be: the relevance of numeracy tasks to students’ main courses, the realism and authenticity of tasks in the relevant vocational field, and the intrinsic interest and challenge of the problems presented.

A definite advantage of the use of open ended and ill-defined problem solving activities, apart from improving student motivation, was to encourage the development of wider numeracy skills. These include: communication of mathematical ideas in a form suitable for decision making, use of practical and common-sense techniques in obtaining solutions to problems, skills in data collection, and estimation of results to appropriate levels of accuracy. A particularly pleasing aspect observed by the researchers was an improved ability by students to inter-relate the numerical, graphical and algebraic representations of data sets.

The framework introduced by Tang et al. (2003) was considered by the teaching staff to provide a range of interesting opportunities for planning and structuring student activities which could be integrated into vocational courses. The student activities proposed by Tang et al. were seen to encourage: problem solving, group co-operative working, and independent learning.
Acknowledgements

Grateful thanks are due to numeracy tutors and students at Coleg Meirion-Dwyfor, Dolgellau, for allowing their work to be observed, and to college managers for allowing and encouraging practitioner research. Any opinions, findings, conclusions or recommendations are those of the author and do not necessarily reflect the views of Coleg Meirion-Dwyfor.

References


This paper concerns the use of prepared dialogue scenes involving mathematics with groups of adult learners. The study is intended to consider how we might characterise discussion following the reading of scenes of dialogue. This paper will report on early, exploratory data collected when investigating the use of scenes of dialogue with adult numeracy learners. One scene is used with two classes of adult numeracy learners. The information collected is assisting in the clarification of the issues of concern and the final decision on the scenes to be used in the main study. One aspect considered is the extent to which reading out the parts develops engagement differently to reading internally. Another concern is the way in which the text may be seen as ‘leading’. Finally, issues of authority are raised which have a potential to constrain the response to the activities.

Key words: dialogue, scenes, discussion, adult, numeracy, exploratory data

Introduction
The study concerns the use of prepared dialogue scenes involving mathematics with groups of adult learners. It is intended to answer the following questions.

What sort of interactions develop using the dialogue scenes? What sort of mathematical discussion is observed?

The idea for this work came from two broad areas, one of which concerns learner-learner interactions and the other concerns the use of participants in reading out the words of others.

A few years ago, I was part of a project in which discussion of mathematical concepts by learners was a key part of the learning intervention. What interested me was that learner-learner interactions were at times rather minimal. A search around learner interactions in the literature produced more teacher-learner interactions than learner-learner. Indeed most of these were concerned with school learners rather than adults, the area which was of most interest to me.

A second influence for me began in an observation that I made when attending a research seminar at ALM. I had noted that one researcher asked participants to read out the parts of dialogue that were collected in the course of the research. I noted that this approach appeared to produce more engagement from the audience than a traditional presentation. From this, I started to use this approach in my teacher training by asking participants to read out loud dialogue (and at times narrator aspects) when investigating various literature.

In this paper, I discuss some exploratory data that has been collected in order clarify and refine the activities which are studied in this research. The interpretation of this data suggests particular lines of enquiry in relation to the scenes that are used and of ways of analysing the data. In particular, issues of authority are raised.

Discussion and collaboration
While it has been recognised for some time that drama may provide a useful learning experience in the learning of mathematics (e.g., Hoyles, 1985), this is arguably a seldom seen aspect either in schools or for adults. Following the work of Vygotsky (e.g., see Vygotsky, 1986) the link between
language and learning has been noted and explored by many writers. A number of authors have argued that discussion in mathematics is a significant part of learning. Nevertheless, although some aspects of ‘effective practice’ are beginning to emerge (see Coben et al., 2007) it is far from clear what type of activities are ‘winners’ in the numeracy classroom.

**A scene about reverse percentages**

This scene was developed as part of a CPD package for teachers along with associated training resources (Swan, 2007). The scene is used here to illustrate what may be achieved although it is not clear to what extent the content is the most appropriate for the target group of this study. The discussion of such ‘reverse percentage’ problems will prove difficult to many participant learners. Prior to the scene starting some background information is provided and a question linked to this. This set up information provides the main task that will be looked at throughout this paper.

**The task**

In January, fares went up by 20%.
In August, they went down by 20%.
Sue claims that:
“The fares are now back to what they were before the January increase”
Do you agree?
If not, what has she done wrong?

Figure 1: Rail prices task (from Swan 2007)

**The scene**

The scene involves a discussion of the situation intended to outline a common issue that occurs with such problems.

Harriet: that’s wrong, because … they went up by 20%, say you had £100 that’s 5, no 10.
Andy: yes, £10 so its 90 quid, no 20% so that’s £80. 20% of 100 is 80, … no, 20.
Harriet: five twenties are in a hundred.
Dan: say the fare was 100 and it went up by 20%, that’s 120.
Sara: then it went back down, so that’s the same.
Harriet: no, because 20% of £120 is more than 20% of £100. It will go down by more so it will be less. Are you with me?
Andy: Would it go down by more?
Harriet: Yes because 20% of 120 is more than 20% of 100.
Andy: What is 20% of 120?
Dan: 96…
Harriet: It will go down more so it will be less than 100.
Dan: it will go down to 96.
(Swan, 2007)

**Using the task and scene**

This paper discusses the use of the rail price task with four groups of learners. Two of the groups read the scene out loud, one group is given the scene to read and discuss (without the instruction to read out loud) and the last group were given the task without the scene. The groups were in two classes of adult numeracy learners at an adult centre of a metropolitan further education college studying for a NQF Level 1 award.

**Group A**

After reading out the scene, the following discussion took place.

Annie: Did anyone understand that, because I didn’t understand that at all

Ben: It’s a discussion about the 20% and whether it’s more or less

Caron: In January it went up by 20%

Annie: So it went up to 120

Caron: Then in August it goes down 20%

Annie: So 20% of 120 is ... 24 pounds isn’t it?

Diana: Yes

Caron: Yes

Annie: So it won’t be the same

Caron: So we don’t agree

Annie: No

At approximately 45 seconds the group appear to have come to the conclusion expected of the text – the ‘correct’ answer. But then the discussion continues in a more interesting manner for another minute.

Caron: That discussion doesn’t make sense to me

Annie: What they’re saying is in the beginning it went up 20%

Caron: How much was the original price?

Annie: Let’s say it was 100 pounds originally. It went up by 20% that makes it 120. Now it’s gone back down to 20%

Ben: That makes it 100

Annie: No ... it’ll be less

Caron: It will be less because it goes to 96

Annie: So... you still get ripped off whichever way

And so despite having concluded that Sue was wrong, the group express some doubts and concerns. They use the text to rehearse the answer once more, and again arrive at the intended response, but one may be left with the feeling that the group accepts the end point rather than really believing it.

A discussion between the researcher and learners followed concerning the activity. An interesting comment was made about the text “it was confusing ... if it was written down then I could understand it better”. Given that the scene was written down, this statement was queried and the learner responded that they would have found it easier to understand a clearly set out calculation more than a discursive scene. “There’s too much dialogue” one expressed.
The next three groups undertook their different tasks simultaneously. Groups B took the parts and read out loud the scene, Group C were asked to read and discuss the task and scene. Finally, Group D were given the task without the scene.

**Group B**

In this group, there were three bilingual learners and one native English speaker. The latter chose to play the smallest part (Sara) and then proceeded to dominate the post scene discussion. The discussion is dominated by one learner with a few, sometimes indistinct, comments from others (ALMost a monologue although the other participants are involved in a number of nonverbal as well as some audible utterances).

Elaine: Right... so...
Felly: We just read once? Yeah?
Elaine: Right, ok, so now we need to figure it out.
Harriet said that’s wrong, that Sue is wrong.
They went up by twenty per cent. Say you had one hundred, that’s five... no... ten. Anyway, [reads out script again]

Now if you take off twenty per cent of one hundred and twenty then you are taking off more than twenty per cent of one hundred. That’s what Dan was trying to say...[interlude involving mobile phone]

So do twenty times one hundred and twenty ... did you do twenty times one hundred and twenty? Do twenty times one hundred and twenty ... divide it by... divide by one hundred
Oh you’ve done it... twenty four.
Ok twenty four... so that will be ninety six. That will be ninety six pounds they’re left over with.
And if you do twenty per cent of one hundred...do twenty percent of one hundred. Do it again? Why are you doing twenty four? Do twenty percent of one hundred. Thanks
So twenty pounds... i want to note these down or i’ll get confused.

[it’s one hundred and twenty yes?]  
One hundred and twenty equals to ninety six and one hundred equals to twenty right? Well eighty basically if you are taking it away.
So which one are you losing more money on? Basically. Not losing ... but you know what i mean?

[Researcher: did you decide whether ... if Sue is correct or not? Or are you not sure yet?]  
Elaine: Dan is correct
Researcher: Dan is correct?
Elaine: Dan says its more so Sue is wrong.
Researcher: Sue is wrong?
Elaine: Yes. Because twenty per cent of one hundred and twenty pounds is ninety six. Well you know what I mean, really its twenty four, that’s what I was trying to do and that’s twenty.
This response to the reading of the scene has some interesting features. The most obvious is the (ALMost) monologue nature of this by the individual who took the smallest role. Nevertheless, we see the same rehearsing of the elements within the scene, the same calculations being run through by the learner, and the same final answer.

Group C

This was a group of three learners, two of which are non-native speakers of English. They read to themselves and start the conversation.

Gabrielle: I think that Harriet is right. Twenty percent of one hundred and twenty is more than one hundred pounds. Twenty percent of one hundred is ... um ... twenty four pounds off one hundred and twenty pounds.

What’s twenty percent of twenty? Twenty percent of twenty is twenty four pounds.

It would be twenty four pounds ... plus ... yeah that

Ismael: That’s not right. That’s wrong.

Gabrielle: Why?

Ismael: Because twenty percent off ... twenty percent off ... um ... twenty percent off one hundred and twenty ... is less than ... Harriet is right.

Gabrielle: Harriet is right. Use one hundred and twenty pounds. Twenty percent of one hundred would be twenty pounds. Then twenty percent of twenty pounds would be four pounds. That’s twenty four pounds off.

Researcher: So is Sue correct or not

Ismael: She is not.

In this somewhat shorter interchange, we see again the rehearsal of the calculations within the scene – at least by Gabrielle. It is interesting to note that Ismael, first expresses one view and then following a few calculations changes his view. This is, perhaps, a sign that he did not really engage with the text until the discussion.

Group D

This is a group of another three learners but also involves the teacher who takes a significant role in the discussion. In particular, the teacher reads out the situation and task before the conversation starts.

Keith: It must be right

Teacher: Do you agree or not?

Keith: I would say yes. Because if it’s gone up ... if it’s gone up in January... January, February, March, April, May, June, July, August...

And then its gone down again. So it must be back to stage one.

Joan: I don’t agree

Teacher: Do you agree?

Joan: No.

Teacher: OK Tell us why?

Joan: Because 10% of something is always different (The teacher says ‘exactly’ here)

Joan: 10% of £100 will be ten pounds, 10% of £200 will be twenty.
So it’s different.
So, if the fare went up 20%, say the price was £4 then it will be, ummm 20% of £4 ... but then ...
Teacher: 20% of £100 will be £120. That is going up? Yes?
Joan: Yes
Teacher: But then 20% of £120 is ...
Joan: It’s different
Keith: Yeah, but what they are saying is that the fares went up 20% in January, then it comes down 20% in August. It doesn’t say ... they’re not saying over a hundred pounds or two hundred pounds.
Joan: Well that’s an example.
Teacher: It says ‘what do you think?’
Joan: But if it goes up ... if it goes up ...
Liv: Nothing has changed.
Teacher: You think that the price is going to be the same. (to another) Do you think it would be the same?
Liv: Yes, because it goes up ...then comes down...
Teacher: You (to Keith) think it will be the same. You (to Joan) think it’s going to change?
Keith: Well how can it change? If you give the 20% and then take the 20% away in August then the original price must remain.
Joan: 20% is not always the same. It depends upon the amount you have.
Keith: Yes, but there is no amount on it.
Joan: I know
Keith: There is no amount on it.
Joan: I know ... but 20% is not always the same. 20% of one hundred pounds is different to 20% of two hundred pounds.
Keith: I didn’t see it. I don’t understand ... maybe I didn’t see it right.
Researcher: So giving yourself ... what if it was one hundred pounds, if so, what would it go up to?
Joan: One hundred and twenty pounds.
Research: Right...
Keith: So if we take off 20% it would go to one hundred
Researcher: What ... what’s twenty per cent of one hundred and twenty pounds?
Keith: Twenty per cent of one hundred and twenty pounds is ...
Teacher: Remember how we calculate ten per cent.
Liv: it’s not the same
Joan: it’s not the same
Liv: Because before it was one hundred and now you take one hundred and twenty
Joan: yeah, that’s what I mean it’s not the same
Keith: So the price goes down to 96 now
Liv: yes
Keith: and by going up it goes to one hundred and twenty. Is that what you were saying?

This interchange is somewhat longer than the earlier ones. There are two learners taking opposite positions with the teacher intervening at points. It is interesting to note that Joan introduces the example of the £100 – not given in the task but introduced in the scene which they were not given – although appears to think of £4 as a more reasonable value for a ticket. Keith finds it difficult to accept the values presented. The text only mentions 20% without values and Keith doubts the validity of any extra information “Yeah, but what they are saying is that the fares went up 20% in January, then it comes down 20% in August. It doesn’t say ... they’re not saying over a hundred pounds or two hundred pounds.” After some interchange – involving the researcher - Keith does appear to accept the intended calculation.

Discussion

It is probably important to note the leading nature of the discussion scene. The calculations suggested by the scene do end by drawing attention to the 96 value. This means that in the groups A-C the text points towards the 'correct' answer that is wanted. This may be the reason why groups A and the learner in Group B fairly quickly come to their response to the task. Yet, at least in the case of group A, there is still some uncertainty about this. It is interesting that there are two individuals in Group C who’s first reaction is to disagree with the intended response although a fairly swift interchange with the example and the text changes this for one of them. This raises the issue of whether this learner had noted the examples in the text.

In group D where there was no scene – just the original task – the learners had to rely on their own discussions and the interventions by the teacher (and to some extent the researcher).

Another issue concerns how authority plays in the decision making of the participants. It is interesting to note that none of Groups A-C challenged the idea of any particular ticket price being used in the way that Keith in Group D did. This suggests that there may be an issue of authority at work here. Keith is able to challenge the notion of choosing a particular value because there is no mention of such values in their text. The participants in Groups A-C do not challenge the ideas presented by the scene.

The exploratory data does suggest looking in some particular directions. The extent to which the scene leads towards a particular answer and the authority of the text needs some consideration. This suggests alternative research tools such as writing some alternative scenes in which the alternative premise is left as the final response (rather than the 96).

There was some evidence that learners who read the scene out loud were more engaged with the text and ready to respond.

Conclusion

This paper has used some empirical data to discuss some of the issues raised by the research proposal. The exploratory data provides some useful practical information about the content of the text and the responses following a range of tasks. The data also suggests that issues of authority are significant and that learners’ responses are contingent upon their understanding of the text, task and the individuals involved in the tasks. These reflections suggest that the interpretation of discussions of scenes will require a framework that involves contextual factors.

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COUNTING OR CARING: EXAMINING A NURSING AIDE’S THIRD EYE USING
BOURDIEU’S CONCEPT OF HABITUS *

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Abstract
This article is derived from analysis of observations and an interview with, Anita, a nursing aide, who was followed in her work in a semi-emergency unit in Sweden. Based on an analysis of this information, it is suggested that the process of going from school to a workplace can be viewed as a transition between different mathematical activities, which involve and require learning. Although it is easy to see transitions occurring between different contexts, they may also occur within the boundaries of a workplace and be connected to critical moments in the execution of work tasks. Adopting a social critical perspective, this article initiates a discussion about the transitions between potentially mathematical activities in work and how the values given to these different activities can be understood. It is further suggested there is difficulty in recognizing some activities in work, because, often, they are over-shadowed by other competences and components needed in work, such as caring.

Key words: workplace mathematics; capital; habitus; transition; nursing aide

Introduction
Adults’ mathematics learning takes place in a wide range of settings throughout life. Notwithstanding this, many of us have school mathematics as a reference for learning mathematics. The focus on mathematics within the context of schooling may make it difficult for one to detect and understand what mathematics may become in other spheres in life. In this article, I investigate potentially mathematical activities in a nursing aide’s work using Bourdieu’s (1992, 2000) concept of habitus, while taking into account that my previous experience as a vocational teacher of mathematics has influenced what I am able to see and understand.

The feeling of having a limited understanding of mathematics in workplaces, and a curiosity to learn more about this has been the driving force for my work. I became aware of my limited understanding of workplace mathematics when I worked as a mathematics teacher in vocational education and prepared tasks on intravenous drips. The students were to become nursing aides and I produced tasks on different drip speed, drip size, and concentrations of active substances. Having received help from a nurse, the tasks seemed realistic, with proper substances and so on. I was very happy with the tasks, until the students reacted with stress, anxiety and fear. Almost crying, they asked me if tasks such as these were really the responsibility of nursing aides’. I tried to calm them down and apologized several times for giving them inappropriate tasks, but I was left with a feeling of how limited I was in understanding the practice they were heading for.

Furthermore, I became more and more in doubt about school mathematics as being useful outside of school, although its relevance is often justified in this way (Dowling, 2005). The differences between mathematics taught in schools compared to mathematics in workplaces may have consequences for how adults’ competence in workplaces is regarded (Gustafsson & Mouwitz, 2008, 68). Habitus is at its most basic definition human’s dispositions to act in the social world.

ALM

68
see also Björklund Boistrup & Gustafsson, in press). In addition, Wake (2013) suggests that workers sometimes do not even consider that what they are doing is related to mathematics, but rather to a goal-directed, workplace activity.

It is obvious that the use of mathematics in the work of nursing aides is situated in a certain context, influenced by many factors, such as the workplace organization, the well-being of patients, and possibly also the relationships that humans have with mathematics. Trying not to diminish these important aspects of the work situation, while remaining focused on the potentially mathematical activities, my aim is to consider how the transitions between different potentially mathematical activities can be understood through Bourdieu’s, concepts of habitus and capital (Bourdieu, 1992, 1996, 2000, 2004). In so doing, I ventured to investigate if it is possible to do two things: (1) capture the mathematical knowledge frequently labelled as tacit, and (2) identify what may be gained and lost in different transitions humans make when moving between contexts.

Mathematics in work

Activities involving mathematics in workplaces are not easily described, as they are often connected to the use of the technology and routines (e.g. FitzSimons, 2013; Hoyles, Noss, Kent, & Bakker, 2010; Jorgensen Zevenbergen, 2010; Wake & Williams, 2007; Wedege, 2000, 2004a). Consequently, the mathematics in these activities has been discussed as being “black-boxed”, both socially and technically (Wake & Williams, 2007). By this, they mean that the use of technology and automation has created a distinct genre of mathematics. With the increased use of technology, mathematics becomes more implicit, and hence technically black-boxed. Moreover, different groups and staff members in the workplace have different norms and rules, and this division of labour creates a social black-boxing. The notion of black-box derives from Latour (1993), and his networks of people, objects and ideas seemingly function as a whole, in which certain parts become invisible. Mathematics in work has also been labelled as tacit, with the possibilities for making it explicit considered difficult although not impossible (FitzSimons, 2002). These difficulties in identifying the mathematics may lead to a gap between adult learners’ perspectives on learning mathematics, compared to those of education policy makers and employers (Evans, Wedege, & Yasukawa, 2013). FitzSimons (in press) found that curriculum and vocational numeracy education mostly was about content knowledge, and hence based on narrow assumption of what vocational students may need. Instead if perceiving simple operations as sufficient for those students, FitzSimons further suggests that there is a need for a more holistic approach. With this approach not only the conceptual understanding is considered but also the creativity required in the workplace, and she notes:

However, in the workplace, as elsewhere in society, problems are ever-evolving and the development of new knowledge – locally new if not universally new – is an essential requirement for completing the task at hand within constraints of time and/or money, so workers often find themselves in ‘unthinkable’ territory, creating new knowledge. (FitzSimons, in press, p.1)

Hence, there is a complexity surrounding the mathematics involved in workplace activities. Another complexity is that researchers use both mathematics and numeracy to describe activities in the workplace. In this article I avoid this sometimes value-based distinction. Instead I use the term mathematics in a wide sense when focusing on the transitions between different potentially-mathematical activities of nursing aides.

Mathematics for nurses

Similar to the case with other workplaces, previous studies have shown that the mathematics used by nurses is strongly interwoven with the practice of nursing, its routines and other important considerations (Cohen, 2010; Pozzi, Noss, & Hoyles 1998). Consequently, there may be differences for nurses in what they learnt in their formal education and what they actually do. For example, Pozzi,
et al. (1998) described how nurses considered that “knowing the drug” was a better safeguard against errors, than using an algorithmic calculation suggested in teaching text for nurses. The safety of patients is crucial in this kind of work, and mistakes in an emergency unit can have serious and fatal consequences (Coben, 2010). In such a context, numeracy is about being confident, competent, and comfortable in deciding whether to use mathematics and how (Coben, 2010).

Although the work of nurses has some similarities to that of a nursing aide, the fact that nursing aides do not have medical responsibility indicates that there are also some differences. For example, there are differences in the social and historical conditions around these professions and the division of labour involved. These kinds of differences are important because they may have an impact on Williams and Wake’s (2007) social black-boxing. Evertsson (1995) claims that the history of the profession of nursing aides is, to a large extent, neglected and overshadowed by a focus on nurses. Caring institutions and hospitals reflect the power structures in society and in the educational system, with regard to class and gender, for example (Evertsson, 1995).

A sociomathematical approach and Bourdieu’s concepts of habitus

In the sociomathematical approach (Wedege, 2004b), mathematics is related to more than mathematics as an academic discipline, and also it takes into account mathematics as a social phenomenon and school subject (Wedege, 2004b). Examples of sociomathematical research interests are peoples’ relation to mathematics, and the function of mathematics education in society (Wedege, 2004b). Both humans and general structures are in focus in this approach, and in particular the interplay between *general* structures and *subjective* meaning is highlighted. The tension between humans and societal structures is captured by Wedege (2004b, 2010), who makes a distinction between *demands* made on humans, for example in school or as requirements for getting a job, and the mathematics *developed* by humans in certain practices.

Following Wedege’s (2004b, 2010) suggestion, I consider general structures of the workplace as having certain mathematical demands on nursing aides, but also that the nursing aides themselves develop their own mathematical competence. This individual creativity may be crucial when facing difficult tasks or demanding tasks (FitzSimons, in press). By this, I do not mean that official demands made on workers are necessarily more or less important than the developed competences, rather they are complementary. One example of a study accounting for both the demanded mathematics and what is developed by workers, could be given by the findings of Pozzi, et al. (1998). They compare the common algorithmic procedures and formulas suggested for drug administration in teaching texts for nurses, with what nurses actually do. The formal and assumed calculations in the teaching texts for nurses are examples of the demanded mathematics. The authors further observed how the nurses instead used the specific concentration and more for each drug as the basis for their calculations. One example of such a calculation was ‘doubling it and put an extra zero’, which was the calculation used for a certain drug (Pozzi, et al., 1998, p.110).

This way of finding alternative arithmetic methods by “knowing the drug”, as described by Pozzi, et al. was also the safeguard against errors. This provides an illustration of the developed mathematics. In this article my focus is the transition between the demanded and the developed mathematics. The urge to capture the knowing to be found in those transitions has also guided my theoretical choice. In the framework of Bourdieu the mutual interplay between humans and society is captured in the concepts of habitus. Habitus is a system of dispositions, defined by Bourdieu (1992) as:

The conditions associated with a particular class of conditions of existence produce habitus, systems of durable, transposable dispositions, structured structures predisposed to function as structuring structures, that is, as principles which generate and organize practices and representations that can be objectively adapted to their outcomes without presupposing a conscious aiming at ends or an express mastery of the
operations necessary in order to attain them. Objectively ‘regulated’ and ‘regular’ without being in any way the product of obedience to rules, they can be collectively orchestrated without being the product of the organizing action of a conductor. (p. 53)

Thus, the habitus is to be found firstly in the conditions of existence, which commit humans to the social structures, sometimes without objective and conscious goal orientation. Moreover, habitus is a complex system of dispositions for acting in the social world, transposable but at the same time durable and carrying collective features. In Wedege’s (1999) research, a woman’s habitus was shown to have influenced her dispositions towards mathematics, and her dispositions for seeing herself as mathematically competent. The woman was born in a saddler’s family in Denmark at the beginning of the previous century, and failed in school mathematics. This outcome was seen as normal for a girl at this time. Later success in mathematics and involvement in mathematics at work and during leisure time, could not completely overcome how the woman perceived herself with regard to mathematics. With this case Wedge provides an example of the complexity of habitus carrying features of both class and gender, not as stereotypical labels but rather inscribed in the person as natural features in a specific context. It is also clear in this woman’s case how habitus is durable yet transposable or changeable, as she never fully ceased to see her failures in mathematics. If mathematics is the foundation of the sociomathematical approach (Wedege; 2004b, 2010), then, as discussed in the next section, Bourdieu’s different capitals act as the link between humans beings and social structures in a framework via habitus.

Bourdieu’s concepts of capital in relation to habitus

Bourdieu (1992, 1996, 2000, 2004), described different forms of capital, such as economic, cultural, and symbolic and saw them as the link between the individual and the social world. Humans act in the social world to convert one form of capital to another, according to which form is valued in the particular social space (Broady, 1998). Cultural capital has to do with education, as a consideration of both upbringing and the educational system. How the cultural capital is valued may differ according to different cultures and school systems. In Bourdieu’s work, the French system was in focus, and so his discussion of the impact of cultural capital may not be valid in another context or at different points in time. However, as Williams (2012) notes that this kind of capital has an exchange value. By this, he means that a particular mark or degree in school mathematics becomes an entrance ticket to certain jobs or further education. Consequently, cultural capital can be considered the formal education for nursing aides in mathematics. Social capital is the social relations or contacts and can also give humans a kind of interest rate on their educational capital. The symbolic capital refers to what is valued in a certain social space. This kind of capital can grow into the body and become part of our habitus, sometimes unconscious and invisible, even to ourselves. For example, when we just know what to do in a given situation, often out an obvious necessity and make use of our embodied symbolic capital (Bourdieu, 2000). Corporal mechanisms and mental schemata in a person’s habitus can even erase the distinction between the physical and the spiritual world (Wacquant, 2004).

In this study, the focus will be on habitus, cultural capital, and symbolic capital. The concepts of Bourdieu have also been used for earlier studies concerning mathematics in work, and were found to be useful tools for the theorization of the world of work, and how mathematical dispositions may promote or hinder workers (Zevenbergen Jorgensen, 2010). The concepts of Bourdieu were in this study useful for understanding the younger workers’ skills, instead of seeing the young workers as having limited numeracy. Zevenbergen Jorgensen found significant differences in habitus, and also how these differences created tensions between old and young workers based on their ways of seeing and enacting numeracy. The younger generations’ habitus were to a larger extent influenced by digital technology, while the older had more manual arithmetic frames of reference.
Bourdieu does not explicitly mention mathematics as a form of capital. In his later work, he did emphasise how there was a shift from Latin to mathematics as a selection tool in the educational system (Williams, 2012). The importance given to mathematics in the education system influences its value. What is considered as important and relevant with regard to mathematics also changes over time as shown by Zevenbergen Jorgensen (2010). Therefore, it is likely that different mathematical activities are valued differently and hence hold various amounts and forms of capital. This is important in a study about nursing aides, where the hierarchical workplace organisation as a practical and rational matter, may conceal other power relations (Evertsson, 1995). These relations affect the valuing and attention paid to certain activities. The focus in this article is potentially mathematical activities, and when nursing aide may need to make transitions between these in critical situations.

Transitions

In transitioning from school to work, for example, it is important to recognise the transformation and creation of new relations between knowledge and social activities, and how this could contribute to an understanding of mathematics in the workplace (Wake, 2013). Meaney and Lange (2013) see transitions between contexts as always involving learning, with contexts being defined as systems of knowledge enacted in social practices. The notion of transition could also be seen as a way around the issue of transfer (Beach, 1999). Beach claims that transfer derives from educational psychology and refers to cognitive matters. From a purely cognitive approach, transfer is seen as relatively unproblematic (Evans, 1999). Evans notes that from a situated perspective, transfer instead should be considered impossible. Beach (1999) suggested an alternative stance from a sociocultural viewpoint, namely that of consequential transitions, which means transitions that are reflected upon from a sociocultural perspective. Thus, the social and historical context of the activity is taken into account as well as the artefacts involved. Beach also identifies several forms of transition. In this article, I make use of Beach’s lateral and encompassing transitions. The former occurs when individuals move between contexts such as school and work, and the latter when change occurs within the boundaries of a social activity.

Encompassing transitions I suggest can be related to the moving between the demanded and developed mathematics in the sociomathematical approach. By this I mean that the official ways to handle a work task are related to the demanded mathematics. Workers also develop complementary ways of completing the potentially mathematical tasks. In other words it is likely that workers in general, and nursing aides in particular, need to make transitions between what is demanded and what they develop. I find it important to shed light on the dichotomy between what is demanded and what they develop. For this purpose I have chosen the concept of habitus (Bourdieu,1992, 2000), firstly because of its possibility to grasp the interplay between individuals and structures. Secondly, my reason for choosing habitus and capital is the fact that habitus has a clear corporal component and different capitals can grow into the body. Hence, there is a possibility that the body becomes itself a black box. It is important to try to understand the significance of the bodily understanding when people transition between the demanded mathematics and the developed. This I see as crucial for reducing the gap between adult learners’ perspectives on learning mathematics and those of education policy makers and employers. The incorporation of capitals is also connected to learning. Bourdieu (2000) describes learning as a durable bodily change (see also Wacquant, 2004). Habitus as a theoretical choice calls for methodological explanation and justification.
Methodology

My intention with this small scale case study (Bryman, 2008) is not to produce a truth, but rather to understand and construe the transitions made within the boundaries of a workplace not familiar to me. This is done through my interpretation of the work of Anita (a pseudonym). As a matter of reflexivity (Hammersly & Atkinson, 1995; Malterud, 2001), my lack of previous experience was used as an advantage. What was obvious for a person with Anita’s long experience was not at all evident to me. This made it possible to pinpoint tacit knowing. Anita is a nursing aide, with more than twenty years of experience, both in her home country in Eastern Europe and in Sweden. The empirical part of the study was conducted with inspiration from ethnography (Hammersly & Atkinson, 1995). However, in a study of this format it is not possible to provide the descriptive thickness normally associated with ethnography. In addition, there is the ethical dilemma of construing another person’s habitus. Bourdieu (2000, p. 128) writes: “Even among specialists of the social sciences, there will always be those who will deny the right to objectify another subject and to produce its objective truth.”

Access was facilitated by a research team member having personal contact with a nurse. From this contact we were introduced to a physician, also head of the ward. He gave us permission to enter the ward with a video-camera. On the ward the nursing aide in charge picked a colleague for us to follow. First our intention was to follow the nursing aide in charge, but she wanted, as she said, to give this opportunity to a colleague of hers. This she told us was because the nursing aides were so rarely paid attention. Two video-recorded visits were made in a hospital in Sweden 2012, each lasting for about an hour. These were then transcribed. After an initial analysis, an informal interview was held with Anita. Having in mind that that mathematics in the workplace might be black-boxed, both technically and socially, the topics of the interview were to a large extent introduced by Anita. She talked much about how the profession of nursing aides had developed from formerly being about assisting nurses to nowadays being what she called “its own profession”. This is aligned with Evertsson’s (1995) historical analysis of the profession overshadowed by a focus on nurses.

The interview was tape-recorded and partly transcribed. The sound was of good quality except a short part which was difficult to hear as Anita and I watched the video together. In qualitative research the reliability is often referred to as dependability (Bryman, 2008), and the data loss when we watched the video was compensated by what was gained by Anita explaining what had happened during the observation. As the interview was conducted a couple of months after the observation, looking at the video were also crucial for refreshing our memory. Another way of ensuring dependability was to look at the video together with researchers in the team before conducting the interview. From the individual case of Anita alone it is not possible to make any generalisations, frequently labelled as transferability in qualitative research (Bryman, 2008; Malterud, 2001). With the concepts of Bourdieu it is, however, possible to connect the individual case to the social structures in society. This is aligned with the methodology proposed by Salling Olesen (2012). He notes that workers or groups of workers invest their body and soul, knowledge and commitment when entering a workplace, but they do so against the background of a life history that is a part of a wider societal context (Salling Olesen, 2008, 2012). About, using an individual case Salling Olesen (2012) claims:

It is to use this individual case to theorize learning as an aspect of the social practice, a moment in a subjective life history embedded in the symbolic and social environment, and contributing to societal processes of reproduction as well as innovations. (p. 5)

This methodological view – taking the connection between individuals and society into account – is aligned with the framework of Bourdieu. The possibility for including the bodily manifestation of habitus was facilitated by the use of video and the opportunity to watch it several times. Thereafter, it was possible to raise questions about issues not understandable by the observation alone. My intention with carrying out firstly observations and then the interview was to grasp the complexity of habitus, in which my own habitus, with its own connection to mathematics education, was also considered.

Therefore, I have tried to be attentive to and reflect on my own relation to mathematics, and to school. School mathematics will have influenced our perceptions of mathematics; both regarding what should be included as mathematics, and also as a personal relation and experience of it. Thus, our understanding of mathematics and emotions related to it are likely to be connected to the school mathematics incorporated into our habitus (Lundin, 2008).

The analysis makes use of the sociomathematical concepts of demanded and developed mathematics. By this, I refer to the demanded mathematics as what is required in this kind of work, in relation to the mathematical activities that are developed in work. I start with a description of the observation, then I analyse what could be seen as demanded. Then the interview with Anita is described. The analysis is supported by the concepts of habitus and capital, and the notion transition.

Visiting Anita at work

The first meeting with Anita was made at the semi-emergency unit where she works. To blend in with the environment, those of us in the research team had to wear the same white clothes as the staff. I followed and observed Anita, while a research colleague was video-recording. This made it possible for me to ask questions in order to understand what was going on, which had to be done in a manner that did not disturb the work.

During this first visit, Anita was monitoring patients or “tag kontroller” (which means “took controls” in English) on the patients, as said it is described on the ward. The patients were connected to digital supervision monitors. Controls, she told us, were made every four hours and included collection of the physiological parameters: respiratory rate, heart rate, blood pressure, temperature, urine output, and alertness. Different values of these parameters were given colours and scores on a chart. The chart (see Figure 1) was coloured outwards, from green in the middle (0), then yellow (1), orange (2), and, finally, red (3) at either end. The red columns indicated the most critical values. A total score ≥ 5 required immediate attentions from a doctor and the emergency team. There is also an additional text in the chart, which says that deep concerns about a patient or acute deterioration are other reasons for contacting the doctor and the emergency team.

During the control of one patient, a doctor was summoned to take a blood sample for a blood gas analysis. The blood gases are connected to several of the physiological parameters in the chart, but give another kind of description of the patient’s condition. The doctor arrived quickly and took a blood sample and disappeared after a few minutes. Anita then took the sample to a digital laboratory where the analysis was performed and automatically transferred onto digital patient records. In the digital laboratory, Anita said: "This will take a minute, but one minute is a long time so I can do other things instead, so I will not wait for the test results". After this, Anita returned to other patients to encourage, console and chat, while further controls were made. None of the controls were apparent to an observer, but these were explained by Anita afterwards. The observation clearly noted that Anita was devoted to caring and comforting.

Figure 1. The coloured chart, with normal and critical values.

After having collected the values from the patients Anita took out a piece of scrap paper from her pocket (Figure 2) and typed in values in the patients’ digital hospital record. The scrap paper shows the data collected from two patients.

Figure 2. Anita’s scrap paper showing one patient’s values are circled.

While these routines appear to be very structured, and even have numerical and mathematical content, the nursing aides on the ward did not seem to have these perceptions. On several occasions, they said "you know" or "you feel" or even "it's the third eye". We were told, during the observation, that the “third eye” was an important characteristic of the nursing aides’ skills. During the interview, Anita told me more about the third eye. She said that “everybody can have it, but not from the beginning,” suggesting that it develops from experience. There also seemed to be a tension between the rational chart, based on numeric values, and the more elusive feeling of just knowing. This feeling is discussed later in more detail.

While the observation clearly noted that Anita was devoted to caring and comforting, it was not noted that she also, for instance, counted breaths minute. This became clear during the interview, when she gave an example of how she is counting breaths. It was also visible on her paper, which she
showed us after she had taken the controls. The respiratory rate or breaths per minute is noted as “24 A” on the paper in Figure 2. Otherwise, the explicit use of numerical values seemed absent, as these were probably not very interesting for the patients. Only once did Anita explicitly talk about values, and it was to convince a patient about her recovery: "Your values are much better today than they were yesterday, so much better".

**Analysis of the demands**

After having visited Anita at work, and also interviewing her, it was obvious that taking the controls on the patients was one of her regular and important work tasks. The coloured chart with its columns and scores can be considered as part of the explicit and demanded mathematics. So, from the sociomathematical viewpoint, handling the chart can be seen as one mathematical requirement for nursing aides. The coloured chart was used for facilitating the judgment of a patient’s condition, and to identify patients at risk of catastrophic deterioration. In order to take the different parameters measured into account, these are given different scores, and a total score of five or more is defined as a risk, which needs attention from a doctor. Understood in mathematical terms, nursing aides need skills in:

- Reading a chart
- Understanding distribution of values, facilitated by colours
- Comparing values
- Adding values

This could be considered as basic mathematics by for example a mathematics teacher. By giving the values different scores which need to be added, it can be reduced to simple calculations. This work can be considered as needing only a limited amount of cultural capital, or education.

**The interview with Anita makes clear that “17 is not always 17”**

When I met Anita we had a conversation about working as a nursing aide. With her many years of experience, also in different countries, she had a lot to tell. Due to her experience and by having a mother tongue other than Swedish she also volunteers as an interpreter on the ward. This she told me has a certain value for doctors and of course for patients, in a semi-emergency unit where quick decisions are crucial. Over and above this she talked about her presence as having a certain influence on immigrant patients because they felt confident with her. She had difficulties in explaining this but phrased it as: “She is like us”. The conversation also covered much about workplace education but did not turn to mathematics, which I wanted to understand more about it in relation to this workplace. (The Swedish original transcript is given in brackets)

**Maria:** I was thinking about this technical, technical education, and such. All the things you do with the tests, reading the monitors, using the charts, and so on. To me it seems somehow like mathematics. (Jag tänkte på det där, det där med teknisk utbildung och sånt. Alla saker du gör med tester, avläsa monitorer, använda tabeller och sånt. För mig verkar det på något sätt som matematik.)

**Anita:** Yes, it is! (Ja, det är det!)

**Maria:** But I don’t know… if I think about school… how could school provide this education? ( Men jag vet inte… om jag tänker på skolan… hur skulle skolan kunna utbilda för detta?)

**Anita:** Ah, okay you mean like that … one should have basic mathematical skills, absolutely, like percentages, one should have the basic knowledge but nobody will ask about sine and cosine, nobody will … but I have learnt it and everybody has but for our profession I mean that we need the basic stuff. It has to do with percentages, addition and subtraction. That is necessary but I take for granted that everybody knows that. (Ah, okej, du menar så… man ska ha, man ska ha grundläggande matematiska

It worth noting that Anita considered trigonometry as something that everybody has learnt. As I perceived that there was something, from my own school mathematical habitus “vaguely mathematical” in her work, I tried to find out more about it:

_Maria_: It is difficult to explain, but all the judgments you make and all the priorities you have, and the fact that you do it differently...like when you read from the monitor and taking the pulse manually. (Det är svårt att förklara men alla bedömningar du gör och alla prioriteringar, och just det att du gör det annorlunda...till exempel når du avläste monitorn och tog pulsen samtidigt.) _Anita_: I think it is normal and obvious. Such thing cannot be learnt in school. (Jag tycker att det är normalt och självklart. Sånt kan man inte lära sig i skolan.)

_Maria_: For you it is obvious but for me coming from school it is very interesting. (För dig är det självklart men för mig som kommer från skolan är det väldigt intressant.)

_Anita_: For example I count the respiratory rate. All people breathe differently and when they are ill even more differently. Such things you don’t learn ... so I count the respiratory rate of one patient and get 17 ... let’s say 17 but I have learnt that this patient has 17 because s/he is ill. I can judge that, I can judge that the other has 17 because s/he really doesn’t feel well, yet another has 17 because s/he is hyperventilating, and that one has 17 by pretending in order to get more morphine than s/he has already got, and that one has 17 because... (Till exempel så räknar jag andningsfrekvensen. Alla människor andas olika och när de är sjuka ännu mer annorlunda. Såna saker lär du inte dig i skolan...så jag räknar andningsfrekvensen hos en patient och får 17, säg 17, men jag har lärt mig att hon har 17 därför att hon är sjuk. Jag kan avgöra det. Jag kan avgöra att en annan har 17 därför att han eller hon verkligen inte mår bra, och en annan har 17 för att han eller hon hyperventilerar, och den har 17 för att den låtsas för att få mer morfin än den redan har fått, och den har 17 för att...)

_Maria_: I think it is really interesting that 17 can mean so many things compared to school, where it means 17. (Jag tycker verkligen att det är intressant att 17 kan betyda så olika för i skolan betyder det ju 17.)

_Anita_: This is something completely different, and everybody here would have told you exactly the same. (Detta är något helt annat och vem du än skulle fråga så skulle du få samma svar.)

Being a bit confused by 17 not being 17, I return to this issue again:

_Maria_: This I find really interesting ... even this you are saying about the respiratory rate. Because you mean that we have different lungs and you cannot know how much oxygen a breath contains neither measure the volume of the lungs, so this is replaced by a feeling...that you feel what 17 means in this case. (Det här är ju verkligen intressant...även detta du säger med andningsfrekvensen. För att du menar att vi har olika lungor och du kan inte veta hur mycket syre varje andetag innehåller eller mäta lungorns volym, så detta ersätter du med en känsla, att du ser och känner vad som menas med 17 för just den patienten.)

_Anita_: Yes, it is the same as with the woman I just looked after. On our ward we have a machine that is connected to the patient and from that I have learnt to read how much air that is getting into the lungs. (Ja, det är samma som med den kvinnan jag nyss tittade till. På vår avdelning har vi en maskin som kopplas till patienten och där vi har lärt oss att avläsa hur mycket luft som kommer in i lungorna.)

_Maria_: Aha... (Aha...)

_Anita_: Such things are learnt here in work (Såna saker lär man sig här på arbetet.)

_Maria_: This machine...now I must try to understand...this machine can measure what you have a feel for? (Alltså den här maskinen...nu måste jag försöka förstå...den här maskinen mäter det du känner på dig?)
Anita: Yes, something like that. (Ja, någonting sånt.)

Maria: It is actually quite... (Det är ju faktiskt ganska…)

Anita: Yes, something like that... (Ja, någonting sånt...)

This extract of the interview with Anita suggests that there is more going on than merely the collection of the patients’ values and comparison of these with the values on the coloured chart. Instead, Anita has developed an experienced-based abstract feeling for the patients’ condition – a third eye. As an example of this feeling she takes 17 breaths per minute to illustrate what differences in meaning an isolated and discrete figure can have.

Analysis of the developed mathematics and the “third eye”

Taking the respiratory rate as an example, the chart gives concrete and decontextualized values. This I suggest is in contrast to what Anita says about counting to 17, as an abstract value related to many other parameters as, for example, the depth of each breath, or about a patient’s simulation of illness. When the rate of breaths is connected to, for example, the volume of lungs, the depth and the pressure, it is closer to a function of oxygen saturation of the blood than to discrete and concrete values. Anita’s explanation of counting to 17 does not explicitly refer to mathematics, although many different parameters and the relations between them are taken into account. Instead I suggest that it refers to “the feeling” the nursing aides have, which they also label as “the third eye”.

I interpret the “third eye” as what is developed from a sociomathematical perspective. So, having the third eye could be seen as a symbolic and also embodied capital shared by competent nursing aides, a disposition to understand the patients’ conditions and act accordingly. In critical situations there is no time for reasoning. Instead, having the habitus of a skilled nursing aide involves the corporal or sensual component of the “third eye”, allowing for judgements and decisions. Furthermore, relating the respiratory rate to many different parameters requires a higher level of abstraction than just calculating a total sum of 5. By this I do not mean that one form of knowing is preferable to the other, but rather how both forms of knowledge can be seen as complementary.

What is, instead, interesting to note is the transition between the explicitly demanded mathematics on the chart and the developed but elusive feeling. This transition I suggest requires a habitus with the “third eye,” but also the demanded mathematics as cultural capital, and hence formal education. Moreover, it requires confidence and some power to, if needed, go against the coloured chart. The mathematics demanded in this case is rather basic, but facilitates the workplace routines and probably increases patient security. However, it seems crucial to be competent, confident, and comfortable about how to and when to use mathematics, as Coben (2010) suggests in her definition of numeracy for nurses. I suggest that the skill of making these transitions should be paid more attention, and also the connection to reasoning and to being critical in general.

Discussion

Although mathematics in work is different from school, it could be relevant to consider the similarities between the mathematics demanded in work, such as the coloured chart, and school mathematics. In doing so it is also necessary to pay attention to the transitions that have to be made in critical situations. An example of this is when Anita compared her capacity, or her “third eye,” to a number on the chart. Therefore, it would be a mistake to consider the explicit demanded mathematics as what is needed purely in terms of school mathematics. In connection to this it is also worth mentioning the limitation that my school mathematical habitus places on understanding what is actually going on. My focus when doing observations was on the chart and technical tools. It was not until I had the conversation with Anita that I became aware of what else was going on.
It would be naïve to believe that this activity can easily be contextualized in school mathematical tasks. Furthermore, the development of a “third eye” could not possibly happen in school, as Anita noted. A third-eye is certainly not gained from so-called real world problems. A misplaced contextualization can even make the task less accessible for several reasons. It may be that it makes students worried because it is not in line with the work they are heading for, as was the case with my intravenous drip task. Another risk is that the contextualization restricts or overshadows the mathematical content, which gets less space and probably becomes insufficient for vocational students. Therefore, the benefit of contextualized tasks should be further investigated, although it is still important to take into account the complexity in work and influencing factors others than mathematics.

Viewing learning as a bodily change (Bourdieu 2000, Wacquant, 2004) the embodied knowledge that Anita developed as a feeling of what 17 means in a particular case is, to some extent, related to mathematics and a crucial competence in Anita’s work. The symbolic capital of the “third eye” grows into and becomes a part of the body and senses and thus a part of habitus, as a form of bodily knowing. However, it is less likely to be acknowledged than the explicit use of mathematics found in the demands and in the chart. So, ironically, in this work transitioning from a lower level of abstraction to a higher leads to a loss of the visible need for cultural capital. The embodied knowledge is rendered invisible as it becomes a part of an experienced nursing aide’s habitus with the “third eye” as an important characteristic. The third eye is consistent with what Wacquant (2004) writes about corporal and mental schemata of habitus erasing the distinction between the physical and the spiritual world. The difficulties in detecting this knowing, together with the historical subordination of nursing aides, may lead to an assumption that abstractions or mathematical reasoning are neither needed nor used by nursing aides.

When observing the semi-emergency unit with a video camera, I could not by any means perceive that Anita was focusing on counting breaths per minute and judging the rate in relation to other conditions. What I perceived was, instead, how she cared for the patients and gave them comfort. I suggest that this could also be seen as an example of the black-boxing, mentioned by Williams and Wake (2007). She was apparently doing both caring and counting simultaneously in order to make the patient feel comfortable while she was counting. This is also aligned with common requirements in a workplace where conceptual knowledge and creativity are mutually dependant when completing work tasks (FitzSimons, in press).

Making the assumption about the profession of nursing aides as being mostly about caring is misleading. Instead, I see a need to further investigate the kind of knowing that is frequently labelled as tacit, or as being black-boxed either technically or socially. It is important to take into account how the profession of nursing aides has been viewed in the past, how it has developed and is viewed in our current society. Certainly, the transitions between the chart and the “third eye” require a particular competence and experience. From a sociomathematical viewpoint, it is an act of balancing between the demanded mathematics and the developed. Seen as a reflected transition these acts of balancing require learning. If vocational students are provided with short courses, or restricted curricula, it will have serious consequences. These will not only affect the possibilities of gaining access to higher education, but may also lead to the presumption that the work force is easily educated and replaceable. This is just the opposite of what Anita explains about her work.

What is happening in the transition between the demanded mathematics and the developed in terms of corporal understanding needs to be further researched. I believe that it is also highly relevant to consider the transitions adult learners have undertaken, such as, for example, moving from school to work, or moving between other kinds of contexts such as different countries. An example is when Anita refers to trigonometry as something that everyone knows, but which is different to how I view it. It seems as if this cultural capital gets lost in her transition to a new country. This could also be
seen in relation to how Anita volunteers as interpreter on the ward. Whether she knows trigonometry, or not, is not of interest in this work. Instead, she had made use of her language skills, and probably gained a position on the ward through doing so. There also seem to be parts of her habitus shared by immigrant patients who feel comfortable and secure with Anita.

The question of whether it is common or rare to know trigonometry is however hanging in the air. It is not possible to know retrospectively if this knowledge could have been an advantage in the Swedish education system. Some parts of habitus or certain capitals may be lost or rendered invisible in different transitions, and others may instead be rendered visible. The question is who benefits from what is gained and lost in these transitions, and the overall question that I think needs further investigation is: What can we learn from the different transitions learners make, and how can these be related to mathematics? For this purpose, the concepts of capital and habitus, and, more specifically, the changes habitus undergoes in transitions, could be useful as analytical tools. An underlying question is if the label tacit knowledge is more relevant for work than for school, or if it could be that certain forms of knowing are silenced?

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References


USING MATHEMATICS AUTOBIOGRAPHIES TO HELP STUDENTS IDENTIFY CRITICAL MOMENTS IMPORTANT TO THEIR SUCCESS

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Abstract
An interesting aspect of teaching mathematics to adults is that they have already had numerous experiences with maths, both in school and in life. Those previous experiences, sometimes unknowingly, can impact their current success. It is important for learners to examine their own mathematics history to uncover critical moments that may still have lingering negative effects. Recognizing those moments and confronting the issues associated with them may be important to their success today. To illustrate this, three vignettes are presented of women in their 40’s returning to college (in a tertiary preparation program) but with negative emotions attached to previous mathematics experience. What is to be done about these situations which most practitioners have to face? This session examines the literature on mathematics autobiographies and discusses how the research can help inform our practice. Practical strategies for implementing mathematical autobiographies as an instructional tool are shared.

Keywords: adult learning, developmental mathematics, autobiography

Introduction
It has been my experience that adults who are learning, or relearning, mathematics can sometimes be hampered by their earlier school or home experiences. Identifying and recognizing those critical moments can help them to better succeed. I find it useful to consider this idea within the conceptual framework of Skovsmose’s cyclical model of disposition, intentions, and actions.

Actions come from intentions which, in turn, emerge from students’ dispositions. For Skovsmose (2005), action, or rather learning as action, refers to intentional action where the student has a choice. As social beings, the learning process is more complex than just having an experience with a concept. Students are simultaneously having experiences with a teacher, classmates, and other aspects of life – a network of experience (2005, p. 91). Actions to learn come from intentions which are described as being directed toward action or the personal meaning of the action. Intentions are the goals and reasons that make activity an action. They emerge from students’ dispositions.

Dispositions are the source of intentions but not the cause. They are mediated by the individual and contain two essential elements. The first is background which is how the term is commonly used but is specifically defined by Skovsmose as the “socially constructed network of relationships belonging to the history of the social group to which the person belongs” (2005, p. 89). The second element is foreground and is defined as “the set of opportunities that the student’s interpretation of his or her socially determined opportunities as ‘real’ opportunities” (2005, p.97). This is an important aspect of the theory because it places the student in a larger life situation recognizing that there are many potential influences on students that will impact intentions.
Skovsmose’s conceptual model is cyclical. Dispositions are the source of intentions and intentions lead to actions. As students reflect on their actions and the consequences of those actions, their dispositions are modified and the cycle continues. Hence, a student with negative experiences while learning mathematics may see a negative effect on their disposition foreground and, consequently, on their future intentions and actions.

My experience confirms for me that dispositions of students can be positively or negatively impacted by earlier experiences. I recently asked some faculty and administrators about their earliest memories of learning anything related to mathematics. One professor recalled an elementary school incident “that stayed with me forever.” *Forever* is a long time and early experiences can have an impact many years later. A staff member recalled being in a mathematic competition designed as a learning game but remembers: “And I didn’t know the answer and I just sat there and like really embarrassed and humiliated, and all the kids are all screaming all around me and I just didn’t know it.” Some are traumatized by these incidents seemingly forever. But maybe, as practitioners, we can help them.

**Three “critical moment” vignettes**

My interest in this area has developed due to several interactions I have had with students while teaching developmental/remedial mathematics at a large public university in the western United States. There are three experiences, in particular, that illustrated the strong emotions that students sometimes associate with learning mathematics. These three stories are all about women in their 40’s returning to college. The names are pseudonyms.

**Mary**

One of my first experiences was in a pre-algebra class with a student I will call Mary. For the first week, she attended but did not participate much in class. She seemed to be about 40 years old and returning to university to get a degree. At the end of the week, from a distance, I saw Mary leaving the department’s advising office. I asked the advisor if she had transferred out of my class. The advisor replied that she had and then explained the reason. Apparently, in high school, while doing her mathematics homework, her step-father would hit her if she got any of the homework problems wrong. So, all these years later, just walking into a mathematics classroom (especially with a male teacher I suppose) would bring all those emotions back. She could not handle that and left the class.

**Maria**

In my first semester of teaching, in an intermediate algebra class, I had just finished doing a multi-step problem on the board. I first had the students attempt the problem and then I worked out the solution right at the end of class. This was during the second week of the term. Maria came up to me and said she had no confidence in math. I asked her what she meant by that and she explained that she had done the problem herself and had actually arrived at the correct answer. However, doubting herself and assuming she must be wrong, she tried it again and ended up with the wrong answer.

Maria proceeded to tell me of an experience she had when she was in the sixth grade. Her teacher asked her to do a problem on the board. Maria did and the answer was incorrect. She stated that the teacher called her a “stupid little girl” in front of the class. As she related this story from at least 25 years earlier, tears were streaming down her cheeks. We were still in the classroom with other students around but she just stood there and cried. I told her I would be happy to work with her and improve her confidence. She ended up dropping the class.
Susan

Now, with three years of teaching experience, I had my most remarkable experience in terms of student emotions and mathematics. This incident helped solidify my thoughts about working with students more effectively in terms of dealing with their past experiences.

Susan, also a woman in her 40’s, was returning to college. She was in a pre-algebra class as part of a program to prepare her for college-level mathematics. During the second week of class she emailed me and stated that she wanted to make an appointment with me because she did not understand the concepts being covered. She warned me that she would probably cry in my office because this was emotional for her. I replied that I would be happy to meet with her and not to worry about crying for “I have tissues and you will not be the first to cry in my office.”

At the appointment she explained how that when she was in middle school, in her mathematics class, she would feel like she was floating in the ocean and a big wave was about to overcome her and drown her. She said, “As I sit in your class I have that same feeling.” Susan cried a little and I told her of some of the experiences I had with students and emotions. We then talked about the mathematics concepts from class.

A few days later I received another email from Susan. She said she had worked everything out and that she was fine now and she would come by and explain. Well, I could not wait to hear what had happened. She later explained that when she was driving home from the appointment she was thinking about her emotions and the mathematics connection. In high school her parents divorced. But, when she was in middle school, her parents argued often and if they had fought the night before, Susan could not focus in school the next day. Since mathematics is so sequential and cumulative, she would have gaps that came from the days she could not pay attention in class. Realizing this, she said to herself, “My emotions have nothing to do with maths; my emotions have to do with my parents. I can do mathematics!” She earned the highest grade in the class on the next exam. Susan finished the course quite successfully. I give her a lot of credit for being able to sort all of that out. Perhaps there are others like Susan, who if they are able to deal with past negative experiences, can be successful. What can I do to help students discover negative moments and get past them?

The literature

I looked to see what the literature had to say about adults and mathematical autobiographies. I found 29 papers published since 2000. Most of the papers deal with using maths autobiographies in pre-service training (e.g., Ellsworth & Buss, 2000; Yow, 2012; Sliva & Roddick, 2002). As students reflect on their own learning experiences, both good and bad, they can gain insight as to how they want to be as teachers. Kalinec-Craig (2012) describes how autobiographies were used by four Latina/o pre-service teachers. Two of those students “shared examples of their own prior experiences as marginalized students and this made them more resolute to not see their students in a deficit light” (p. 179). Ellis and Malloy (2007) suggest using autobiographies as one method to disrupt ‘students’ preconceived ideas about what mathematics is and how it is learned” (p. 162) and “this leads to discussions about the varied experiences students in the class have had with mathematics and moves them toward understanding their personal experience is not universal” (p. 163).

Only a few articles were related to using maths autobiographies as a strategy for student success. Miller-Reilly (2008) does a wonderful job of describing working with a 33-year old student, Charles, who had significant trouble with mathematics. Charles’ mathematics autobiography helped provide an understanding of his background. The author notes that she believed “it was important to listen and accept, without blame, his views about the impact of these experiences on his life” (p. 45). Miller-Reilly reports: “After Charles had finished reading aloud his autobiography during the first session, he said: That's really true, it is just horrible. It's such a shame no-one … really understood. You're the
first person.” (p. 48). This suggests that despite any other benefits, even the act of asking students for an autobiography may provide a way to show you care and make a connection with a student.

Hauk (2005) stated that “instead of seeking to rid students of their reactions to mathematics, a mathematical autobiography allows students to acknowledge these responses and build reflective awareness of them” (p. 49). For developmental reasons, “mathematical autobiography may be especially useful among college populations” (p. 50). This is also important to Nolting (2008) and his statement that “math anxiety is a learned condition, its causes are unique with each student, but they are all rooted in individuals’ past experience” (p. 61). Often, he says, those experiences are related to teachers, peer embarrassment and humiliation, or trauma from family trying to help. “One way to overcome math anxiety is to try to find out when it first occurred and how it is still affecting you” (p. 63). Nolting describes math autobiographies as a healing tool.

**Practical strategy**

I decided to be more proactive with my students. Rather than dealing with situations as they come up, I wanted to give students an opportunity to reflect on their past experiences and an opportunity to talk with me about those experiences.

A colleague of mine, Keith White, gives his students what he calls a “beginning quiz.” To get credit for the quiz they have to make an appointment to see him within the first few weeks of the term and then go over the questions on the quiz. The questions are related to time management, workload, keys to success, their expectations for the course, and their longer-term educational goals. It provides a nice opportunity to meet students on-on-one and get a chance to know their situations.

I adopted the beginning quiz idea and assigned enough token points to motivate students to make an appointment. If nothing else, I hope that the meeting breaks the ice and helps students feel more comfortable to ask for help during the term. The meetings typically take five to ten minutes but may go longer in some cases, depending on if the student wants to talk.

Initially, I added a question about their earliest remembrance of learning mathematics. Most students tend to remember learning multiplication tables in third grade. Some remember a parent quizzing them on math even as a first grader. I would then talk with them about how those early experiences may or may not have affected their attitudes towards mathematics. That worked fairly well. If there were early negative experiences I could help them understand that they do not have to let those experiences affect them now. As adults they can start over, in a manner of speaking, and move past their negative feelings. Now they are motivated to be successful in math even if they were not successful in the past. That is easier said than done in some cases. I am careful not to pretend to be a psychologist because I certainly am not trained to do that. However, there is some good that can come from helping a student confront their past.

Recently, in addition to the earliest-memory question, I have asked for a graph of their confidence in doing maths. The horizontal axis is time and I pre-label that with pre-school, elementary school, middle school, high school, and postsecondary. The vertical axis is confidence and labeled from zero to ten. One advantage of this is they are doing a little math by completing the graph. Some students do line graphs, some do bar graphs. In either case, it is great to be able to see how their confidence level may have changed over time. It provides for questions like: Why did your confidence dip and stay low after middle school? What caused the dramatic rise in confidence in high school? Those types of questions raise some interesting issues and provide a great basis for discussion when first meeting a student.
Final thoughts

When I think of the experience with Susan above, I realize that she was able to figure out her issues but it was after she requested a meeting with me. Our conversation about emotions stimulated her thinking as she drove home. How many other Susans have been in my classes that I have not known about, that were unwilling to make an appointment to talk about their mathematics experience? By requesting that each student see me early in the term, I hope to be proactive in helping students overcome past difficulties.

References


CRITICAL ISSUES IN ADULT NUMERACY PRACTICE – CONTRADICTIONS AND STRATEGIES *

David Kaye

Abstract
This paper discusses the critical situations I have been asked to ‘improve’ by providing professional development for teams of adult numeracy and functional mathematics teachers in the post-16 sector in London. These situations have not been identified through any research process, but arise from internal management reviews of course outcomes and staff development provision. The assessment by the institution’s management of these situations is often very different from that of the teaching staff. And my view as a teacher trainer is probably different again. The main focus of my intervention is to suggest changes to planning and teaching strategies. However, organisational structures have also to be considered. The author argues that three significant theories, ‘multiple intelligences’, ‘a profound understanding of fundamental mathematics’ and ‘how the mind creates mathematics’ provided guidance for the reflection of practice. The approach taken is supported by the Open University’s guide to action research.

Keywords: numeracy, mathematics skills, adult mathematics learning, critical issues, strategies.

Introduction
This paper provides a review of a series of interventions into adult numeracy teaching in London, United Kingdom (UK) over a two-year period from 2011 to 2013. The interventions were made at the request of Further Education Colleges to improve the standard of teaching. With reflection, the concerns of the local management have been identified as critical issues in the teaching of numeracy to adults. Similar issues were identified in a number of Colleges and contradictions between the teaching aims and methods were also identified. To help improve the outcomes some activities were suggested. These have since been reviewed and can now be examined as a set of strategies to improve teaching and learning. This paper recounts this journey from support for professional staff to a set of key theories that underpin innovative interventions in practice.

Though I aim to analyse a range of research sources that are relevant to this journey, I will follow a narrative that is founded on the experiences of giving support both in structured sessions and during teaching practice observations. This set of experiences was not designed at the time as a research project, but do now form the basis for a, retrospective, critical review of strategies for improving adults learning mathematics.

Critical Situations
The critical situations that form the teaching practice, core to this analysis, arose out of the formal provision of professional development to improve teaching and learning standards. Over a number of years the UK government funded support to educational and training institutions on a national basis. Such support reflected various formats, and included partner institutions supporting each other, banks of on-line resources or the provision of specialist trainers. There was, for a short period, a particular focus on adult numeracy, and it was this situation that provided the opportunity for staff development visits to be made. See, for example, the pages on “Whole Organisation Approach to literacy, language and numeracy (LLN) Framework” on the Excellence Gateway site for Supporting Skills and

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Improving Practice.

In retrospect, I identified the following as the main situations that concerned the institutional management about their numeracy teaching, and for which they requested some specialist help:

- Working with students on vocational courses
- Working with ESOL students
- Raising students’ level from Level 1 to Level 2
- Preparing for functional mathematics assessments
- Making the numeracy class more interesting

Let us look at these in a little more detail.

Working with students on vocational courses comes out of a long history of adult numeracy and mathematics being seen as one of the basic skills that underpin success in Almost all vocational education and training. Those familiar with the policy issues in this field in the UK since 2000 might be aware of the debates that have developed over the issues of integration, embedding and context. (See for example the NRDC report on embedding literacy, language and numeracy [Casey, H. et al. 2006]). The iColleges were concerned about attendance and outcomes on numeracy and mathematics support classes.

Teaching ESOL students is a particularly large part of the work of adult numeracy practitioners working in London. The expression, ESOL, a contraction for “English for speakers of other languages” is used as shorthand for students who do not have English as their first language, whether or not they are attending language classes. Many numeracy teachers work with classes that are largely or entirely comprised of ‘ESOL’ students and so institutions are concerned with how best to serve this cohort.

Raising students’ level from Level 1 to Level 2 is with reference to the levels of the Adult Numeracy Core Curriculum (ANCC) and to the more recently introduced Functional Mathematics. The content of these levels can be explored on the Excellence Gateway site for Skills for Life Core Curriculum, particularly in the “numeracy progression overview” document. For some teachers and curriculum managers the change of content from Level 1 to Level 2 is seen as a much larger challenge than movement between other levels, when planning teaching and learning.

Preparing for functional mathematics assessments is particular to the English situation, as this was a new form of assessment for the sector introduced in pilot form in 2007. It has, only quite recently, become the main form of assessment for adult students. It is a very different form of assessment compared to the national tests that were used previously. The national tests were multiple-choice questions, whereas functional mathematics aims to measure process skills and requires more writing and explanation. The mathematical content however, is very similar.

Making the numeracy class more interesting is a very broad category that in practice covers issues in which the curriculum managers considered that the mathematics teaching was too traditional, and the teaching staff were not open to new approaches. See for example, the approaches associated with collaborative learning, such as described by Malcolm Swan (Swan, 2007).

The practice for this ‘reflection-on-action’ [Schön quoted in OU (2005) p24] comprised staff development sessions devised by the author. These took place in colleges of further education and local adult education services in the London (UK) area. The courses at these institutions were for students aged 16 or above. However for organisational and funding purposes the courses are usually

organised separately for young adults, aged 16 to 19 and adult classes for those aged 20 and above. The courses can generally be classified under three headings: vocational, functional mathematics and English language (ESOL). The teachers attending the staff development sessions included mathematics and numeracy specialists, support teachers (for literacy and numeracy) and specialist vocational teachers.

Contradiction and strategy 1 – Order of numeracy topics

The impact of reports about poor numeracy, particularly the Moser report (DfEE 1999), led to the publication of the Adult Numeracy Core Curriculum (ANCC) in 2001 (Basic Skills Agency). There remains considerable dispute whether this document is properly described as a curriculum, despite its name. However, what is certain is that it set out a list of topics divided into sections, sub-sections and curriculum elements. These curriculum elements were presented across three levels: Entry Level, Level 1 and Level 2. The Entry Level was itself sub-divided into three, Entry 1, 2 and 3.

The three sections of the ANCC are number, measure, shape & space and handling data. These were based on a model established by the National Curriculum for primary school mathematics. An example of an element from the number section at Entry 3 is “add and subtract using three-digit whole numbers”. An example of an element from the measure shape & space section at Level 1 is “work out the perimeter of simple shapes”. The Core Curriculum is now available as an on-line document, however, for about 5 years the printed document was the only version available and the order of the elements tended to be followed as a syllabus by many numeracy teachers. This close adherence to the printed document was further compounded by the common practice in many institutions to encourage (at the very least) numeracy teachers to identify the numeracy elements covered in their lesson plan by their distinct element reference number. The ANCC itself encourages this.

The curriculum elements must be clear and used with learners. The aim must be that learners develop the concepts and the language that will help them make sense of their learning and go on doing it. Evidence shows that the inclusion of explicit curriculum targets in learning programmes has resulted in a clearer identification of outcomes by learners, and in better attendance and progression by learners (BSA, 2001, p. 8).

As the core curriculum has been used as a syllabus, schemes of work begin with the four arithmetic operations, proceed through whole numbers and then decimals and fractions and percentages. Here is the contradiction. All of these teachers are aware that it is considered good practice to take the students experience into account and place calculating techniques into context. Yet the part of the curriculum most removed from any context is introduced first and can easily take up half of the course time. The ANCC itself emphasises the need to take into account the students’ past experiences.

The skills and knowledge elements in the adult numeracy core curriculum are generic. They are the basic building blocks that everyone needs in order to use numeracy skills effectively in everyday life. What is different is how adults use these skills and the widely differing past experience that they bring to their learning. This is the context that the learner provides . . . (BSA, 2001, p.8)

The strategy I propose is simple and straightforward, yet experience has shown it is frequently condemned and rejected. The ANCC is divided into three sections, Number, Measure, shape & space and Handling data. That strategy is simply to start the course in a section other than Number - to begin the course with some aspect of measuring or collecting data. There are three main advantages to be gained from this strategy.

1. It avoids presenting adult students with the mathematical techniques, such as mental calculations, that they probably find the most difficult, if not impossible, right at the start of the course. This is often countered with the argument that they ‘have to know how to multiply
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– to know their tables’. Perhaps they do. However, I question whether this traditional approach can work with most adult students. The students are in the adult numeracy class because they have not achieved previously. If they have completed secondary school they will have been shown the techniques for multiplication at least 10 times; if they have already had additional help in school and attended other post-16 classes this is probably closer to 15 times. Why should this occasion be any different?

2. Measure shape & space and handling data provide ‘in-built’ context for working with numbers. Something must always be measured or a shape must be a shape of something, and have dimensions. If data is being collected it must be about something. Starting a programme of study with topics drawn from these sections provides the opportunity for the examples used to be relevant to the students’ lives or the other courses they are studying. All of the calculating techniques from the ‘Number’ section occur when manipulating problems within these topics. Over time, appropriate support can be developed where it is necessary.

3. By starting with measuring or data not only are we avoiding starting with topics that are likely to be the most challenging for students – there is the opportunity to start with topics that the students are more familiar with. Very often the students themselves do not identify what they can do as mathematics at all (Colwell, 1997). For example, a student may have poor multiplication skills, and therefore have considerable difficulty in converting measurements. However they may have excellent estimating skills, demonstrating a thorough understanding of measurement, but the students may well consider this ‘just common sense’.

Contradiction and Strategy 2 – Numeracy for speakers of other languages

The problem as it is posed is ‘what we have to do to teach mathematics to the students who do not have English as their first language?’ In discussing this further with the teachers concerned, there appears to be a contradiction between what the teachers think they should be teaching and what the students need to learn. For teachers in stand-alone adult numeracy classes, this problem has been compounded by the recent introduction of Functional Mathematics. As was described above the new Functional Mathematics assessments require more writing to explain why a particular solution has been chosen. Part of the strategy here is to know about and understand the background of these students. The term ‘ESOL’ is used to refer to a very wide range of students. Many of the students will have lived in Britain for a comparatively short period of time, and therefore their schooling or education would have taken place elsewhere. In many institutions ESOL students are placed in classes according to the level they have been assessed at in English, and these are often at Entry Level. In the mathematics class the teaching is likely to begin with calculating methods, as discussed above. This may well be totally unnecessary and even cause confusion.

The students may well (currently) have a low level of English, but that does not mean that they cannot calculate; they may well have a good knowledge of mathematics. If a student has completed their secondary education in another country they are likely to be fully competent in their calculating skills. They may well be proficient using other methods, and this is where confusion can occur. If a different way to calculate is demonstrated, they may well think that they are doing something wrong using the one they have been taught previously in school. Given they may have a low level of English it will be difficult to discuss this, and so care needs to be taken to ensure previously acquired skills are recognised and supported. It is important to recognise that the skill some students need to learn is the language of mathematics. There is quite a complex relationship between the language in which mathematics was learnt and the current learning medium of English. Dhamma Colwell (1997) gives examples of the processes people experience as they move from one language to another in their mathematical practices. For example M changed from Cantonese speaking school to an English-
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speaking one at the age of eleven. She found that maths was the only subject that she could understand easily, because the symbols used were the same in both languages (Colwell, 1997 p67)

In this example skills in mathematics are compensating for the lack of skills in English, by depending on familiar symbols.

The other part of the strategy is to ensure that connections are repeatedly made between the mathematical items, saying and writing the words that describe it, and the symbols used to represent it. An example of this is ‘ratio’. This is the mathematical item. It is written as ‘3:2’ and said as “three to two”. The concept of manipulating quantities in ratio may well be understood, but to discuss it and ask questions it is necessary to have the written and spoken language of ‘3:2’ and “three to two”.

This can be represented by an image using the concept of a number.

![Symbol 3](image1.png) ![Word Three](image2.png) ![Concept 3:2](image3.png)

*Figure 1. Representations for number three*

Explanations given in a numeracy or mathematics lesson usually use all three - representing the concept in some form, saying or writing in words a definition or explanation and presenting the concept in symbolic form. These are very often not presented at the same time and moving from one to the other, with the intention to explain more clearly, can cause confusion.

**Contradiction and strategy 3 – Numbers with and without context**

The need to consider the context is particularly relevant to working with students on vocational courses. The pressure on institutions to ensure students have the mathematical skills to achieve their primary learning goal on a vocational course has long been an issue. For example Gail FitzSimmons discusses this in the Australian context in the late 1990s (FitzSimmons 1997). It is still a very live issue. At the time of writing, August 2013, the UK Government has just announced new measures for 17 year olds to continue to learn English and mathematics. Professor Alison Wolf, who headed a government review of vocational qualifications, described continuing in the two subjects as the most important recommendation of her inquiry. “Good English and maths grades are fundamental to young people’s employment and education prospects,” she added. “Individuals with very low literacy and numeracy are severely disadvantaged in the labour market.” (Wolf, 2013)

The contradiction is that mathematics can be presented differently in a vocational class to how it is introduced in the mathematics support class. An example of this was observed during an LSIS support session (see LSIS Support Programme – Barking and Dagenham College). In a painting and decorating class the students had to make a six-colour wheel on the doors they were decorating. Under the instruction of the painting and decorating teacher the students drew a circle. They then marked out the length of the radius of the circle six times around the circumference of the circle and drew lines from these marks to the centre. They completed the activity by painting in the three primary colours of red, yellow and blue, and by overlapping creating the three secondary colours of green, orange and purple (or violet). The mathematical solution to this problem would involve
considering that a circle can be divided into 360 degrees and that to divide the circle into six equal parts then requires the calculation of 360 divided by six. To complete the practical task angles of 60° would then need to be measured or constructed.

This situation raises many more questions about the purpose of certain problems, and the reasons given for doing certain calculations. However, for the purposes here the strategy to be noted is that practical solutions are used in vocational classes that are different from those a mathematics teacher is likely to use. If this is not taken into account the numeracy / mathematics support classes are likely to be seen as irrelevant. The recognition of different sorts of mathematics in vocational and cultural contexts has been developed far more deeply, practically, pedagogically and theoretically under the heading of ‘ethnomathematics’, particularly in South America. (See for example Knijnik’s (2007) study of the mathematical practices in the Brazilian Landless Movement).

Theoretical inspiration

The contradictions and strategies I have been discussing arose out of my own practice in teaching adult numeracy, in teacher education and in professional development. This practice was informed by reflection on the feedback received from teachers and discussions with colleagues and also on a whole body of theories and research on teaching adults mathematics. In reflecting on my own practice, I realised that I was concerned that such reflection and evaluation should lead to change. This was associated with certain approaches to action research, such as that described in the Open University guide for action research:

The second approach has other attractions. As noted, it draws upon Schön’s (1983; 1987) ideas of ‘the reflective practitioner’ and ‘reflection-on-action’: the active and critical consideration and reflection by us, as practitioners, on such aspects as the motives behind and the consequences of our professional practice. This is achieved through a process of action-reflection-action and is what permits us as teachers to analyse our practice, both for ourselves and for others, and thus to change and develop. (OU, 2005, p.24)

The next section provides a summary of my thoughts about the contradictions and strategies in teaching adults under three headings:

- Different ways of thinking about a problem . . . and solutions
- A deeper understanding of how people calculate
- Considering how the brain manipulates numbers

These ideas have been inspired by the work of three very different researchers, whose work has helped to explain the contradictions and inspire the new strategies. The first is the theory of ‘Multiple intelligences’. Howard Gardner first published this in 1983 in Frames of Mind. Since then he has updated the theory by taking into account how others have used this theory and adding one more intelligence to the original seven (Gardner, 2006). Gardner’s theory, in its current form, identifies eight different sorts of intelligences. Two of these are linguistic and logical-mathematical, and in his debate with the psychometricians (those who work with intelligence tests) he argued that the traditional tests primarily measured these two only.

The other intelligences that Gardner describes are musical, spatial, bodily kinaesthetic, interpersonal, intrapersonal and naturalist. What I found particularly helpful from this theory is that it provides a theoretical basis for recognising that people can be poor at some tasks but very good at others. Particularly they may have poor mathematical skills, or mathematics approached in a particular way, but have many other talents. If that is the case, then these talents can be used to build their numeracy experience, rather than continuing to focus most on the parts of mathematics they cannot do.
The second source is that of the researcher Liping Ma, in her study Knowing and Teaching Elementary Mathematics (Ma, 1999). The main focus of this study is to compare the mathematical knowledge and teaching practices of teachers trained in the USA and China. The examples she focuses on are very instructive, such as looking at how teachers understand the rules for dividing a fraction by a fraction. However, what I found particularly instructive was the section entitled: ‘Profound Understanding Of Fundamental Mathematics’ (Ma, 1999, pp118).

What this provides is an argument for having a deep understanding of the concepts that underpin the processes involved in basic calculating. This, once again, provides support for the development of alternative strategies. With this ‘profound understanding of fundamental mathematics,’ a teacher would be easily able to adapt a calculating process to suit a particular student, and would have the personal skills to evaluate a different method used by a student. Without such understanding, the teacher is left with only the method they have learnt, which they may be able to perform by rote, but cannot be explain or deviate from.

The third source is the work of Stanislas Dehaene (1999). His ideas are summarised in the book, The Number Sense which is sub-titled ‘how the mind creates mathematics’. There are three things that give me inspiration from this book. The first is the introduction the author presents to the neuroscientific approach to understanding mathematics. He introduces the reader to studies of the brain, which show where, and possibly how, numbers and quantities are manipulated. Much of the work of the neuroscientists Dehaene showcased has been to work with patients who have lost specific number skills, after an illness or an accident, and identify which parts of the brain have been damaged. The second is the introduction to the concept of ‘subitizing’. This is described as a particular ability that enables one, two or three (and possibly four) objects to be recognised and distinguished without one to one counting. It is used to show there is a number sense in very young babies and animals and to support arguments for some aspects of understanding numbers as being innate.

The third is introducing the term ‘numerosity’. This is the attribute of a group of things that gives it countable quantity. It is recognising amounts. This I found useful in discussing at a fundamental level what we mean when we talk about ‘a number’ or ‘numbers’. The word ‘numbers’ has so many meanings that having a specific word which refers to the concept of ‘amounts’ rather than how a number is written or said can help clarify thinking and from that, how number concepts are explained and demonstrated.

Finally there is one more source that needs to be noted. I have spoken briefly about the importance of collaborative work with colleagues. Over recent years my reflections and self-evaluation of staff development initiatives have been supported by discussions and joint work with my colleagues and by the initiatives in teacher training for adult numeracy specialists. This body of knowledge and experience can be found summarised in ‘Teaching in Adult Numeracy’ (Griffiths & Stone, 2013).

Conclusion
In this paper the experience of working with a wide range of adult numeracy professionals is reflected upon in order to identify the key changes to teaching strategies that were being promoted. The key changes to teaching strategies are recognised as being underpinned by three diverse theories: Howard Gardner’s ‘multiple intelligences’, (2006); Liping Ma’s ‘a profound understanding of fundamental mathematics’ (1999) and Stanislas Dehaene’s ‘how the mind creates mathematics’ (1999). The process has been seen to have similarities with the reflective practices associated with action research.

References
Jorgensen, M. (2014). Using mathematics autobiographies to help students identify critical moments important to their success


**Resources from the Excellence Gateway**

Functional mathematics: Standards: http://www.excellencegateway.org.uk/node/20517

Teaching and learning support material http://www.excellencegateway.org.uk/node/22188

LSIS Support Programme – Barking and Dagenham College Collaboration between functional skills specialists and vocational specialists

http://repository.excellencegateway.org.uk/fedora/objects/eg:5390/datastreams/DOC/content accessed September 2013


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LEARNING MATHS AT WORK: THE RESEARCH STORY SO FAR

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Abstract
The purpose of the research is to understand why people learn maths at work and the value the learners give to that learning. My research seeks to further understand why learners who were often unsuccessful at school are motivated to achieve a mathematics qualification while at work. I am working with trade unions, as they currently negotiate opportunities for people in the UK to learn maths while at work, using resources provided through the Union Learning Fund (ULF). The purpose of the research is to give a voice to those learners who are often disregarded by those in the mainstream education because of the low status allocated to both learning at work and the adult numeracy curriculum in the UK. The report includes a description of my research journey including the development of a grounded theory approach and some findings so far.

Introduction
In UK society, the education system contains a hierarchy of qualifications and institutions of learning. Vocational learning, apprenticeships and learning at work tend to be perceived as having lower quality and value than academic knowledge. The recent move to downgrade several vocational qualifications by the current government and sections of UK education society in relation to GCSEs reflects this hierarchy (TES, 2012; Wolf, 2011).

Another hierarchy exists within the teaching of mathematical ideas where traditional mathematical courses such as GCSE and A levels tend to be privileged over mathematics learned in vocational contexts and as such are used as gatekeepers to further progress in academia and society (Benn, 1997). Within this hierarchy, adult learning in mathematics up to GCSE level, until recently known as numeracy, tended to be seen as even more contentious (Coben, 2003) and of lower value. So why would people want to learn maths at work

My perspective
The research is carried out from a constructivist perspective, where mathematics is seen as value–laden and fallibilist (Ernest, 1998), ‘a human-construct, fallible and ever-changing’ (White-Fredette, 2009/10, p. 22). Mathematics teaching is a product of those values and understandings overladen with society’s latest political concerns and so contains a value structure of knowledge designed to retain and reinforce those positions of power.

This work is underpinned by my own belief that learning mathematics, at whatever level, is valuable if it is related to the empowerment of that person and enables them to live a fuller life that contributes to the betterment of themselves, their environment and society. I agree with D’Ambrosio when he identifies the goals of education are ‘to promote creativity, helping people to fulfil their potentials, but being careful not to promote docile citizens’ (D’Ambrosio, 2007, p. 26) and more particularly that ‘Mathematicians and math educators must accept, as priority, the pursuit of a civilization with dignity for all, in which inequity, arrogance and bigotry have no place’ (D’Ambrosio,

2007, p. 25). So this research is concerned with ethical and political dimensions of mathematics education.

The work was also motivated by my lifelong commitment to the trade union movement, and my belief in the power of joint endeavour to change people’s lives, especially working class lives, through the support given by the trade union community in the workplace. I also view this research from a feminist perspective in the sense that I seek to foreground women’s voices as much as those of men’s in the research. This is important to me as a result of my own experiences of being in a minority and experiencing discriminatory practices against women while learning maths in college and during my teacher training. As well as observing discriminatory practices against working class males and females on vocational programmes during 20 years of teaching mathematics and numeracy in Further Education.

My approach to the research project

In this first section I will describe briefly the phases of my research journey, the process of research and reflect upon on some issues of quality in the chosen research process.

Background

At the outset of my doctorate studies I undertook a wide range of reading about methods and methodology as well as adults learning maths in different contexts. I knew the purpose of the research but remained unsure of my research methodology. After I had a break from my research studies for a year, due to illness, I began to question the purpose of the research. My illness had been serious, and life threatening, so I needed to reconfirm the value of the research to myself. This first section of the article describes my research journey. My research falls into the following four distinct phases:

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**Phase One** was before the illness. This phase consisted of me doing a wide range of reading and making contacts with trade unions involved in supporting teaching and training at work. I made contact with trade unions Unite the Union and USDAW, as well as Unionlearn, (which is) the learning and skills organisation of the TUC, to explain my research and ask for their assistance in contacting trade union members. I was interested in working with trade unions, as they negotiate opportunities for workers to learn maths while at work using resources provided through the Union Learning Fund (ULF). This fund was established in 1998 by the government to help promote trade union activity in creating a learning culture. UnionLearn was established to support and monitor the use of the fund.

**Phase 2** started after my illness was diagnosed and I had recovered from the treatment. This whole process took nearly a year. I had to reassess my own motivation for undertaking the research and so I undertook two early interviews with learners to convince myself of my continued personal interest in the topic. Undertaking the interviews and sharing my analysis of the data with colleagues and interviewees as well as exploring the research texts convinced me I was still interested in the topic and had something to contribute.

I also needed to try to reconnect with the research literature to confirm my methods of data collection and my methodology. If I was to make the research meaningful I also needed to test my questionnaire. The original had been developed for a slightly different context, and I wanted to see if
the adapted version produced data that I could use in my analysis. At this point, I also started to use Nvivo to help track the analysis of my qualitative research data and attended two different training sessions to develop my skills with this software. I began to realise that I was using a grounded theory approach to research.

**In Phase 3** I began by conducting more interviews and imputing the data into the software Nvivo, and coding the interview data to help in the analysis of the learners’ words. In this phase my literature search has further extended to include motivation, emotion, empowerment and identity. These notions were emerging themes from the data and I wanted to explore them further. I also planned to undertake more interviews with women, as I needed more in my sample. The total interviewees so far were three women and 12 men.

**Phase 4** is the final phase of the research, extending my literature review, re-analysing the data and continuing the process of writing up my research.

**Issues of quality for this research**

On returning to the research I was exploring two aspects: firstly to see if the data I collected could be linked to research already relevant to my area as one way of assessing the credibility of the data in the sense of relevance to the field; secondly, I needed to see if the data collection method and questionnaire were appropriate to produce a rich enough source of data. These questions are about the quality of data collected.

In quantitative data quality of data is discussed through notions of validity, concerned with the integrity of conclusions and reliability, concerned with the repeatability of the results of studies (Bryman, 2012). In qualitative data collection, but especially in grounded theory, quality of the data collection and the resulting analysis are linked to notions of ‘trustworthiness and authenticity’ (Bryman, 2012) and credibility (Charmaz, 2006). These ideas are concerned with recognising the truthfulness of the research but not based on a notion of absolute truth which underpins the positivist tradition of quantitative data. There have been extensive discussions on what criteria can be used to judge quality in qualitative research, (Bryman, 2012; Charmaz, 2006); Corbin & Strauss, 2008; but Corbin postulates that, in the end, it has to ‘resonate(s) with the readers’ and the participants’ life experiences. It is research that is interesting, clear, logical…that has substance, gives insight, shows sensitivity and is not just a repeat of the “same old stuff” (Corbin & Strauss, 2008, p. 302).

On the first issue of relevance to the research field, I had undertaken a wide range of background reading early in my research but ended up focusing on two particular pieces of research that I identified as close to my work: one into adults learning maths in Further Education (Swain, 2005); and the second into adults learning through trade unions (Ross, Kumarappan, Moore, & Wood, 2011). I used them both to explore the interpretation of the learners’ words about motivation already in the research field, partially as a type of initial test of credibility of my findings. I wanted to see if any of the concepts of motivation that I had identified in my analysis had appeared in other published research close to my topic as a way of checking my own findings with the research of others who worked in similar fields. This can be described as a form of triangulation (Bryman, 2012). I found similar words and expressions on a number of concepts of motivation including self-esteem, expressing more confidence when working with others and the importance of the supporting children.

On the second issue of data collection, I wanted to ensure the questions I asked, and the discussion I had with interviewees provided relevant data for the research. I did this by building on the questionnaire I had already developed for a previous piece of research, undertaken during my earlier doctoral studies, to identify people’s motivation to learn at work (Kelly, 2010, unpublished). I then adapted some of the questions as the context had changed to learning maths at work through opportunities provided through trade union membership. During the interviews I found that the data
collected through the revised questionnaire went beyond the descriptions of motivations for learning at work and included the effects of the learning maths on the learners themselves and their lives; this added to the richness and the credibility of the data.

As the interviews proceeded I also found that emerging themes developed which necessitated asking more questions on certain issues such as what was it that made learning through the union different or better than previous learning experiences.

In testing the credibility of my data I then wanted to check my analysis of the first two interviews to make sure I had not lost the ‘essence’ of the interviewees descriptions of their motivations to learn maths at work and had not missed anything important. I sent my interviewees my draft analysis a week before I went back to speak with them. I asked them to read my work and then sought their opinions, thus putting my writing under their scrutiny. This process is a form of ‘respondent validation’ which aims to seek corroboration or otherwise of the researchers account, and frequently used by qualitative researchers (Bryman, 2012). At this early stage they were positive about my analysis. I asked them about their feelings about the analysis, one said “It was nice that you quoted us exactly, I may not be grammatically correct how we said it, but that is what was said….it makes it more realistic. You were capturing a moment…it was a true situation and that’s how people feel” (p. 391).

When discussing the idea of trying to write truthfully and honestly for the research another said: “If someone is trying to say what they think they want you to hear, that’s wrong. But if you interview someone long enough I think the truth does creep out. If you ask the right question” This raises the issue of interviewees wishing to please the researcher, or give what they see as ‘socially desirable’ answers, or simply wanting to agree with the researcher in the form of ‘acquiescence’ (Bryman, 2012, p. 228).

**The research process**

In this section I will explain the overall theoretical approach to the research, using a Grounded Theory approach. I will explain further the context of working with trade unions to access people learning maths at work, give a brief overview of the interview process and begin to explain how the data collected from the interviews was analysed using Grounded Theory practice.

My approach for the overall research project is reflected in Figure 1, as described by Melanie Birks and Jane Mills in Grounded Theory (Birks & Mills, 2011) where they show three interlinked cogs. The major cog includes the data collection with concurrent research and analysis. The second cog describes a phase of theoretical sensitivity, where the researcher brings their personal histories and experiences to revisiting data and background research to identify their interpretation of key issues. The final cog is the advanced phase where the categories are finessed and become saturated with data (See Birks & Mills, 2011, pp. 9-17).
My research has followed a similar process. In Phase 2, I undertook some purposeful sampling and started to collect and code data. I then generated and analysed data, identifying concepts and possible categories. In Phase 3, I went through this data generation phase again, this time using Nvivo. At this time I was also constantly integrating and reintegrating the background literature research into the analysis, using memos to aid this process. In this way I strengthened, adapted and changed the concepts and reassessed the categories, beginning the process of saturating the analysis with data.

**Theoretical saturation**

Theoretical saturation describes a point where there is no further reason to review my data to see how well they fit with my concepts and categories and when new data no longer adds any more to the concept already developed (Bryman, 2012).

**Grounded theory and previous research**

So the overall approach I used is rooted in grounded theory methodology (Birks & Mills, 2011) (Corbin & Strauss, 2008). Originally, grounded theory was a 'specific methodology developed by Glaser and Strauss (1967) for the purpose of building theory from data'. Corbin and Strauss now use the term in ‘a more generic sense to denote theoretical constructs derived from qualitative research methods’ (Corbin & Strauss, 2008, p. 1).

A continuing debate within the grounded theory research community is about the point at which a researcher introduces the background research literature into the analysis of the data. Initially Glaser saw the importance of leaving the introduction of background literature into the analysis as late as possible, to allow the researcher to develop new theories and ideas rather than reanalysing using older theories (Charmaz, 2006). On the other hand, Bringer et al. (2006) are less prescriptive stating ‘ultimately, it is a balance between reading enough to be aware of and understand possible factors that could influence the area of study while still remaining open-minded to what participants have to say’ (Bringer, Hailey, & Brackenridge, 2006).

My approach takes this later, more pragmatic approach. I have been a teacher of teachers who specialise in teaching numeracy to adults, so I already read widely in the areas of adults learning, adults learning mathematics and teaching and learning mathematics. As a life-long, active, trade
unionist, I also have an awareness of key trade union issues. So I cannot come to analyse the data without recognising that my ideas and concepts have been influenced by that earlier professional knowledge and experience. These are preconceptions and prejudices that I must continually be aware of during my analysis.

The trade union context

Trade unions have been involved in training at work for many years but only since the Union Learning Fund (ULF) was established did it become involved in developing the Literacy, Numeracy and ICT skills. Union Learn was also established at this time to administer and monitor the ULF. NIACE has worked with Unionlearn since its establishment.

Engaging with trade union, ensuring relevance of the research

My early interviews took place through links with NIACE, Union Learn and USDAW. I also made contact with Unite the Union as I worked with their Education department on developing quality assurance processes for some of their trainer training programmes in 2007-9.

In May 2007 Unite the Union was formed by the amalgamation of two separate trade unions, the Transport and General Workers Union and Amicus. In 2012 there was an election of a single General Secretary. This resulted in a significant alteration in the union structure and a lot of people were moved around, posts were changed and new people employed in different roles.

The change in personnel gave me an opportunity to offer my research proposal for further scrutiny by the new Director of Education and convince him of the value of my research. He was very interested in my work and introduced me to members of the new Education team. Through this meeting I was invited to a Union Learning Representative (ULR) conference in London and I used this opportunity to meet as many ULRs and regional organisers as possible as these people were pivotal to helping me accessing and interviewing learners in the workplace.

Union learning reps (ULRS)

Union Learning Reps (ULRs) are seen as key in encouraging members in the trade unions to improve their literacy and numeracy skills and as a consequence are given specialist training and support to develop their own skills in organising and giving advice and guidance.

To further encourage workers to engage in learning, the ULRs usually also negotiate time off from work for the members to learn. This often takes the form of one hour given by the company and one hour given by the employee. But this agreement can vary: some companies give two hours, some give none. So ‘time to learn remains one of the greatest challenges for workers and ULRs’ (UnionLearn with the TUC, p. 5).

The workplace training context

Organisations that recognised the value of training and up skilling their employees, such as KappaSmurfit, signed agreements at a national level and then Regional Organisers and ULRs negotiated the practicalities of delivering the training within local companies. This training was provided by tutors within the Union or lecturers from local colleges or universities who were bought into the workplace through union and management negotiations.

Some training was mainly computer based others were delivered to small groups on company premises. In one instance people who had been successful at level 1 were going to go as a group to the local college.
The interview process

The interviews were undertaken in the workplace. I identified the category of person I was seeking to interview, sent the information to the Regional Organisers and ULRs who identified people with these characteristics in specific companies and negotiated with those companies to allow me access to premises and time for me to interview learners. This did mean that I relied on people to understand my requirements and make the choices of interviewees for me. This did impact on the choice of interviewees as became apparent later in the research although it did not hinder the data collection process.

The interview sample

The principle characteristic of the interviewees required for the research was that they had learned mathematics while they were at work. The sample of interviewees can be defined as a cluster sample of learners within a trade union, mainly Unite the union. It could be described as a ‘snowball sample’ (Dowling & Brown, 2010) in that I use one person to connect with another with particular characteristics within an organisation, as such I was unable to choose the sample randomly from a larger population. In this case I had to gain the agreement of the Director of Education for Unite, who instructed his Regional Directors to help me contact Regional Organisers (ROs) and ULRs. The ROs and ULRs who were willing to help then identified people who had learned maths in their places of work and were willing to be interviewed. They then negotiated with the management of companies for me to interview the learners, during work time. This method of sampling was necessary, as I required interviewees with special characteristics, those of having learned maths while working, and this group of people is not always easy to get hold of.

The interview approach

My initial interviews were with union members at Rye Park Learning Centre in Hoddesden, which is part of a large Sainsbury’s distribution centre. These interviews took place in July with two employees who were also union members (USDAW) and union learning reps (ULRs).

These interviews and those later were carried out in the workplace using a common set of questions with a semi-structured approach to allow for some ability to ‘increase the comparability of the data’ and ensure ‘the topics relevant to the research are covered’ (Flick, 2005) while allowing for the interesting personal stories to emerge.

So far I interviewed people, in Hertfordshire, Birmingham, Sheffield, and Northampton. In my next round of interviews I will need to interview more women as their numbers so far were very small, even when compared with the trade union’s own statistics of women involved in training through the union.70

The data generation process

My analysis of the content of the interviews started early to ensure that the responses were providing me with the information I was seeking and to allow me to reflect on any further information I might like to gather. Corbin and Strauss (2008), when writing about Grounded theory, encourage analysis to begin early, suggesting ‘if it is possible analysis should begin immediately after the first data have been collected’. They also encourage continual analysis after each individual interview, if at all

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70 To date I have interviewed 12 men but only 3 women. Although the Unite statistics on trade union members involved in learning during 2012 show only 25% of learners are women (unpublished internal document viewed in October 2012), my sample so far was only 20% women
possible, to enable ‘a greater sensitivity of data’ and to enable ‘the researcher to redirect and revise interview questions or observations as he or she proceeds’ (Corbin & Strauss, 2008, p. 58)

**Coding the data**

I started to analyse my pieces of primary data from Phase 2 by highlighting descriptions that I thought were key and common in the learner’s accounts of their motivations for learning maths at work. This process is described as ‘coding’ by Corbin and Strauss (2008, p. 65) - the process of ‘deriving and developing concepts from data, while Bryman (2012) describes it as breaking up data ‘into component parts which are given names’ (p. 710).

**Identifying Concepts**

Initially I analysed the data to identify phenomena and common ideas that appeared in the interview texts and the research. Bryman defines as ‘concepts’ labels that are given to discrete phenomena’ (Bryman, 2012, p. 570). Using coding allowed me to develop concepts to be used in my early analysis. For example, during my early coding phase I identified several concepts one of which was increasing self-confidence. Interviewees made such statements, as “I am now more confident, I am in control more I would rather have a go at working out problems myself now. If anyone says do you want to have a go, I say yes, I will take up any challenge”. Another said “So many opportunities opened to me since I did my numeracy, (it) built my confidence up; I can sit and explain how I found out things”. So these descriptions use the words confidence but, more than that, they then explained how this change in confidence expressed itself through their lives. Learners spoke of a willingness to take up another challenge, or to be able to explain their mathematical thinking to others.

**Building Categories**

After I had identified several concepts I re-analysed the data to see if there were commonalities within groups of concepts, sometimes termed categories. As Bryman points out, ‘a category may subsume two or more concepts’ (p. 570). So in my research I identified groups of concepts, known as categories, that have a particular common characteristic or phenomena the trade unionists spoke about in relation to motivation to learn maths at work. During this analysis I concentrated on the concepts related to the purposes or reasons people described for undertaking the maths courses.

Some spoke of their purpose to learn being related to their work, i.e. to keep their job, or being goal related” to get a certificate” so I grouped these concepts into a category I have called ‘instrumental’. Others spoke about their reasons being linked to things outside their work, i.e. helping children. Those who spoke about helping others often went on to describe how learning the maths had changed the way they viewed themselves and their lives. So I grouped these concepts and called the category ‘transformational’; trying to capture that change in their lives or themselves that they spoke about.

The concepts grouped in the transformational category I perceived as a higher level of abstraction in that it included notions of ‘change’ in people’s lives. It included concepts of increased confidence and self-esteem (a change in their personal self-perception), as well as taking the chance to return to learning again through the union (a change in their lives).

**Emerging Themes**

An early emerging theme, or concept, was the idea of what makes the learning through the union a ‘better or easier’ experience than that experienced previously. Some people spoke of very difficult situations or lack of interest at school, so what is the difference now? Questions on this theme have been developed during the second phase of interviews.

Another emerging theme is the notion of the **community of practice** and how this works to support learning. This is both in a positive sense within the group out also I the support the group gives when coping with hostility from those outside the group. Questions about this will be included in the third round of interviews.

The emotional language that people use to describe their learning journey is also an emerging theme linked to often quite significant changes in their own lives.

Another emerging theme is linked to the collection of the data. This is when I realised that all of the people I have interviewed all have had positive outcomes in their terms in that they ‘succeeded’ in the sense that they gained a qualification through their courses. My interviewees are people who were contacted through the Unite Union Learning Reps (ULRs) and so the ULRs may have wanted to provide me with learners who have been perceived as successful in their learning. On further reflection, one ULR I interviewed did not initially discuss the fact that she had undergone a level 2 programme of study but had failed to achieve the qualification. She only referred to her level 1 course and qualification, it was only later in the interview I became aware of the time she spent on a level 2 course of study. This reinforces that notion that ULRs may have only identified learners who had achieved a maths qualification, even though I explicitly asked for people who learned maths at work.

There may have be some ‘political’ reasons within the union to try to ensure I only saw success stories about the learning within the union, or the ULRs may be seeking to ‘please the researcher’ by only identifying their notion of ‘success’ stories, thinking this is what the union wanted. However, it could also have been that while I spent hours worrying about the wording of my documents and questions, for the ULRs notions of learning and achieving a certificate may have been ALMost synonymous, especially as they also had their ‘day job’ to think about. However this is one theme I can further investigate during the later round of interviews: one of the useful flexibilities of a grounded theory approach to research is investigating emerging themes.

**Conclusion**

The research journey has been an interesting one in finding out about myself and my own motivations and ways of working as well developing a greater understanding of the process of research. I will continue to immerse myself in the data developing the analysis by testing the concepts and categories and working towards theoretical saturation. I will make more use of the memos to help develop my analysis, developing the categories and analysing the stories of the participants using ideas developed in research literature, to help theory building.

The value of sharing my early findings at the ALM conference with research colleagues and peers cannot be underestimated. It helps to explore new ways of looking at and analysing your data. One voice of experience suggested “you may have to pull the whole analysis apart and start again”. This sounded pessimistic but has very quickly become a reality as I do not want to solidify my findings too early.

The sharing also provided an opportunity for colleagues to suggest further reading with international perspectives, which again have been highly relevant and useful. So presenting at ALM offered a challenging but supportive environment to take my research forward.

**References**


UnionLearn with the TUC. (ND) Union learning adding value: an evaluation of Unionlearn and the union learning fund. LONDON: Unionlearn.


FINANCIAL LITERACY COMPETENCIES PROJECT: REFLECTING ON THE RESOURCES, ACTIVITIES AND OUTCOMES

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Abstract
This is a report on the Financial Literacy Project organised under the Grundtvig programme with 8 European partner countries that ran from 2010 -2012. The project aimed to improve the financial literacy competencies of adult learners in order to ‘prepare them for the challenges and temptations of the consumer society and to prevent situations of financial indebtedness’. In order to accomplish this, a toolbox for adult learners, a handbook for trainers and a curriculum were developed that was shared across the nine countries and accessed through a website. The project aimed to base the development of these resources on local research in each of the partner countries. At ALM 18 we reported on Year One of the project. This is the final report on the project and its outcomes, as well as a description of the pedagogic approach used at ALM 20 to share the resources with ALM members at the conference.

Introduction
This paper has two main aims. Firstly to describe the European Financial Literacy Competences (FinLiCo) project, that some members of ALM from the UK were involved in. Secondly, to describe the pedagogic approach used in the ALM workshop, known as a carousel of activities, to display some of the resources developed by the different countries in the project.

Background
The Financial Literacy Competencies for Adult Learners (FinLiCo) project ran from 2010-2012. It aimed to ‘improve the financial literacy competencies of adult learners’. The project was funded through the European Grundtvig programme for adult education and involved 8 other countries (partners): Austria, Cyprus, the Czech Republic, Italy, Portugal, Slovakia, Slovenia, and Switzerland (as a silent partner). Portugal took the lead partner. The proposal submitted by the partners to the EU argued that such work was important “in order to prepare [adults] for the challenges and temptations of the consumer society” and to “prevent situations of financial indebtedness”.

The project aimed to impact not only on adult learners' competencies, but also use new training methodologies and resources that reflect current educational thinking in each of the partner countries. The FinLiCo project itself was based on findings from an earlier EU funded ‘Financial Literacy’ project and the results were made available through a website developed by the Austrian partners (See http://www.financial-literacy.eu/index.php?id=29). This original project found that some European countries had developed examples of good practice aimed at minimising and/or overcoming the lack of financial literacy in adults. However despite efforts more and more families had to deal with debt
and efforts to reduce indebtedness had not been successful. The previous project had argued that this lack of progress was in part due to the short-term nature of such proposed solutions.

The Global Financial Context

It was also problematic that the project was taking place within the context of a world economic recession. Starting in 1997 with the BNP Paribas closure of selected hedge funds, the economic situation worsened until by May 2010 when the economic crisis threatened governments, such as Greece, as well as banks. By the end of the FinLiCo project there is an increasing discrepancy between the economies of newly developing countries such as China and India, while most European economies still lie under a blanket of austerity and economic development remains slow to nonexistent (Elliott, 2011).

Economic impact on Learning Unlimited, the UK partner

The UK partner also underwent considerable changes during the project, partially due to economic pressures. In Year One, ALM members employed by LLU+, a training organisation that had been supporting adult learning for over 30 years, took over the UK partnership from another organisation that had been involved in planning for the project but had gone into liquidation just before the project started. During this first year LLU+ itself was closed down by its hosting university. However the numeracy specialists involved in the FinLiCo project helped establish a social enterprise called Learning Unlimited through which the work continued. Learning Unlimited is now in its third year of trading.

Definitions

The Organisation of Economic Co-operation and Development (OECD) has been involved for the past decade in issues of Financial Literacy and Education has provided the following definition for financial literacy as

“Financial Literacy is knowledge and understanding of financial concepts and risks, and the skills motivation and confidence to apply such knowledge and understanding in order to make effective decisions across a range of financial contexts, to improve financial well being of individuals and society, and to enable participation in economic life.” (OECD, 2013)

In the UK the term ‘financial capability’ is used rather than ‘financial literacy’. The use of this different terminology signalled for us that there had been developments for some time in this field in the UK, led by the financial services industry that were very different from our experiences in teaching adult numeracy.

FinLiCo - The first year

The first year of the project involved each of the members of the project carrying out research into the policies and the provision of resources currently available in their own country.

UK policy and resource research

Research by the UK financial sector identified the need for more financial capability skills development and support amongst the population. The main findings are:

- Many financial institutions have developed informative and interactive websites in response to the identified need. (Thoresen, 2008) (Kempson et al. 2010)
- Most websites on financial literacy in the UK are developed independently of the education sector. UK schools provision is linked to the PSHE programme but there appears to be little
on offer in either Further or Higher Education (FinLiCO Survey, 2011 unpublished)

- There is general agreement that financial capability includes budgeting, keeping track of finances, planning ahead, choosing appropriate financial products and staying informed about financial matters. (FSA, 2006a)

- People are more interested in developing these skills at particular times in their lives, usually at a time of change. This could be when starting a job, starting a new course at college or university, dealing with a purchase or a debt, becoming a parent, becoming unemployed or retiring. Mundy (2011) identifies these as “teachable moments”.

- People do not usually want to plan too far ahead and are often over confident with the evaluation of their own financial skills. Mundy (2011)

Each of the 8 countries undertook their own country wide research so that the content development in Year Two would be informed by the research undertaken and the surveys carried out. To this end it was planned that the content would not duplicate resources that were already available but would simply signpost them. Thus the “Toolbox” of resources developed by the project would be additions to the resources available.

**Year 2 of the project**

In Year Two the 8 project partners produced a Toolbox, a Handbook and Curricula in financial literacy all available on a website at (http://www.financial-literacy.eu/index.php?id=29).

It was intended that the Toolbox would consist of a collection of resources for use with learners, the Handbook would be a guide to the use of the resources, and the Curricula would contain examples of approaches and content that had been used to develop financial literacy skills with particular groups of learners. The resources and tools were categorised under the following 11 Modules:

1. Personal
2. Critical Thinking
3. Risks
4. Budgeting and Planning
5. Savings and investments
6. Income and taxes
7. Basic Mathematics
8. Financial Products
9. Indebtedness
10. Credit
11. Shopping and Consumer Rights

Each partner organisation identified resources that already existed in their countries that would fit into the Modules and added new resources they had developed. Any perceived gaps were allocated to individual partners to research and try to find appropriate content.

As part of the quality assurance process all of the partner countries tested some of the new resources that were intended for the Toolbox. Each country tested some resources they had developed themselves and some developed by partners. The UK had the responsibility of piloting four activities
developed by themselves and one activity from the partner in Cyprus. As a result of this process some resources had to be revised to refine and adapt the content.

Because some of the resources identified by some countries were not applicable to the UK financial situation each country produced their own version of the Handbooks and the Curricula.

**A carousel of activities**

In order to introduce the range of FinLiCo resources developed to the ALM conference we decided to use “a carousel of activities” pedagogic approach. It would be interesting to know how many of you (the readers of these proceedings) immediately know what the title of this section means. As numeracy teacher trainers we have been using this phrase to describe the use of a set of activities for about 10 years, but are still unaware of how widespread this concept is.

The approach is a way of introducing a group of ideas, linked by theme or level, to small groups of participants through a range of activities. The activities, usually between five and ten in number, are set out on separate tables and are each complete in themselves, with instructions and self-check answers as well as the activity itself. The participants are asked to move from one activity to another in pairs or threes, attempting or completing each activity in their own time, and then moving onto others. Participants are encouraged to discuss the solution or process of each activity and to support each other. A checklist of the activities is provided to keep track of what activities have been visited, and to record reactions to each activity as part of a self-evaluation process. The checklist used in the ALM workshop is attached as an appendix.

Our use of this approach in adult numeracy has its origins in seeking an alternative to the written tests used for initial assessment of adult learners. It is very common for a group of learners or participants in a mathematics-based course or session to be given a short assessment that is introduced as being ‘not a test’. In what ways it is ‘not’ a test is something that should be more closely investigated. It may not be a test for the teacher or trainer, but it certainly feels like a test to the participant.

As adult numeracy teacher trainers we were very aware of the extreme anxiety many adult learners face in being forced to take a ‘maths test’. We are not only aware of this from our own experience, but from research around ‘maths anxiety’ and the emotional impact of learning (or not learning) mathematics. There is a growing body of research into the important role that emotions play when considering motivation and learning maths. (Evans & Wedege, 2004)

Illeris’s research into identity and learning identifies the importance of interplay between the cognitive, the social and the emotional in the process of learning (Illeris, 2014). Hannula’s research highlights the role of emotional control linked to motivation when people learn maths (Illeris, 2014).

The carousel approach to recapping and remembering maths topics has been used with many different groups of learners. A particular context arose which enabled this approach to be developed with an emphasis on self-awareness and motivation. This was a context in which education professionals in the post-compulsory sector, who were not numeracy/mathematics specialists, had to consider introducing some numeracy into their teaching training to meet the requirements of the ‘minimum core’ (See http://www.excellencegateway.org.uk/node/12019 for information on defining the minimum core). In this context well-qualified educationalists were re-introduced to mathematical topics without being sat down at a desk with a test paper.

In discussions that arose out of these self-assessment events some very significant concepts became apparent. As is often the case in these experimental situations, the new ideas seem simple and obvious once they are identified.

These can be summarised as follows.

1. The carousel experience is social and not individual-
2. Discussion with peers is encouraged, rather than considered cheating
3. Learning takes place by watching others, often peers, complete an activity, rather than the humiliation of leaving a question blank
4. Partial skills are an asset, and can develop as a quasi-teaching relationship develops with other group members
5. With visual and tactile activities mathematical patterns can be seen to appear which show a solution.
6. The over-all experience evidences what is known rather than what is not known

These concepts have a long research history.

The advantages of learning in a social, shared environment has long been discussed under the headings of social constructivism (associated with Vygotsky) and andragogy (associated with Knowles) (Tusting and Barton 2003).

Though not so well documented is the use of language in learning numeracy and in the context of working with others on mathematical tasks, half-formed ideas can be discussed and developed in guided conversations. See for example the discussion about language and mathematics by Rebecca Woolley (2013).

The opportunity to watch someone else solve a problem has obvious advantages that borrow both from the social nature of the carousel experience and the lack of emotional pressure, both referred to above.

In the situation in which the participants can question each other over suggested solutions brings into play methods that explore errors and misconceptions as described by Malcolm Swan (2006). The design of the activities has borrowed from the experience of those working with learners requiring innovative approaches, such as those with dyslexia and drawing on theories of different learning preferences. See for example the study by Kirby and Sellers (2006).

The fact that the carousel approach enables participants to begin with what they know, since each participant can contribute what they recognise as they approach each activity, can be seen as an example of a social practice approach. This is described by Carolyn Brooks (2013) who also makes connections with the theories of ethnomathematics and other critical approaches to mathematics learning. What is of particular note about the carousel is in putting together all of these approaches in one ‘mega’-activity, and using it for numeracy (mathematics) or financial literacy, it is thereby combining (and even multiplying) the combined impact of these strategies.

**FinLiCo Carousel**

Generally the experience was reported as being one in which participants became aware of having skills they did not know they had, or recognising that skills they have developed since formal education could be considered mathematics. With this experience in mind a carousel was designed for the final multiplier conference of the FinLiCo project held in Porto, Portugal. Here a number of the activities designed for the project were presented in a carousel style for the conference participants.

We adapted the content of this carousel for our workshop at ALM20 and chose a range of the resources available from the FinLiCo toolkit. The carousel was introduced with guidance to the participants that it was both an opportunity to investigate a range of resources for financial literacy training, and also to experience the pedagogic approach of a carousel of activities. The activities chosen were as follows:

1. **People Bingo (UK)**

   An activity to start a session, which encourages participants to introduce themselves to each other.

   Comment: This content could be adapted to differing content in each module identified and could also be translated into different languages, as was the case at the multiplier conference in Portugal.
CARD A
Find someone who:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>has had a stall at a car boot</td>
<td>spends less than £20 a month on</td>
<td>has written a letter or</td>
</tr>
<tr>
<td>sale</td>
<td>their mobile phone</td>
<td>email of complaint in the</td>
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<tr>
<td></td>
<td></td>
<td>last year</td>
</tr>
<tr>
<td>has bought something on</td>
<td>has ever got a refund in a shop</td>
<td></td>
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<tr>
<td>an internet auction site</td>
<td></td>
<td>has bought something</td>
</tr>
<tr>
<td>such as eBay</td>
<td></td>
<td>from an advert in a newspaper</td>
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</table>

2. Finlico Board Game (Portugal)

A standard board game format played with dice and counters in which movement along the board is determined both by dice throws and answering questions on financial terms and situations. Comment: The UK version of this game had to have considerable changes made to the content of the questions for this activity to take into account the different currency and financial legislation used in the UK.
3. **Pay slip (UK)**

A card sorting activity to identify parts of a typical pay slip, by placing labels in the correct places.

**Comment:** The discussion in this activity is flexible and could focus on addition and subtraction of amounts, but also extend to labelling to enable a deeper understanding of the role of a payslip eg to collect (the appropriate) taxation, national insurance and pensions.

<table>
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<tr>
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<th>Tax Year</th>
<th>Divn</th>
<th>Dept</th>
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<td>7.50</td>
<td>1180.00</td>
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<tr>
<td>OVERTIME</td>
<td>16</td>
<td>11.25</td>
<td>180.00</td>
<td>EES NI CONT.</td>
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<tr>
<td>EXPENSES</td>
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<td></td>
<td>42.50</td>
<td>EES PEN 1</td>
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<tbody>
<tr>
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<td></td>
<td>123456</td>
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</table>

<table>
<thead>
<tr>
<th>Total Hours</th>
<th>Payment Details</th>
<th>Other Information</th>
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<tbody>
<tr>
<td>985.85</td>
<td>BACS 985.85</td>
<td>*****0001</td>
</tr>
</tbody>
</table>

4. **Quizzes (Slovakia)**

A set of computer based quizzes on a number of financial literacy topics such as budgeting, shopping and financial products.

**Comment:** Once again this quiz had to be adapted to the UK currency and financial legislation.

1. Which of the following is the most accurate description of budgeting?
   a) Buying things for the lowest price on the market
   b) Working out how much money is available for a purpose
   c) Moving money between accounts
   d) Borrowing money at a low interest rate

5. **Best Buys (UK)**

A card matching activity to encourage practice in calculating the ‘best buy’ between two different sized packages of the same product.

**Comment:** This was one of a number of UK activities originally designed for the Office of Fair Trading.

6. **Animated Film (Czech Republic)**

Three short animated films about a young person getting into debt by making the wrong decisions.

**Comment:** Although the language is Czech the financial message is clear and the film can be used as a useful stimulation for role play or discussion.
7. Cartoon Posters (Slovenia)

Three sets of humorous cartoon story lines that illustrate, without words, situations that require decisions on personal finance.

**Comment:** They are seen as a resource to stimulate discussion or as a marketing tool (in poster format) for events or courses.

8. Identity, freedom and high tech world (Slovenia)

A cartoon or PowerPoint animation warning of the dangers of disclosing personal information on the internet.

**Comment:** This is linked to the growth of on line banking.

As the participants were engaging with the eight activities there was discussion about the financial literacy content of the activities, other activities available in the participants own countries, the carousel approach to learning and other approaches used by the participants in different contexts.

**Reflecting on the Project**

**Financial Literacy languages**

In the early stages of the research it became apparent that there are many different terms being used to describe this field of work. For the purposes of the project the consortium defined “Financial

Literacy” as the ability to understand finance. More specifically, it refers to the set of skills and knowledge that allow an individual to make informed and effective decisions through their understanding of finances.

The content of the toolbox consisted of a variety of resources aimed at different target audiences

Some countries saw financial capability or financial literacy with entrepreneurship. (Mundy 2011, 4) This was certainly true in the Finlico project where partners in the project all worked with adults but the client groups shared different characteristics. For example, the Italian partners worked with clients on their employability and entrepreneurial skills developing their ‘financial literacy’, where as the Czech Republic were engaging with younger people who were disengaged from school, and were introducing the idea of financial literacy for the first time. This client group required different pedagogical approaches and resources to engage with the notion of financial literacy.

Transferability between contexts

Some of the resources developed were appropriate for the economic situation in that country, or the client group using the resources, but were not necessarily easily transferable. For example some of the images, or language used was not appropriate for different contexts. Also some questions had to be rewritten for the particular circumstances of different countries. This was particularly true for the UK which is not part of the Euro and therefore was governed by different financial legislation.

Different pedagogical approaches

The development of the resources became a real opportunity to share different pedagogical approaches to learning that were used in different countries. The project partners also developed a variety of videos, board games, posters and on –line interactive quizzes to help develop financial skills.

Conclusion

Comment of the FinLiCo project

The opportunity to share ideas on how to develop financial literacy skills across 8 Countries, provided challenges but also many benefits to broadening thinking and approaches to developing adult skills. Whether the resources alone will be able to help ‘improve the financial literacy competencies of adult learners in order to prepare them for the challenges of a consumer society’ will depend not only on the individuals concerned in teaching and learning but also the economic context in which the development takes place.

Nevertheless, the resources can contribute to interesting and engaging ways of developing individual’s skills and knowledge.

Comment on carousel approach used in the workshop

The use of the carousel in the ALM workshop was a development from its use as a self-assessment tool. The participants were not being assessed in any way, whatsoever, even by themselves. If anything was being assessed it was the resources. However, the structure of the carousel activity gave a comfortable format for the participants to engage with each of the resources in their own time and giving time to their preferred choices. The self-directed approach also meant that if any participants felt nervous about their lack of knowledge of the topic, this would not be exposed. They could still engage in discussion about the presentation of the activity.

There was very little comment made about the carousel approach itself, and we consider this a success. The carousel structure is a tool for presenting activities in an accessible way. There was focused engagement with all the financial literacy activities, and discussions took place around these, about both the activity and more general financial education matters. We view the fact that the carousel structure became almost invisible is a considerable asset to be noted.

References


Big Money Test https://www.bbc.co.uk/labuk/articles/money/faq.html (accessed October 28th)


Appendices

Appendix 1 - Financial Literacy / Capability / Education Websites in the UK

ASDAN Budgeting activities produced for awarding body with the cooperative college
http://teacher.beecoop.co.uk/?q=node/120

The Citizens Advice Bureau has produced a range of resources and reports on Financial Capability in the UK. The main advice site is http://www.financialskillsforlife.org.uk/ and the reports can be found at http://www.financialskillsforlife.org.uk/index/partnerships/financialskillsforlife/fsfl_resourcespublications/fsfl_r_p_publications.htm. In addition there is advice for young people on the Money Talks site including an interactive game on running a car http://www.citizensadvice.co.uk/en/moneytalks/MT-Toolkit/

CfBT Education Trust has recently (2011) produced a perspective report Financial capability: Why is it important and how can it be improved? This report is aimed at “those with an interest in the development of national financial capability strategies and those who are developing or implementing financial capability programme” http://www.cfbt.com/evidenceforeducation/pdf/FinancialCapability.pdf

Direct Gov. Lots of links to useful websites about money, taxes and benefits

Dius -Read Write Plus Reading and writing and calculating with money- Entry 3 – focus on decimal points http://rwp.qia.oxi.net/learning_material/portal/reading-writing-and-calculating-with-money_num_e3/m04/t19/index.htm

Financial capability framework The UK developed a framework for financial capability in 2000 which has been used to structure training and qualifications http://shop.niace.org.uk/adult-financial-capability.html.

Financial Services Authority (FSA) – advice on wide range of consumer advice http://www.fsa.gov.uk/Pages/consumerinformation/scamsandswindles/index.shtml The FSA has also produced a number of reports including Establishing a Baseline which reports on a survey of financial capability of 5300 adults, Consumer Research http://www.fsa.gov.uk/pubs/other/fincap_baseline.pdf

Martins Money Tips Advice website http://www.moneysavingexpert.com/ and weekly tips on how to save money by email MartinsMoneyT@moneysavingexpert.com

There was also the Consumer Financial Education Body (CFEB) set up by the FSA and since April 2011 it has become the Money Advice Service http://www.moneyadviceservice.org.uk/

Money made Clear - Loads of information on home, everyday money, cards and loans, mortgages, insurance, pensions & retirement, savings and investments, tax and benefitshttp://www.moneymadeclear.org.uk/tools/budget_planner.html –

Money Matters a practical guide to family finance. Many interactive pages such as: using an ATM, checking change, budgeting, Bank and Building society charges video, Money word search http://www.moneymatterstome.com/default.htm

Mums net Shopping and discount tips as well as loads of other information on parenting http://www.mumsnet.com/

NIACE has also produced a range of resources from projects linked to financial capability and learning. These can be found at http://www.niace.org.uk/current-work/area/financial-learning

Office of Fair Training (OFT) – consumer advice and activities www.oft.gov.uk/skilledtogo

Personal Finance Education Group (PFEG). Online resources on financial awareness developed for schools, primary, secondary and 14-19 year olds, funded by banks and other financial institutions http://www.pfeg.org/

Younger people Financial advice aimed at students - A quick quiz to see your financial style and then 10 areas with a quiz for each e.g. banking, borrowing, bills, debts, etc http://www.moneymakesense.co.uk/ -.
Appendix 2 - ALM Carousel of Activities - Review Sheet

Please use this sheet to record your responses to each of the activities.
In the financial literacy column please consider the usefulness or relevance you think the topic would have for a participant on a financial literacy course.
In the teaching /learning column please consider what you think of the resource as an approach to teaching and learning.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Financial literacy content – usefulness/relevance?</th>
<th>Teaching /learning approach used in this activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>People Bingo (UK) Exercise No 1 - starter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finlico Board Game (Portugal) Exercise No 17</td>
<td></td>
<td></td>
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<tr>
<td>Pay slip (UK) Exercise No 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quizzes (Slovakia) Exercise No 27- 33</td>
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<td></td>
</tr>
<tr>
<td>Best Buys (UK) Exercise No 18</td>
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<td></td>
</tr>
<tr>
<td>Animated Film – Pujcka2 (Czech Republic)</td>
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<tr>
<td>Cartoon Posters (Slovenia) Exercise No 47 and 13</td>
<td></td>
<td></td>
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<tr>
<td>Identity, freedom and high tech world (Slovenia) Exercise No 35</td>
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</tbody>
</table>
TEACHING EVERYDAY MATHS AND FINANCE THROUGH OPEN ONLINE LEARNING: SOME CRITICAL PERSPECTIVES

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Abstract
The authors have recently contributed to a national project, Maths4Us, funded by the UK government through the National Institute for Adult and Continuing Education in the UK (NIACE). The project is aimed at supporting the development of adult numeracy skills. The result of this strand of the project is a set of courses which aim to use creative approaches through online resource development. A number of interesting themes have arisen during the project, and are discussed in the paper, for example:

- The wide range of aims of the different stakeholders in the project in terms of national education policy, social, political and financial considerations, technological developments and pedagogical approaches, and how the project has attempted to address these. For example the interface between the writing team's philosophy of critical and social practice in course design and the behaviourist-influenced approaches that are common in online learning tools development.
- Significant moments in the development of the course content, for example: the wider social context of this project, such as the decision to develop the financial literacy course at a time when the benefits system in the UK is changing significantly
- The changes in policy and practice encouraging the use of technology, the open access nature of the medium and the emphasis on learners to be self-directed.

Introduction
This paper arises from a workshop that we presented at ALM20, giving participants the opportunity to try out some new interactive online course materials on the topics of Everyday Maths and Everyday Finance. During the workshop we discussed the development of the project from a number of critical perspectives such as: the definition of a MOOC (massive open online course), the boundary between formal mathematics and its use in solving everyday problems, and some of the differences between face to face and online teaching and learning.

Background
In December 2012, mathematics specialists from Learning Unlimited in the UK were asked to help develop a Massive Open Online Course (MOOC) to support adults whose maths skills were below National Qualifications Framework Level 2 in the UK (equivalent to an A-C grade at GCSE level).

The aims of the resources were to:

- Engage adults in using and exploring maths within everyday contexts, and
- Be accessible as individual activities, class room maths courses or through one to one support.
The project originated from the UK government's commitment to promote a national mathematics campaign (BIS 2011, p11). NIACE, the National Institute for Adult and Continuing Education in the UK was given the lead for the initiative, known as 'Maths4Us', working with a range of organisations including Union Learn, Jisc, The Women’s Institute, National Numeracy and Learning Unlimited. The use of technology was seen as essential to the Maths4Us initiative, and MOOCs were identified as the vehicle to use for the online maths courses.

What is a MOOC?

There is no single definition of a MOOC, so this produced some early discussions about what one was and what it would look like. Some saw MOOCs as "a type of online course aimed at large-scale participation and open access via the web" (Daniel, 2012). Others saw them as supporting “..opportunistic ad hoc engagement with individual activities or resources, as well as a more disciplined commitment to the course as a whole” (Sharples et al., 2012).

By the end of 2012, there were two recognized approaches. ‘cMOOCs’ are based on 'connectivist' principles, whereupon: “Personal knowledge is comprised of a network, which feeds into organizations and institutions, which in turn feed back into the network, and then continue to provide learning to the individual” (Siemens, 2004).

In the connectivist paradigm, learning is a process involving the connecting of different sources of information. In cMOOCs this is achieved by encouraging learners to use blogs, wikis and other social network media to contribute to the course within an open, flexible and responsive learning environment (Morrison 2013). One of the pioneers of MOOCs, Stephen Downes, described his vision of a MOOC thus:

A MOOC is a way of gathering people and having them interact, each from their own individual perspective or point of view, in such a way that the structure of the interactions produces new knowledge, ... A MOOC is a vehicle for learning, yes, but it acts this way primarily by being a vehicle for discovery and experience (and not, say, content transmission). (Downes, 2013)

In this way, cMOOCs are about facilitating a creative, dynamic, learner-centred process.

The second type of MOOC is the 'xMOOC'. Here the 'x' stands for an 'extension' of traditional learning. These were based on behaviourist principles, developed through organisations such as Stanford University in the USA. Daniel (2012) describes an xMOOC as, typically, a college lecture split into sections, with problems set to measure ‘algorithmic’ rather than ‘conceptual’ learning, and feedback given purely as grades.

Maths4Us MOOC

When the Maths4Us MOOC project started there was no shared understanding between the partners of what a Maths4Us MOOC would look like. The numeracy specialists and IT resource developers became excited about a version of cMOOCs, and envisaged the use of online community forums, and of people stumbling onto the course having done a more general search on, for example, ways to budget, or to manage their time, or to understand food nutrition labels or to help their children.

However, one difference between xMOOCs and cMOOCs is the role of stakeholders. The principle behind cMOOC is that the content is generated by the individuals who are taking part in it. xMOOCs, in contrast, have more predetermined content which is funded by interested parties (usually universities). For example, in this project the UK government department for Business, Innovation and Skills (BIS) funded the development. However, it quickly became apparent that rather than having 3 years of funding, as originally planned, the project was limited to one year. The restricted time for the project became an issue and created tensions between the ideals and visions of the
numeracy and the IT developers and the practical constraints within which they were working. Eventually a 'bottom-up' approach was adopted, with the numeracy specialists beginning to generate ideas and course content, whilst discussions continued at management level about the funding and the possible functions of the website.

The short time span also meant some resources were invented and reinvented, reviewed, revised and sometimes 'retro-fitted. Often in a project of this type, this review and revision of resources will be planned into the schedule. However, because time was compressed, this sometimes happened in parallel rather than sequence. The volume and quality of the output is a consequence of the creative skills and commitment of all those involved. The platform on which resources are stored, and the home page, has been developed towards the end of the resource creation phase and some aspects of it, such as the social networks functions, are still to be activated.

Engaging adult learners

Another aspect of the development that was discussed extensively was how a MOOC style format would best serve adult numeracy learners; many of whom were already disengaged from formal learning. Many of the partners believed a 'lecture and quiz' style xMOOC would not capture the interests of a diverse group of learners. In the experience of the numeracy specialists, many adult numeracy learners also have difficulties with literacy creating extra challenges in accessing and engaging with MOOC-style content.

Working through these concerns from an early stage resulted in a growing collaboration between the numeracy experts and the IT developers enabling the creation of interesting, accessible and interactive resources. The result, to date, is neither an xMOOC nor a cMOOC, but rather a collection of open online learning materials. These materials can be used and adapted in a number of ways, for example as stand-alone materials, as part of a MOOC type programme or as part of a blended or face to face series of learning events. The discussion about how to make the online resources into a MOOC continues, with possible plans to create a ‘network’ of learners, depending on further funding.

The numeracy specialists used their expertise from working in a wide variety of adult learning contexts to develop resources that aimed to engage learners but not patronise them. Three areas of content were specified: Everyday Maths, Everyday Finance and Helping Children with Maths. Each area would contain two topics (for example, Everyday maths had Numbers in Food and About Time. Each topic would include an introductory video, interactive activities, quizzes, games, and links to other sites that could help develop the maths skills further or give more advice on the topic of the unit.

The interactive content and games were of particular importance as we wanted the online courses to be fun and engaging for people who might be reluctant learners. In this way, some of the nature of the content differed from other, more 'traditional' MOOCs. Designing these resources within the constraints of budget, software availability, timescales and areas of expertise was a challenge, but resulted in an explosion of creative output. We worked with artists, film-makers, animators, musicians, adult numeracy learners - and their children - and IT specialists to develop innovative numeracy content. We also worked with specialists in both adult literacy and teaching English to speakers of other languages to ensure the level of language was appropriate for a range of learners, and accessibility specialists to ensure that the content was accessible to as many learners as possible, for example with extra audio support and video subtitles.

The 'blue sky' element of the process was both inspiring and frustrating, as any creative process will be, but we believe that the project was ground-breaking in the ways in which we attempted to take online learning forward in the area of mathematics and numeracy.
Maths4Us online learning resources

In the remainder of this article we describe the online resources in relation to critical perspectives and significant moments. We have focused on the Everyday Maths and Everyday Finance courses as the Helping your Child course is discussed elsewhere in these proceedings.

The social, cultural and political context of everyday finance

The idea of ‘significant moments’ originated from the notion of ‘teachable moments’ as defined by Mundy (2011) in his report on Financial Capability, in which he proposes that people are more interested in developing financial capability skills at particular times in their lives, usually at a time of change. For example: when starting or losing a job, starting a course at college, dealing with a debt, or becoming a parent.

Our 'Everyday Finance' course contained two units: Pay and Wages (money coming in) and Managing your Money (money going out). A ‘significant moment’ in this case was the introduction of Universal Credit, a change in the way welfare benefits would be paid to claimants in the UK. Two critical factors were identified in this change of system: people on welfare benefit would be (a) paid monthly instead of weekly and (b) paid through a bank account rather than cash through the post office. To understand the impact of these changes and identify the challenges for people affected, numeracy specialists worked with two organisations: the Citizens Advice Bureau (CAB), a UK organisation that provides advice for people who face problems and Homeless Link, a national charity supporting people and organizations working with homeless people in England. This influenced the purpose of the resources, with a focus on developing numeracy skills that might help to empower people to make more informed choices and decisions in relation to their circumstances.

The tensions between giving advice, discussing rights and providing support for appropriate mathematics skills were very apparent in designing these units. On the one hand we wished to adopt a critical pedagogic approach, where learning numeracy is a possible way of empowering individuals in their own lives as described by Frankinstein (2010) and Skovsmose (2005). But on the other hand we also needed to be careful about straying into the area of financial advice. Furthermore, we wished to avoid the suggestion that having improved numeracy skills is the best or only solution to budgeting issues. To this end we developed learning objectives that included:

- Practice in budgeting
- Calculating gross pay based on a number of hours worked at a particular hourly rate
- Using rules of thumb to estimate monthly earnings based on weekly earnings

At the same time, we realised how everyday life is too complicated to be accurately portrayed in this kind of material. For example:

- Take home pay, while related to gross pay, is not the same as gross pay, but the calculations for it were too complex to look at here
- In everyday life both benefits and pay will vary month by month

In current everyday life in the UK, many people struggle to budget for their families within their incomes (see, for example, Sharma 2013). This practicality would have led us into debt management, an important topic but outside the remit of the project.

How we responded in the design of the materials

We saw budgeting as an open ended activity, a process to be considered, with no set answers, especially when monthly income and outgoings vary with everything life can throw at one. Many
online budgeting tools that we had seen were not suitable: they gave no feedback, they did not allow for variation and were too complex. We designed the simple activity below to give to support and develop the underlying activity of budgeting, giving the user flexibility and feedback. It is based on the notion of allocating money to four main areas of spending: rent, bills, groceries and travel with a 'rainy day' pot for what is left over. In the activity the user drags money into four pots:

We provided hints and tips, such as, for the 'bills' pot, dividing a given annual spend by twelve: many bills nowadays show annual spending. Importantly the check function allows for variable amounts to be put in the 'groceries/travel' and 'rainy day' pots. To add a sense of authenticity to this activity, we filmed 'vox pops' of people from Homeless link and the CAB giving tips on budgeting.

In this way we attempted to create a learner-centred, authentic, but scaffolded, experience of budgeting (followed by more accurate budget calculations using a calculator). The 'criticality' of these materials is implicit in the subject matter. We would hope that tutor mediators would generate or facilitate discussion about the new benefits system in the UK, or 'zero hours' contracts, arising naturally from the use of the materials. This is where the functionality of a 'social network discussion forum' would be invaluable to enable the sharing of these ideas. We hope the development of online communities is part of the next development phase.

**The social, cultural and political context of Everyday Maths**

We were also requested to address the topic of time management, arising from the fact that people in the UK may now have their welfare benefits sanctioned as a result of missing a benefits appointment (see, for example, Wintour 2013). We developed a course unit on 'time', but, recognised that addressing mathematics skills can only go so far with respect to solving issues of attending interviews. There is a danger of formal mathematics being seen as a 'cure-all', when in fact the reasons that some people may experience difficulties may have nothing to do with their mathematics skills. With this in mind, and other considerations such as the broad range of learners we hoped to engage with, we chose contexts for the 'About Time' course that had no obvious connection with interview schedules, so that no 'agenda' was apparent, and the user was free to take what they wished from the activity.
A similar tension between giving advice, supporting mathematics skills and raising critical awareness was also apparent in the 'Numbers in our Food' unit. We did not wish to lecture learners on how to eat healthily, but to provide information about food nutrition labels - along with support to develop the skills needed to decipher such labels - so that people could make informed decisions about what food they bought. An example is given below.

Here, a general knowledge 'predictive' question about the amount of salt in different foods is followed by a focus in on the mathematics involved in interpreting the percentage figures given. It should be noted that these screens were preceded by several sections introducing nutrition 'traffic light' labels, fractions and decimal numbers, guideline daily amounts and the relationship between fractions and percentages.

**Critical issues around 'everyday'-ness**

Early in the project it was agreed that the mathematics did not have to be at a particular level, it was more important to get the content right. This decision was informed by research into adult education that showed adults had ‘spiky profiles’ when it came to learning (DfES 2002), and the resources were about engaging learners, not guiding them through a curriculum. There were already websites in existence that took a 'skills-based' approach, and did this very well (e.g. bbc.co.uk/skillswise). In
contrast it was felt there was a need for content arising from everyday themes and topics, such as managing money or planning journeys. This position links to theories of numeracy as a social practice (e.g. Street et al. 2005), where value is given to the numeracy practices that people carry out in their own lives. We felt that this approach was particularly important for adult numeracy learners in the UK, given that much of the research and publicity around the apparent dearth of skills in the adult focuses on a deficit view of learners (Oughton 2013:13). In developing the materials for the Everyday Maths course, however, we found a tension at the boundary between 'everyday-ness' and 'maths'. We are led to believe that mathematics or numeracy skills are essential in helping us to solve everyday problems:

Numeracy is a life skill – necessary to allow each of us to make informed choices and decisions in all aspects of everyday life. This can be at home, at work, as a consumer, as a parent. It touches activities not only such as choosing a mortgage or a utilities contract, checking invoices or wage slips, working out a monthly budget or helping with children’s homework, but also planning a journey, cooking a meal, reading a newspaper, playing sport or placing a bet. (National Numeracy 2013)

However, some research (such as Gigerenzer, Todd, & Research Group, 1999) suggests that:

humans have evolved a set of heuristics which are effective in a range of … decision-making situations, and they offer evidence that in some situations heuristical thinking is more effective than formal mathematical … methods. (O'Hagan 2011:306)

As part of the online materials, we wanted on the one hand to introduce learners to some formal mathematics through the medium of everyday topics, and on the other hand, our experience as teachers had led us to believe that adults do not rely on formal mathematics alone to help them make decisions in their everyday lives, and in fact use all sorts of strategies, heuristics and extra information.

**How we responded in the design of the materials**

One way of responding to this was by including open questions and problems as part of the materials, in addition to more traditional closed questions. Here are some examples from the 'About Time' unit (part of the Everyday Maths course), beginning with a closed, multiple choice problem:
Here, learners are asked to decide when someone should start making a cheesecake to have it ready for 8 pm. An example of a mathematical solution is given in (animated) diagrammatical form with an audio commentary:

However, learners are then asked if they would work it out differently. To simulate learners having a discussion about how they would approach the problem we used characters and speech bubbles.

One character says he would add up all the times given to get a total, and then count back from 8pm. Another says that she would make it the day before, and even the audio commentator himself remarks that he would buy a cheesecake from the shop to use as a back-up. In this way we attempted to simulate something of a learner discussion, mixing up the maths with the 'everydayness' to reflect more accurately how people go about making such decisions in their own lives.
Another example of blurring the boundaries between formal mathematics and 'everyday common sense' was in the use of an interactive comic in the 'About Time' course, where the learner chooses one of two possible endings to a given story. It was important to design the activity so that there were no right or wrong choices, but with ample opportunity to use and apply language, concepts and skills relating to reading and calculating with time.

At the end of the story the learner is given, not only some closed multiple choice questions about the specifics of the story, but a series of discussion and estimation questions, again designed to blur the maths/every day boundary. In this way we attempted to move beyond the idea that having a set of pre-determined essential numeracy skills is sufficient to help one make efficient decisions. However, without tutor mediation or learner feedback it is difficult to know what an adult numeracy learner, perhaps accessing these materials alone, might make of such questions.

Another issue concerning the tension between 'everyday' mathematics and formal mathematics was the degree of accuracy to which calculations needed to be done, and the different methods used by individuals when performing calculations. In the 'Pay and Wages' unit, we tackled the first of these issues in a game where users are awarded points for being within 10% of an accurate answer, discussed further below. This also arose when using a calculator to work out pay, when the answer was £360.356. Do we focus on the mathematical accuracy of 'rounding 'to the correct penny £360.36 or do we recognize that £360.35 or £360.36 are both good enough when working in real life with money.

A further consideration was the different ways people do calculations. Here we used film to demonstrate how people would calculate a week's pay for a given hourly rate. These were not numeracy teachers, and in fact the film included people who were stopped in the street and asked for a method. In this way we were able to demonstrate a range of methods of calculation, providing downloadable notes as a record and back-up. We supplied the participants with a 'grease pen' and a shop window (with permission from the shop). This enabled the participants to demonstrate their methods visually as well as orally. However, the introduction of a pen meant that they leaned towards formal written methods rather than informal, ad hoc estimates. Only one participant made an estimate using mental maths and then a calculator for accuracy. Nevertheless, we feel that we captured spontaneity and supported real learners' differing approaches to calculations.
Critical issues of pedagogy

The technical environment of stand-alone interactive on-line resources narrows the pedagogic choices that can be made for teaching and learning, especially when compared with face to face teaching. We found it a challenge to stretch the technology towards the approaches we use, by choice, when teaching face to face; for example, collaborative learning, open ended discussions, using learners’ misconceptions and other constructivist-based and learner-centred approaches (Brooks 2013).

The striking difference is that the learning objects must stand alone and there is likely to be no teacher-to-learner or learner-to-learner interaction, although, as mentioned, learners could be encouraged to communicate through existing social media. Assessment must be marked by machine, feedback can be general only, not learner specific, and, as the resources currently stand, spontaneous discussion is not possible. In our experience, in face to face contexts many teachers use a variety of teaching or learning techniques, switching dynamically in response to the learners. When designing the online materials, however, we had to make decisions beforehand and the learning or teaching approaches chosen were fixed in the learning objects.

Assessments modelled on behaviourist principles, where the learner is asked to provide ‘correct’ answers, can be used, such as when reading a bank statement, using multiple-choice answers. However, while this may be useful in some contexts, it is also limited. This contrasts with assessment based on constructivist principles, when teachers or peers attempt to understand the learner’s current thinking about the topic, using questioning and discussion, leading to learners constructing new understanding (Swan 2006). But constructivist assessment is particularly difficult in the online environment which lends itself far more readily to a behaviourist-linked approach, especially when there is no social network to build and share ideas, so the development platforms we used had limited possibilities for programming flexible or responsive comments. Essentially, therefore, we had to use pre-set ‘correct’ answers. However in the game in the Pay and Wages unit we were able to shift the boundaries a little, and encourage estimation, by awarding points if the user was within 10% of the accurate answer.

Clearly we could not employ constructivist style assessment in an online ‘automated’ environment, but on the other hand we did not simply give ‘correct’/‘incorrect’ responses, but designed encouraging feedback in all of the resources.
Learners were also invited to try questions more than once before the software gave an answer and moved the learner on. Animation and video clips were used to provide feedback to learners in a variety of formats, especially where we wished to model more than one method or approach for reaching an answer. Although we hope the material will be used with a tutor or a peer, it was also necessary to design the resources with a lone user in mind.

In a fluid, face to face, teaching situation teachers will adapt the journey through the material to suit the learners. We used different approaches to this: sometimes the material is presented as a set of choices on a web page and the learner may choose what to do and the order in which to do it, other times the user is taken through the material in a fixed path.

A study with school children (Askew et al., 2003) found that the most effective teaching approach in that context was a 'connectionist' one, where links between different areas of mathematics are explored and made explicit. The technologies we worked with lent themselves more to a 'transmission' approach. However, we tried to embed some opportunity for the learner to discover outcomes for themselves. One example is the comic in 'About Time', where the user makes a decision which affects the outcome of the story. In the hourly pay game the user has the opportunity to discover that a high hourly rate is not sufficient for higher take home pay - it depends on the hours worked.

On the other hand, web-based software works very well in being able to make connections between topics. Our modules focus on general domains in which different mathematics skills are needed. As an example, casualised working needs arithmetic (working out wages), while time management includes reading timetables, telling the time and calculating with time. As well as using different areas of maths within a module, we planned links between the modules and to external sites. These features can be seen as implementing a connectionist approach (Askew et al., 2003), although we have had to pre-determine the links between mathematics topics, rather than base them on learners' own ideas and experiences.

**Accessibility**

Working face to face teachers constantly adapt materials and interactions to support accessibility for specific learners, as an example using larger fonts, adjusting language and pace and so on. We needed to build accessibility in to the resources in a way that minimised the number of users excluded from using the materials. The choice of development platform can have an effect on accessibility.
functionality. We used 'Xerte' (www.xerte.org.uk) and 'Articulate Storyline' compromising between Xerte's better accessibility facilities and Storyline's greater flexibility. As mentioned earlier we worked with other experts to improve language and design options. An audio commentary was provided which gave 'added value' to the resource by acting as a friendly guide and offering extra explanation or context where needed. Finally, the use of illustrators to create a set of characters to present information and instructions and act out 'stories', gave the materials an informal, and personal feel.

Summary and conclusion (ways forward)

The numeracy specialists working on the project started with a blank page, other than a requirement to develop MOOCs to support adults' use of numeracy skills in everyday life. This gave us immense opportunities to be creative but in a very short space of time. In order to engage adults the specialists worked in the mathematics/real life boundaries involved in every day problem solving, hoping to enable the learners, as far as possible, to make decisions during their learning. Working together with IT developers, video makers and artists and pushing the boundaries of on-line learning, an exciting and imaginative set of resources have been created. The resources can be enriched still further, by supporting learner discussions through social media and developing on-line as well as face-to-face communities of learners. The first phase of this could be developing an on-line community of teachers and tutors who could share ways of using the resources within various learning contexts.

Despite the constraints of the project, both time and money-related, we had an opportunity to work in a ground breaking way to develop on-line learning materials that are more learner-centred than were previously available. Given further funding the creative development could be continued.

References


See www.articulate.com/products/storyline-overview.php


A WORKPLACE CONTEXTUALISATION OF MATHEMATICS: MEASURING WORKPLACE CONTEXT COMPLEXITY *

Knowing what you know, as distinct from what you do, can facilitate re-contextualisation for change

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Abstract

Recent research undertaken by the authors (Keogh, 2013; Keogh, Maguire, & O'Donoghue, 2010, 2011, 2012), identified the mathematics activity that underpinned what may be regarded as low-skilled, low paid jobs, and aligned it with the National Framework of Qualifications in Ireland. In the course of this research, it emerged that although the mathematics expertise deployed was modest in terms of complicatedness, it was used by workers in circumstances that were both sophisticated and volatile in varying degrees. To this extent, it was discernable that mastery of routine mathematics alone was a poor indicator of a person’s ability to ‘do the job’. Furthermore, a National Survey of People at Work in Ireland, while confirming the Mathematics use/denial paradox, revealed that work was not perceived to be ‘straightforward’ despite widespread adherence to processes, procedures and routines. The authors argue that there exists a spectrum of factors that operate to ‘complexify’ otherwise routine mathematics, with the possible consequence of concealing the role of mathematics and intensifying its invisibility in the workplace and all that entails. This paper describes these affective factors as comprising a workplace contextualization of mathematics which elaborates the complexity of the workplace context in which mathematics at varying levels of complicatedness may be expressed. In this way, workers, employers and providers of learning opportunities may be better informed regarding employability and worker mobility in the long term.

Keywords: complicatedness, complexify, invisibility, employability, mobility

Introduction

A National Survey of People at Work in Ireland, augmented by several case studies, produced strong evidence regarding the character and role of workplace mathematics. It seems that although procedures and routines proliferate in the workplace, and workers adhere to their procedures, they soundly reject the suggestion that their work is straightforward (Keogh, 2013; Keogh et al., 2010; 2011; 2012). The survey substantially confirmed the mathematics use/denial paradox, while the case studies identified hundreds of instances of numerate behaviour in encounter with all Mathematics Domains, but at quite a modest level. The implication is that Mathematics Knowledge Skill and Competence (MKSC) in the workplace was not captured by identifying the level of complicatedness alone, which suggest that all jobs with the same levels of MKSC may not be considered equivalent.
Further analysis of the discourse surrounding the case studies, revealed that work is a social activity, having multiple properties and facets, is performed under pressure of time and accuracy, with attendant materiality, depth, scope and peer to peer accountability, not necessarily aligned with the authority conferred by seniority or role status. These dimensions arise across a range of spectra and combinations such as may differentiate the MKSC required in one job when compared to another, the novice from the expert, between what a worker ‘knows’ and what s/he ‘does’, and may not feature in the official accounts of a case study’s Standard Operating Procedures (SOP). Whether learnt formally, informally, non-formally, tacitly or through analogical rationality (Gustafsson & Mouwitz, 2010), they are highly valued in the workplace. The descriptor ‘work experience’ is used as a unitary concept, implying a depth of understanding that is commensurate with the quantity of time served. However, the case studies, and the findings of the National Survey of People at Work in Ireland, provided the basis for a workplace characterization that is rather more profound and may be described more completely in terms of its Complexity (Keogh et al., 2011). The authors now elaborate these themes as a contextualization of the workplace, in 5 dimensions namely, Accountability, Clarity, Familiarity, Stressors and Volatility in which mathematics knowledge skills and competence, regardless of level of complicatedness, are deployed. Each of these characteristics in turn comprises constituent strands as described in the following sections.

Accountability
A common dictionary definition of the term ‘accountability’ is having to do with taking responsibility or being in some way culpable, connoting a degree of power and control as might be associated with a supervisory or management role. The corollary is that the ‘ordinary’ worker, for whom there are no official levers of power, is unaccountable and completely free of responsibility. The case studies suggest that accountability is a more immediate and tangible concept, comprising a range of components, each defining part of its context namely Audit Materiality, Decision Making, Initiative, Concreteness, Judgment, Planning and Responsibility in degrees of intensity that vary from job to job, as elaborated in the following sub-sections.

Audit Materiality
This facet refers to the impact of error, ranging from the negligible to the catastrophic. For example, a worker in a supermarket may use the same MKSC as a person packing parachutes. This contrast highlights that workers can, by making a simple mistake, compromise the service provided by the employer and expose the organization to embarrassment, loss of business, reputation and the risk of complete failure, despite the presence of appropriate procedures and SOPs.

Decision making
Whether the worker is permitted or expected to make decisions, to what extent, and under what conditions, extends the remit of that worker beyond simply executing a sequence of tasks. This may be further nuanced by the influence of other stressors which may produce both formal and informal interpretations of the decision-making rules or guidelines.

Initiative
A worker may have complete latitude to assess a novel situation and respond accordingly, or be required to apply the SOPs to the letter. There may be a ‘fuzzy’ understanding of when the worker is expected to use his/her initiative and when not. A worker who assumes responsibility for having acted ultra vires, adds an extra tier to the dimension of Initiative component of a job, with a possible consequence of placing his/her continued employment at risk.
Concreteness

It is plain that the lowest level of manual work e.g. digging soil, comprises elements that are fully recognisable, physically present and few, whereas, at the opposite end, some or many work components may be abstract, theoretical or imagined. In the central range of concreteness, a tradesperson may handle elements that are concrete and specific, but expected to take into account other factors such as the appearance of the finished product and its aesthetic fit with work accomplished by other people.

Judgment

From time to time, a worker may have resolve conflicting variables. Such an intervention may form part of the job specification, may be conditioned or may require knowledge and expertise from elsewhere. In this way, the exercise of judgement, in what circumstances and to what extent, adds to the fabric of the context in which MKSC are deployed in work.

Planning

Planning, as a component of context at the highest end of the spectrum, is typically associated with optimising the likelihood of a satisfactory outcome. Low-grade jobs may have little or no involvement in planning, although this may not be the case in the strictest sense. The authors argue that every job contains some element of sequencing tasks with the benefit of local knowledge, keeping in mind tasks that follow, for example, loading goods on a truck while being conscious of the delivery sequence and/or load stability. In this way, the planning dimension of a job may be learned explicitly or tacitly, and may be subject to rules and guidelines that vary in specificity.

Responsibility

Responsibility has become synonymous with guilt and the definition of who pays compensation when something goes wrong. While it is associated with high status and the power to command resources, the authors suggest that it trickles down through the hierarchy, depositing degrees of responsibility at every identifiable level, including those at the lowest level. Each worker has some degree of responsibility to his/her peers, regardless of their principal activities, to produce work on time and in line with specifications.

Clarity

Clarity around the aims and objectives is a desirable feature of the workplace, and one that is obtained in varying degrees. It is a difficult concept to describe succinctly, as its meaning is dependent on the situation it intends to describe, particularly so in a rapidly changing workplace. At every level in an organization, it is critical that everybody has a clear understanding of their purpose, whether in anticipation of an outcome in the near-, mid- or long-term. The authors suggest that the extent of clarity in the workplace is a combination of the interaction of several factors namely, *Distracters, Priorities, Reflectivity, Information Sources, Vision* and *Information Completeness*.

Distracters

This refers to the likely presence of elements that may distract the worker from their purpose, or add the potential for confusion and error. Simple, tightly defined jobs, involving one or few elements would seem to be free of distracters, except perhaps boredom born of narrow, repetitive cycles. Other
distracters may be explicit and easily identified and discarded. Towards the upper end, it may become more difficult to discriminate between pertinent factors and distracters that are embedded and plausible.

**Priorities**

The setting of priorities is a function of the control and command structure in organisations, but not exclusively so. In the more project-mature organizations, such milestones are agreed amongst the individuals with the relevant expertise, each of whom must juggle their local resources. Discretion regarding priorities is not necessarily aligned with job status, especially in global enterprises that commission very specific outcomes from their plants spread across the World. To this extent, the exposure to competing priorities, however set, is another descriptor of workplace context.

**Reflectivity**

Reflective practice in industry is common, although it may be realised as project review, strategic planning, periodic reports, performance review, and systems and financial audits. It is pervasive and hierarchical insofar as the outcomes tend to flow upstream. It may be initiated in reaction to a costly error, to identify a systemic flaw, in which case the remedies flow downstream. Reflection, in pursuit of continuous improvement may inject a force for change in the metrics and methods employed in, and therefore, constituting, work practice.

**Information Sources**

The sources of work information may range from single, simple source, expressed in job specific terms at the lower end, to multiple sources in various formats, referencing concrete, abstract and theoretical data on familiar and unfamiliar topics. It may be verbal and non-specific, requiring interpretation and locally-attuned inference. It may be deduced from dialogue and rumour, or adduced from relevant experience and may vary in reliability. Dealing with multiple information sources would seem to describe a crucial element of any job, and could impinge on other context strands such as clarity, and accountability.

**Vision**

Vision, in this sense, has to do with the meaningfulness of the job to the individual. It alludes to the sense of purpose, beyond the boundaries of the job and how the output of the job integrates with surrounding activity to produce something that is whole in itself. For example, the collection of meter readings for input to a spreadsheet is a limited experience in the absence of further explanation. In contrast, acquiring a broad view of an organisation’s aims and position within the market can influence the way in which work is done and the utility of the supporting artefacts, including MKSC.

**Information Completeness**

Work information is likely to be complete in circumstances that are tightly controlled and closely monitored, although not necessarily so. Incomplete or imprecise information, imports guesswork and uncertainty, however informed, and tends to increase the risk of error. At the leading edge of industrial research and development, complete information is the object being pursued. Creative and innovative activities feature aspects that are known and unknown in extent, and the recognition that there may be other unknown-unknows, and perhaps even the unknowable. That this is a facet in the workplace that varies in impact on how work is done is another workplace context attribute.

Exposure over time may contribute to the extent to which the characteristics and properties of the workplace become familiar.
Familiarity

Familiarity is a gauge of what has become known as the ‘comfort zone’. This is a concept rooted in Adventure Education which indicates an anxiety-neutral, risk-free environment conducive to steady performance (White, 2009). It may be realised in the workplace as a state in which the worker is well practiced in the performance of a sequence of tasks, in unchanging surroundings, in encounter with stable, recognised components. Beyond the ‘comfort zone’, lies the ‘stretch zone’ in which it is thought there exists a fundamental disequilibrium which promotes intellectual development and personal growth (Panicucci, 2007). Such a workplace presents challenges to the worker that are, nonetheless, within their capacity to achieve.

An overall sense of familiarity, or otherwise, may be the product of Specificity, the nature of the Principal Activity, the range of job-related Elements, their associated Facets, the impact of Groups in work and Routine.

Specificity

This refers to the extent to which components of a job are specific, recognised and unvarying at one extreme, in contrast with the abstract, theoretical, and widely varying at the other, with gradations in between to account for degrees of transformation from one to the other. The implications for the context in which the experience of work occurs are clear, encapsulating a factor which presents more challenges as specificity diminishes in proportion to the advance towards the abstract.

Principal Activity

The worker’s principal activity adds a determining context characteristic. A single, closely defined and monitored, solitary activity has a simplifying effect on the worker’s job. In contrast, a professional person, at the leading edge of his/her discipline is likely to encounter a wide variety of familiar and unfamiliar situations, diagnose problems, develop creative solutions and implement them, in multiple interacting activities. In the interim, individuals may switch between increasingly varied activities in response to workplace demands.

Elements

A job may comprise a single element at the basic level, or progress through an unvarying sequence of tasks, to one that is moderately, or extensively influenced by internal or external factors, some of which may be unfamiliar. This reflects complexity in the sense of the number of elements and ways in which the elements can be combined. As these quantities increase so too does the degree of complexity.

Facets

Not to be confused with Elements, Facets, in this case, deals with the extent to which elements may be nuanced, and not solely an empirical count. This connotes a capacity to detect and interpret a particular instance of an element and to act accordingly. Facets may become familiar over time, but that may not preclude the emergence of a novel occurrence, all of which conjures up an influential consideration of the workplace context. For example, the job’s SOP addresses each Element i.e. work order, delivery address, delivery type (document, computer media, property deed etc.), related security and operating principles. However, each individual client may have formal and informal preferences or Facets, to which the worker must adhere to retain their custom.

Group

Solitary activity can be challenging to those unsuited to working alone, but may be appropriate to a
person unsuited to working in a group. Engaging with a small group, becoming familiar over time, may present less challenges than belonging to a larger group that is mainly co-located. The ability to participate in an unfamiliar group, which may be large and partially or substantially distributed across a number of locations in geography, time and culture, implies a maturing set of knowledge skills and competence, and confidence in one’s mathematics and other capabilities at their point of use.

**Routine**

Following a familiar set of tasks in the same sequence, repeatedly, may be a product of the constraints imposed by procedure or a set of procedures, conditioned by internal or external factors. However, as the survey findings have shown, procedure accounts for just over half of workplace activity, the balance being evoked by unspecified factors such as this present workplace contextualization is seeking to capture. Routine is a ubiquitous dimension in work, and is not completely positive in its implications, but is worth regarding for its descriptive qualities. However, many workplaces may differ in the range of factors, including routine, that could contribute to stress experienced by workers.

**Stressors**

The uniqueness of the individual makes it impossible to be definitive about the causes and effects of stress in the workplace. The authors do not presume to comment on the possible effect of ‘distress’ in the workplace, but rather to introduce a range of factors that either singly or in combination, may change the experience of work, while using the same level of MKSC or other skills. The suggested factors are: Constraints, Pressure, Problem-potential range, Solutions, Sources of stress, and Structure of the workplace.

**Constraints**

In the unlikely event of limitless resources, constraints are imposed to optimize output minimize the input, in terms of time, materials and labour. Ranging from the clear and simple at one end of the spectrum, to those which are broad, imprecisely defined and inferred from internal and external conditions at the other, constraints have the potential to simplify or complexify work. The presence of a few clear and fixed constraints is characteristic of a job at the lower end of the scale, whereas, multiple, flexible, interrelated and mutually regulating constraints may add substantially to the performance of work towards a specific outcome.

**Pressure**

Workplace pressures come in many guises including the cultural, temporal, personal, professional, philosophical and political. Most common of these has to do with priority, urgency, accuracy and expectations. For example, completing a set of calculations under extreme and continuous time pressure is quite a different proposition to performing the same mathematical activity at leisure. In this way, the experience of work may be described by levels of pressure ranging from none, through loosely defined expectations, to issues of volume throughput targets, compliance, quality, accuracy, culminating in extreme pressure as may feature in cases of emergency.

**Problem - potential range**

Simple jobs exhibit little or no potential for problems, excepting equipment breakdown. Even then, the worker may be required, or permitted only, to report the situation by triggering a call for attention. Jobs may increase in complexity in line with the number and possible range of familiar problems, through to levels of expertise needed to deal with multiple, mutually dependent, independent and/or novel problems.
Solutions

Similarly, the range of available responses to problem situations escalate from there being one response to all problems, through a continuum of the application of familiar solutions to familiar problems, progressing to mainly unfamiliar problems to that requiring novel responses and creative solutions to unfamiliar problems. Each of these levels of expertise, adds to the palette with which to discriminate between the experience value of different jobs, and the selection of the appropriate mathematics-based response.

Sources of Stress

There may be few or many centres from which workplace stress may arise. They may be internal or external to which the individual is exposed partially, moderately or broadly. They may be avoidable, or an integral part of the work, having a relentless and cumulative effect. A more complete treatment of stress in the workplace is beyond the scope of this document, however, dealing with multiple sources of stress in work, is, potentially, very challenging to the individual, and may affect deeply, the environment in which MKSC finds expression.

Structure

Working in a highly structured, tightly defined organization, lends simplicity to its functions, albeit at the cost of flexibility, which itself might cause stress. Clarity concerning demarcation, rules, accountability and so on, may cause lower levels of stress. Loosely structured, broadly defined, matrix-configured organizations, may give rise to increased levels of stress as a result of their fluid, inherently unstable nature, which could be described in terms of volatility.

Volutility

Volutility is the property of frequent and unanticipated change that may be short-lived. The extent of volatility in the workplace necessitates the capacity to respond to sudden and new developments in the market or the customers’ demands. It may be characterized as occurring over 5 transitions namely, completely stable, mainly stable, moderately unstable, mainly unstable, and totally unstable.

Organizations and their embedded jobs are subject to change with varying degrees of need and urgency, as may be profiled by Conditionality, Demands, Diversity, Predictability, Range and Risk.

Conditionality

The performance of work may be subject to a variety of conditions, the state of which may be determined by known or unknown, internal or external factors, themselves being influenced by other conditions. The range of affective conditions may differ in quantity and power. Other jobs may be immune to conditions, requiring the same response every time. The recognition of conditionality and the extent to which it pertains to a job, reflects the set of appropriate knowledge and skills and the competence, in the broadest sense, that it develops.

Demands

The demands on a job justify its existence insofar as it has been created to fill a perceived need. Simple jobs have few demands that are clearly defined and relatively easily met. More complex jobs feature multiple demands that may not easily coalesce and may compete for resources. At this extreme, the worker sequences his/her activities, and may deploy innovative methods to cope. The effect of multiple, competing demands, may de-stabilize the job to an extent that is unlikely in a job profiled by one or few demands.
Diversity

Diversity is the property of difference, rather than breadth. In the workplace, it refers to the extent of heterogeneity, and coherence of the tasks. While it makes sense to gather together mutually dependent tasks, requiring elaborations of related sets of knowledge, skills and competence, there are jobs that occupy the boundaries of other specialities enabling cooperation and communication. For example, a change-management specialist may need to communicate with engineers, accountants and computer software developers, in order to ensure cohesion and the desired outcome. In contrast, a completely homogenous workplace implies little scope for diversity that may not be accounted for otherwise.

Predictability

Complete predictability in a job engenders familiarity, stability, clarity, and the establishment of routine. Complete unpredictability adds depth to many of the other factors including stress, accountability, familiarity and the absence of clarity. The majority of jobs probably lie between these two poles, as evidenced by the survey findings and case studies.

Range

The breadth of components associated with a job confers the potential for complexity commensurate with its range. Single-issue jobs are simpler and more straightforward when compared to those encompassing several issues distributed a broad, yet coherent, landscape.

Risk

In this context, risk alludes to certainty of outcome and the extent to which it is confined. Jobs for which the outcome is almost certain (e.g. attending a machine that cuts metal forms with a die) have quite a different character from stock-broking. The risk associated with the former has more to do with the wellbeing of the machine operator rather than whether the die will produce the expected form. The activities of the latter risk the organization’s resources in the expectation of substantial gain, while at the same time exposing it to potentially catastrophic loss. Risk may be classified as that component of a decision-making process for which there is insufficient information. It may not be permanent and pervasive and may be conditioned and limited. Most jobs are located along a continuum between these extremes, exerting concomitant influence on the context in which Mathematics and other knowledge, skills and competence are used.

Workplace Context-Complexity Protocol

The Workplace Contextualization of Mathematics described in preceding paragraphs, represents an extensive range of parameters with which to differentiate between jobs, regardless of the level of complicatedness of their mathematics knowledge skills and competence. The unique nature of each job may be reflected by the extent to which these parameters are present in the job specification and profile. That these workplace characteristics shaped the context in which MKSC were used, inspired the authors to develop an appropriate framework to capture the essence of the workplace namely a Workplace Context-Complexity Protocol, to enable the context in which MKSC are used in the workplace to be more fully reported.

Protocol Structure

Each of the main context headings, Accountability, Clarity, Familiarity, Stressors and Volatility, is listed with its attendant properties as sub-headings, in the attached Appendix 6.1. Each property of the protocol is scaled and described across 5 transition states, and assigned a two-step scoring range to permit interpretation toward the lower or upper end of the scale. For example, The Volatility property, Predictability, may be scored at 5 or 6 to indicate that a job may feature moderate unpredictability that...
is more than the lower adjacent category (4) but somewhat less than would justify the next higher category (7), i.e. mainly unpredictable. This scoring system recognizes that there is no empirical scale to measure these things yet, and that the boundaries are not sharp and clear cut. Nevertheless, guided by the evidence available and by working through each heading and sub-heading in turn, it is possible to produce a detailed profile of the workplace context. In this way, the Workplace Contextualisation of Mathematics can be used as a protocol for profiling the Context-Complexity of a workplace. The idea is that it is possible to capture the complex circumstances in which fairly routine mathematics knowledge skills and competence are used in many workplaces. The possibility that an individual may deny their use of mathematics, or dismiss it as common sense, argues in favour of a mechanism that is capable of making the mathematics more visible and more fully accounted for. The structure and application of the National Framework of Qualifications in Ireland (NFQ)(QQI, 2012) and its alignment with formally established complicatedness of mathematics at different levels is reported elsewhere (Keogh et al., 2010).

This present work suggests an augmentation to the NFQ to facilitate the recognition of, and communication about, mathematics activity in work for the benefit of mathematics teaching, learning and assessment.

Extended NFQ Illustrated

The provisions and structure of the of the NFQ reflect its provenance and purpose namely to set and maintain the standards expected as learning outcomes, formally acquired, across 10 levels, and detailed in terms of Knowledge, Skills and Competence. In contrast, the learning outcomes required in the workplace are dynamic, in reaction to change to meet its own needs, regardless of domain, and untrammelled by the depth and breadth necessary for progression in formal learning environment. Competence in the workplace is a concept that bears little resemblance to that accounted for in the NFQ, and presents a more ‘spikey’ profile that is tuned to local conditions rather than conformance with a remote, generalized description. In this way, it seems that mathematics in the workplace may not be accounted for fully in terms of complicatedness alone.

The Workplace Contextualization of Mathematics, described herein, and the Context-Complexity Protocol which it underpins, are the products of in-depth case studies comprising doctoral research. At the time of writing, no comparable frameworks had been located to capture similar facets of the modern workplace. Nevertheless, these tools offer the prospect of extending the provisions of the NFQ, to enhance mathematics visibility, and to recognize the sophisticated circumstances in which MKSC is used in the workplace. The application of the Context-Complexity Protocol to a sample case study discussed in the next section, demonstrates the added power to communicate an extended NFQ would offer for the benefit of the individual, employer, recruiter and curriculum developer.

Sample Case Study

‘R’ is a Warehouse Picker. He is required to retrieve 60 items per hour from a warehouse that stores approximately 3 million separate documents, files, deeds, legal briefs, and computer media. He is guided by a ‘work order’, one for each customer, issued by his line manager. The ‘picks’ are distributed across 2 buildings, each of 4 floors, fitted with up to 26 storage racks on each floor, each with 52 bays, each with 3 shelves, each of which may contain 27-30 boxes of documents. There are several fireproof safes and secure vaults to contain sensitive documents and electronic media. Each ‘pick’ is tagged with a barcode which indicates its location by referencing building, floor, row, bay and shelf, but no more. R is provided with a scanning device which lists the barcodes in alphabetical sequence – not by optimal route. It is not feasible to accumulate picks as his work progresses from beginning to end. Instead, he deposits parts of the pick at strategic locations around the warehouse to be gathered at the end of the session. The pick route is planned by his taking account of the locations
of cargo lifts, stairs and access points between buildings, and the next ‘nearest neighbour’. He must decide how much time to devote to a pick that is not in its reported location, bearing in mind the need to complete his work within the time allotted and the impact on the delivery person and customer service of omitting the requested document.

This warehouse picker has little formal education. The level of mathematics he actually displays in the performance of his job scarcely meets the learning outcomes at level 1. He has the lowest status in the workforce, yet he bears ultimate responsibility for picking the correct item and making it available for delivery to the correct customer. The work instructions he is provided with are clear in general, but surrounded by distracters, competing priorities, and moderately incomplete information. He reflects on his work and introduces unauthorised ‘work-arounds’ to compensate for the shortcomings in the warehouses’ design. He is informed by different but familiar information sources, although constrained, partially, by the preceding and following picks. Several years of experience has resulted in mid-range familiarity and subject to stressors generally in the middle range. In arriving at complexity level indicators, each item of the protocol was considered in turn and matched to the band that most closely described his work.

The outcome of this matching process is shown in the next section.

Extended NFQ – Sample Case Study

The standard NFQ approach to the accreditation of learning when applied to a sample case study, represents the identified mathematics knowledge and skills at level 1, having met the criteria detailed in the relevant Significant Learning Outcomes (SLO) set out in the assessment criteria. In keeping with standard custom and practice, the same level is credited to the four Competence sub-strands, namely Context, Role, Learning to Learn and Insight, each shown separately in Figure 1.1 on the assumption that these properties are somehow embedded in the learning process.

![Case Study 1. NFQ Level - Standard](image)

*Figure 1.1. Company A, Case Study 1, Mathematics Knowledge, Skills and the Competence Strands of Context, Role, Learning to Learn and Insight - Standard interpretation.*

However, an evaluation of the Competence in Context and Role, based on the evidence of observations and on interpreting the formal provisions of the NFQ, exceed that of the Mathematics Knowledge and Skills levels identified in the Case Study – Job Shadowing phase. Figure 1.2.
The scale of Learning to Learn-recognition is biased in favour of the formal learning structures, leaving no scope for the recognition of tacit, informal and non-formal learning. The apparently extreme score recorded for Insight, reflects intelligent exposure to the workplace and its capacity to promote tacit rationality and analogical thinking.

The impact of having applied the Context-Complexity Protocol to Case Study 1, is shown in Figure 1.3. While a separate trace is shown for each mathematics domain for consistency with the broad aims of the research, their confluence would seem to indicate their interdependence rather than distinct and discrete behaviour. The plots shown represent the mean score of the factors comprising each dimension of workplace context-complexity.

When these data are combined, the resultant graphic, Figure 1.4, captures not only how complicated the Mathematics Knowledge and Skills deployed in this particular workplace are, (plotted at NFQ level 1), it also shows the observed, rather than assumed, levels of competence in Context, Role, Learning to Learn and Insight, appropriate to each Mathematics Domain. The key additional job profile information reports Context-Complexity dimensions which effective performance in the workplace demands.
The profile of the context-complexity communicates new information about the workplace and a sense of what the individual ‘knows’ in addition to what s/he ‘does’. While the complicatedness of the MKSC at NFQ level 1 may be characterized as routine, the circumstances under which they are used requires their deep understanding, in support of thinking and as a guide to action.

**Implications for Mathematics Teaching & Learning**

The implications for mathematics teaching and learning for and by adults, may be profound, especially when considered in tandem with other outcomes of this research. The findings of the national survey associated with this research tended to confirm the importance of the context in which mathematics knowledge, skills and competence are realised. While this is not new information, it contributed to the formation of the Workplace Contextualisation of Mathematics detailed in the attached appendix, 6.1. By embracing this contextualisation of the workplace, teachers of mathematics have the opportunity to mould the learning environment accordingly. For example, a problem could be posed that, while requiring the application of mathematics techniques, might invite an answer expressed in terms of the ‘least-worse’ outcome. While this strategy may challenge the teacher’s imagination, it could highlight the idea that mathematics can support strategic thinking and need not be an end in itself. In a forthcoming companion document, the authors introduce the concept of a subject-centric perspective of cultural historical activity theory as a possible explanation of mathematics invisibility in the workplace and suggest a mechanism by which it may be measured. Taken together, these devices may offer an holistic approach to establishing a realistic starting point for adults learning mathematics, and a road map for future action.

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ACCREDITATION NOT AGGRAVATION

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Abstract
This paper describes an action research project that investigated a range of activities to improve learners’ mathematical communication skills. It also gives details of a subsequent case study that illustrates how technology can provide a means of overcoming some of the difficulties learners and tutors face in communicating about numeracy, while developing confidence and enhancing skills in a rapidly changing learning environment.

Key words: accreditation, communication, confidence, evidence, and technology

Background
For many, especially older, adult learners, the experience of mathematics is that of rote learning and being asked to complete pages of ‘sums’ independently of one another. In recent years the shift in accreditation of numeracy skills towards communicating ideas and meaning has been an awkward one for both learners and assessors and Chinn suggests that ‘problems and confusions are both with the vocabulary of maths and with the language (semantics) of maths’ and that difficulties are a ‘consequence of the way word problems are written and constructed’ (Chinn, 2012).

Improving communication skills within the context of, and with specific application to, numeracy is a key part of adult numeracy learning and tutors of adult learners are faced with the challenge of providing evidence of learners’ descriptions and explanations of mathematical processes and outcomes for accreditation or other purposes. This paper describes an action research project that investigated a range of activities to improve learners’ mathematical communication skills. It also gives details of a subsequent case study that illustrates how technology can provide a means of overcoming some of the difficulties learners and tutors face in communicating about numeracy, while developing confidence and enhancing skills in a rapidly changing learning environment.

Action Research
Learners within Monmouthshire Adult & Community Education took part in an action research project between October 2012 and February 2013. The purpose of the project was to investigate ways of developing the communication skills of adult numeracy learners, with specific relevance to fulfilling the Essential Skills Wales (ESW) qualification requirements at Level 1 and 2 of ‘describing a practical problem or task’ and ‘describing and explaining the results of calculations’.

At the start of the action research, learners from two small adult numeracy classes assessed their own confidence in four key communication skills: identifying facts and ideas; choosing appropriate vocabulary; verbal presentation skills and writing skills. A range of interventions was trialled over a three-month period. These included: peer review of work completed by previous learners; use of writing scaffolding sheets and mini practice tasks. The learners as a group and, following the trial then discussed the interventions; they were required to repeat a self-assessment of confidence in these skill
areas. (Fig. 1 shows an example of the results collated from the skill ‘choosing appropriate vocabulary’)

![Figure 1](image-url)

**Figure 1. Finding words to describe what I mean.**

Although the results of the action research showed that the interventions had developed communication skills overall, it was noted that it would be beneficial to investigate alternative methods of supporting and developing skills, which may be particularly important to learners with specific learning difficulties such as dyslexia.

Following the action research project and through discussion it became apparent that one form of intervention that had not already been explored was the use of technology. Although learners in both of the classes involved in the research have regular access to computers and word processing software and use these when writing about mathematics, the process of typing a word processed document is much the same as hand-writing onto a page with no inherent support for the organisation of the writing.

The availability of Apple iPads for use within numeracy classes in Monmouthshire Adult & Community Education led to the discovery of the application ‘Story Creator’, an education tool that allows iPad users to create simple e-books using video, photos, text and audio.

**Accreditation**

The question that could be asked by both teachers and learners is why, when learners are being assessed for their numeracy/mathematics skills, are they being asked to provide explanations of their choice of methods and results? The reason for this requirement is that in real life, mathematical thinking and processes do not begin and end with manipulation of numbers (Ball, 2007; Schoenfeld, 1992). If learners are to apply their learning then they need to be able to consider how they are going to address problems, where they will find the data necessary to solve problems, which computational methods should be employed and how to evaluate obtained results. If accreditation is to reflect a learner’s ability to use mathematics purposefully then this whole process needs to be assessed.

While computational expertise can be easily evidenced without the need for any words, explanations and evaluations often need to be verbalised. Assessment of these skills may take place in...
the classroom during discussions or by integration within other projects or activities but evidence that the learner has achieved these skills needs to be recorded in some way to ensure the rigour of outcomes. Traditionally the learner providing written accounts, accompanied by documentation of teacher assessment, records explanations and evaluations; however, the exclusive use of this method of evidence needs to be challenged with regard to its validity (Scottish Qualifications Authority, 2009). This is particularly so where the learners have little or no literacy, even though their cognitive skills mean that they are able to use numbers within everyday applications and may be developing appropriate evaluative skills. We need to make clear distinctions between assessment of skills and means of providing evidence.

Unless awarding organisations specify an assessment method it is up to the teacher/assessor to select how that is to be achieved. Internal quality processes need to be in place to ensure that the method chosen meets the usual assessment requirements of reliability, authenticity, validity etc. Where learners have literacy difficulties, it could be argued that the validity of the assessment may be compromised if learners are asked to record their ideas in writing. Are we assessing the learner’s ability to write or their ability to evaluate?

Endeavouring to minimise assessment issues which arise as a result of a learner’s ability (or inability) to write does not mean that communication skills should not be addressed in our mathematical teaching. This project does not aim to put writing skills to one side but to look at how the development of communication skills can be embedded within mathematical teaching.

In this project the accreditation chosen was a credit-based qualification (Agored Cymru, 2013). This type of qualification enables learners to target specific skills determined by their personal, academic and vocational needs and allows them to combine units of communication, maths and ICT within a qualification. Even though the units chosen address specific skills, these skills are not taught or used in isolation. In this instance the focus of the unit was on measure but it also required the learner to use the four rules of number, ratios, estimation, 3D shapes, knowledge and use of mathematical language, problem solving and interpreting the results of calculations. In addition to this the learners were developing their communication and ICT skills.

The Learners

The ‘Story Creator’ application was used with a group of three adult learners. Two of the learners, both female, had progressed to the class having previously attended local Family Learning provision and the third was a new learner, male, wishing to work towards achieving a level two numeracy qualification in order to access further education. All three learners were assessed as currently working at level one of the Essential Skills Wales standards (Essential Skills Wales, 2009). Both female learners had engaged in Family Learning as a means of improving their own skills whilst also being able to support their children. It was acknowledged early in the course that all three had recollections of negative mathematical experiences in school but that, for the two women, the Family Learning class had provided an opportunity to begin to change their perceptions of, and build confidence in, their own mathematical abilities.

Since this class commenced quite late in the academic year, it was considered more appropriate to offer a short numeracy course using Agored Cymru accreditation. This gave the learners the opportunity to demonstrate the skills required for measure within the context of a garden design project. The specific assessment criteria include ‘outline problems to be tackled’ and ‘present and explain the results of calculations using measurements’ giving the learners an opportunity to use their numeracy communication skills.
**Issues Surrounding the Use of Mobile Technology for Evidencing the Assessment of Skills**

Whilst the education centre used for the study was in the fortunate position of having the use of iPads within the classroom, it did not have access to Wi-Fi which meant that learners were not able to download the graphics which could have further enhanced the presentation of their work. In this instance the problem was overcome by the learners taking photographs or drawing. In effect they were creating their own graphics.

Not all learners initially embraced the use of iPads, which were seen as another barrier to overcome within the learning process. The benefits of keeping up with new learning and leisure tools, particularly for those with children, were explored with the learners. Any anxieties were soon overcome as they became more adept with their iPads.

The experience of the teacher in using mobile technology was also a limiting factor. Story Creator may not be the most appropriate application and the time to trial others would be beneficial. For example, it would be desirable to use an application which included graphical backgrounds to facilitate multiplication using the lattice method or to aid the drawing of 3d shapes. In this instance, complex calculations were carried out on paper and photographed for inclusion in the Story Creator work. This was not ideal but did demonstrate the learners’ problem-solving skills in overcoming the issue. (The original paper based calculations were then submitted for accreditation alongside the e-portfolios.)

Maintaining copies of learners’ work also created a challenge, especially with no immediate Wi-Fi access. This was easily overcome by the tutor using standard internet storage devices once the lesson was complete. Another possible solution would be to use a tablet device that allows the attachment of USB storage devices.

**Outcomes**

Apple iPads with the Story Creator application were available for the class to use in the eighth session of a ten-week course and learners created e-books to record evidence of how they had calculated the cost of soil to fill their plant tubs and how much water they needed in order to fill a circular pond. Learners studied the mathematical skills required to complete the garden design task in the preceding weeks and, during these sessions, evidence for assessment criteria concerning computational skills was collected using non-ICT based methods and presented in a traditional paper based portfolio.

The learners had no experience with the application before the session and after an initial reluctance to try it, possibly caused by a lack of confidence in using new technology, they engaged with this method of learning and collecting evidence quickly and fully. Learners expressed a strong desire to complete their e-books regardless of how much additional time it would take outside of the usual session duration.

An unexpected outcome of using the e-books as a means of recording evidence was the way in which it supported learners to organise their thoughts and calculations. Since there is a limited amount of text space available (a maximum of one line), and only one photograph or diagram per page, learners were encouraged to consider the order in which they tackle the stages of a practical numerical problem. All three learners, one of whom has been formally assessed as having dyslexia, were able to organise their e-evidence in such a way as to introduce the problem, explain the information to be collected and used, describe the calculations step-by-step and both describe and explained their results. This was in contrast to the results of the action research project, where several learners still had immense difficulty organising their numerical problems even after the interventions. Additional research using this or a similar application is needed in order to test this hypothesis. This would be of particular value to learners for whom organisation of ideas is a problem.
One of the original aims of using a multi-media storybook was to alleviate anxiety around writing down ideas and to encourage learners to make audio recordings as an alternative. In fact, all three learners refused to use the audio recording tool, feeling too self-conscious to do so and preferring to revert to writing. However the quality of the text produced was high and the structure of the e-book, allowing only one line of typed text per page, meant that learners were required to focus on the main topic of each stage of the calculation and to express this succinctly.

With the restriction in the amount of text allowed, learners were keen to fill each page with visual evidence to support their text. They did this by using photographs taken during the session and simple drawings (not to scale), which were labelled to show the measurements they needed and had taken. The photographs included learners taking measurements, showing measurements on measuring instruments, screen shots of web information, idea boards from group discussions and shots of written calculations. The combination of visual and text based evidence appeared to give the learners confidence in what they were describing and explaining.

During the final session the e-evidence books were shared with the rest of the class and learners were given an opportunity to discuss their experiences using the iPads as a tool within the classroom. All agreed that it had been a more fun way of producing evidence than simply writing on paper and that they had enjoyed the task more because of the availability of mobile technology and its multi-media approach. The global consensus was a sense of pride in the style, quality and completeness of what had been achieved in such as small space of time and a sense of excitement at the possibilities of using the tool again in learning and exploring its uses in other settings.

Since the main aim of the e-books is to provide an alternate method of presenting evidence for accreditation, it has been imperative that the e-evidence created by the learners undergo standard Agored Cymru quality processes (Agored Cymru - Quality Assurance). Reactions from internal quality assessors have been mixed – in fact there appeared to be some reluctance to internally verify the assessment of this work. This was at odds with the excitement shown by the learners, and teacher, at the opportunity to explore and use new technology. The lack of traditional paper evidence appeared to unnerve some internal verifiers although once they were shown how to access the e-evidence they were reassured that the learners had indeed fulfilled all the criteria.

The question of authenticity arose since it could not be proven purely from the e-evidence that it was the learner’s own work. It can be argued that this is the same for traditional paper based portfolios of evidence. Internal quality processes need to be in place to ensure that authenticity can be guaranteed whichever form of evidence is used. In fact, the e-book provides very personalised evidence of mathematical task organisation, implementation and evaluation. The use of photographs of written calculations meant that some assessors found it difficult to read, and therefore check, the calculations; however these could be validated by comparison with the accompanying paper based calculations.

**Conclusion**

Overall the experience of using mobile technology to record and present evidence has been a very positive one for the learners in terms of enjoyment of learning and development of organisation, communication and numeracy skills. In addition, it demonstrates that evidence-gathering methodology need not impede the assessment process and this innovative approach removed the often perceived toil of portfolio building. There are still issues that need to be addressed; most notably the engagement of those internally verifying the assessment process and it is considered that they would benefit from observing the use of such technology within the classroom in order to fulfil the complete quality assurance process and to build their own confidence in alternative methods of evidencing skills.
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USING GREEK AND UK CULTURE COLLABORATIVELY TO IMPROVE MATHS TEACHING AND LEARNING

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Abstract
Evgenia, a teacher of mathematics with 20 years’ experience in Greece has recently completed the Diploma in Teaching and Learning in the UK. Zaeed, who has taught Maths for the last 7 years in the UK, has mentored Evgenia through the teaching programme in the UK. Evgenia decided to carry out a research project to evaluate teaching methodologies and cultures adopted in Greece and compare them with what she found during her placement with a group of 24 students taking GCSE Maths in an evening provision at Kendal College. The results were quite profound and led to an attempt at devising the perfect solution for the United Kingdom’s ‘maths deficit’.

Key words: mathematics; learner-centred, improving teaching and learning; UK; Greece.

Introduction
Before her return to the UK, Evgenia had taught in Greece for 20 years. However, it was in Britain that she had obtained her BSc and MSc in 1990, before she started her teaching career. A number of questions arose in her mind while Evgenia was teaching adult mathematics in Kendal College under Zaeed’s mentoring. In particular, the British educational system seemed very different from not only the Greek system but also the one she had encountered as a student of a British University in the 80s.

Since both the British and Greek systems have pros and cons, an action research project (Anagnostopoulou, 2013) was undertaken to examine and compare the two teaching methodologies, aiming at a combination that could improve the mathematics teaching and learning experience. Within the project, many aspects were considered:

- The educational theories and principles followed along with their applications in practice
- The background knowledge of the adult learners, i.e. the mathematical concepts and the depth of the curriculum that they acquired in primary and secondary education
- The school hours spent and the individual study of the learners
- Teachers’ expertise including their subject knowledge and the requirements for becoming a mathematics teacher imposed by the governments
- How the actual lesson is structured, the level of activities and the infrastructure of the classrooms
- How the teachers feel with respect to their teaching job and the learners’ feelings concerning the mathematics lesson
- The market competition and the social trends of each of the two countries
Teaching and learning mathematics in UK and Greece

Teaching and learning mathematics in the UK and Greece are two different things. There are similarities of course, but the differences are more evident. To see the actual picture, we discuss each of the above aspects below.

Education theory

No difference in theory

According to the teacher training courses in the UK and Greece (Evgenia completed both), it is evident that the theories and principles are exactly the same. Both systems support a learner-centred environment where inclusion, differentiation, equality and diversity must be evident. So why are they so different? Evgenia’s action research project concluded that even the learners are different with respect to their attitude concerning learning (Anagnostopoulou, 2013).

Difference in practice (?)

The answer to the above question is that it is the practice that differs; i.e. the theory that the teachers in each country learn is exactly the same, but when it comes to practice, external factors like time constraints, legislation, common practice, colleagues’ attitude, prior history, fear of losing their jobs, following what the others are doing, fear of differentiation, curriculum design and competiveness, lead the teachers to completely different practices.

In Greece, teachers are more teacher-centred despite what they learnt, because the system and the society support a teacher-centred environment. The paradox here is that the same system that teaches teachers to be learner-centred pushes them in the opposite direction.

On the other hand, in the UK, teachers are far too learner-centred. According to the theory, teachers and learners are allocated responsibilities and rights concerning the teaching and learning processes. However, when it comes to practice, a great deal of rights belong to the students, whereas almost all the responsibilities fall on the teacher. For example, the teacher is responsible for the learning outcomes, the classroom management, the success of their learners, their absences, etc. Here, the paradox is that the teacher is the centre of a learner-centred education. It seems like the definition of ‘learner-centred’ is degenerated, as others decide for the learner in a learner-centred system. Ackland (2013) spoke at the 20th ALM Conference about how we limit the mathematics’ powerful potential, restricting adults to the applicable functional learning; she, characteristically, said:

“…selling maths only for the practical reasons… Where does the learner take part in it, when we narrow down the possibilities of exploring the areas of mathematics? How much learner-centred is this? Is it teacher-guided-learner-centred?”

Evgenia quotes her personal discussion with her tutor of DTLLS, Mr. Paul Smith:

“Wait a minute Paul. I am an adult. I’m supposed to make my own decisions. So I decide that I am happy with what I am learning here, but I am too bored to complete my portfolio and among other things in life I have to do, I decide NOT to complete my portfolio but to fail this course; because it is MY choice. Would you be hold responsible for my failure?”

Mr. Smith replied:

“Yes, because I failed to inspire and motivate you enough to complete the course.”

So, in fact, the adult learner does not have full control of their decisions. Others should do their job and try to motivate and inspire the learner in order to do what they are supposed to be taught.

To sum up, both educational systems are based on a learner-centred theory, but they extrapolate into different directions when it comes to practice. The result is a Greek system that is not learner-centred enough and the UK one being overly so, as illustrated in Figure 1 below:

![Diagram of educational systems]

**Background knowledge of the adult learners**

It is observed that the English adult learners have a much lower background knowledge that the adult learners in Greece.

Michael Gove (2011), Secretary of State for Education, in his speech to the Royal Society on mathematics and science, compares the UK learners’ background knowledge with other countries and states:

… it’s clear that not enough young people secure a basic level of competence in maths. Every year, about half of our pupils leave school without even a ‘C’ in maths GCSE. But it’s not just those pupils who give us cause for concern. We still send powerful signals throughout our education system that it’s somehow acceptable to give up on maths. (p42)

He also states that this observed deficiency in mathematics has its roots in primary education and suggests that measures should be taken to improve mathematics in Primary Schools in order to be more ambitious in secondary education. An interesting point is that in the UK, formal school starts at the age of five, unlike Greece and most European countries where school starts a year later. Although, according to Riggall and Sharp (2008), there is no research evidence which supports that the early primary school starting age leads to higher standards.

On the other hand, Greek students have a high mathematical background; to be fair, too high. Evgenia’s children joined the English Secondary School at Years 10 and 11 respectively, when they moved to live in the UK. They were excellent in their mathematics classes, as the level of mathematics in these years was similar to the corresponding Years 7 and 8 in Greece. Gove (2011) makes a similar statement for China:

“At school, British 15-year-olds’ maths skills are now more than two whole academic years behind 15-year-olds in China.” (p22)

**Mathematical Concepts and Depth of Curriculum**
The mathematics taught in the UK is too ‘everyday life’; i.e. teaching and learning takes place through working more with an ‘everyday life’ way of thinking and not building a mathematical way of thinking. Mathematics has its own concepts and language and it is very important to start learning them from the early stages. It is similar to the learning of languages. Suppose someone wants to learn Spanish but the only knowledge that they get is the, so called, everyday phrases for travel. They will learn to speak and communicate, but at on a minimal basis and they will never get the chance to advance beyond a certain level, unless they actually start going into the depth and roots of the language.

Ackland (2013) discussed how trivial mathematics is taught nowadays, thus limiting its powerful potential to purely practical purposes, and hence the choices of the learner. She stated that restricting adults to applicable functional learning closes down their opportunities for a better deal i.e to explore the power of mathematics.

When speaking for the mathematics curriculum in other countries, among them Greece, Gove (2011) pointed out that in other countries a greater focus is given on fundamental number concepts, fractions and the building blocks of algebra in primary school. Their curriculum is set to provide the standards so that practically all children have a firm foundation for secondary education. He suggested that what should be emphasised in the primary curriculum is pre-algebra and data handling and some other subjects should be removed.

Standards in the Greek curriculum, on the other hand, are extremely high. In the Primary School years it focuses on building a mathematical way of thinking, helping children to get acquainted with the mathematical terms and terminology, teaching the use of mathematical symbols and meanings. The times tables are taught in Year 3 and by Year 6 the students are able to complete all fraction calculations, work with percentages, perform arithmetic operations, use simple identities and solve first order equations. In Secondary School, the curriculum gradually builds up to higher and higher levels, reaching ‘A’ Level standard, if not above, in the final year. The language used is far too scientific and the curriculum contains too much complicated information. This can be seen as a downside overall, as many students struggle to complete Secondary School and almost all seek external private tuition at the parents’ expenses.

_towards higher education_

The low level curriculum of the UK Secondary Education system creates a gap towards the A’ Levels. Gove (2011) says:

The ‘maths gap’ that most pupils now experience after the age of 16 means that even those who did well at GCSE have forgotten much of the maths they learnt by the time they start their degree or a job. ACME’s most recent figures on the take-up of mathematics among 17 year-olds are particularly worrying. … So our schools system is failing to provide anything like the number of suitably equipped students to meet the needs of Higher Education. (p41)

In Greece, there is no gap towards A’ Levels as the GSCE Level is too high and it gradually builds up to ‘A’ Levels. However, a problem arises because the higher education is incorporated in the Secondary Schools. All students have to be taught mathematics at such a demanding level, irrespective of whether they continue their studies at a higher institution or not. There is a new policy in place that separates higher education from the secondary one, giving students the chance not to choose to go to a University (Papazoglou, 2010). However, the level of mathematics in secondary education remains high enough to account for the students who wish to proceed to higher education. As we will see below, the percentage of students who attempt to enter a University is extremely high; however, not many students succeed in entering University, not because of their level of mathematical knowledge but due to the assessing system called ‘Panellinies (Panhellenic)’, which is constantly

criticised as an unfair one. According to this system, the Universities do not make an offer to the applicants, but those with the higher marks fill the available places at a University. It may sound fair, but if we consider the competition each year, we have excellent students left out simply because the places were filled up with students of, say, marks of 98-99%, and they have got only 97%. This is very discouraging and disappointing for superb students who invested a large amount of time, money and dreams for their future studies and the only thing left to do is try again the following year.

School Hours and Individual Study

Whereas in the UK mathematics is taught about four hours per week, the Greek curriculum allocates about five to seven hours per week depending on the Grade. The GCSE classes for adults in Kendal College are scheduled for three hours per week. Comparing with other European countries, it is evident that too little time is allocated for mathematics in the UK.

What was further observed in the GCSE adult classes is that the learners associate the learning of mathematics with the classroom; i.e. they start their learning when they are in the classroom and the learning stops when they exit, until the next lesson. It seems that, in the learner-centred system, the learners do not take their learning as a personal issue. There is very little individual study and homework even from the primary school years. On the contrary, in Greece, learners are forced to do too much individual study to compensate for the lack of in-class systems and curriculum demands. A Greek student is expected to study individually about one to two hours daily just for mathematics. They are given too much homework to complete by the next day, every day. Adding the extra private tuition they have to do after school, we end up with a student that starts their learning day at 8:00 and finishes about 21:00. Obviously this is a very stressful situation which discourages the students.

Individual study is essential for mathematics learning as it helps the learners to take control of their study, dissociate the learning from the actual classroom and become more independent (Anagnostopoulou, 2013). Furthermore, Lang (2012) concluded that with the appropriate methods of individual study and homework the self-confidence and motivation of the students could be greatly improved.

Teacher expertise

It is interesting that the saying: “Those who can DO; those who can’t TEACH” has no meaning in Greece, as those who can’t do, can’t teach. One of the main differences between the two educational systems is the teacher expertise on the subject.

In Greece and in most European countries, there are high standards of qualifications for teachers especially when it comes to the specialisation of their subject. The teachers of mathematics have to take a subject knowledge test along with their teaching qualification test before they enter education, even if they hold a Degree or a Masters in the subject. However, about 80% of the test contains mathematical knowledge and 20% teaching theories and practice. In the UK, a different situation is observed where there is a variety of access courses in the teaching profession, dealing greatly with the teaching methods and very little or not at all with the mathematical knowledge of the teacher.

Teacher expertise is a very important issue and tends to be devalued in the UK. According to The Independent” newspaper (23 September 2013), more than 100,000 secondary school students will be taught mathematics and science by teachers untrained in the subjects because of a chronic shortage of new recruits. Gove (2011) particularly emphasised the need for improving the supply of teachers with specialist subject knowledge in mathematics. This can be done through training programmes, such as School Direct, that enable graduates of mathematics to acquire the specialist subject knowledge necessary to train and serve as teachers in their subject.

Based on the conceptual and syntactical structure of subject knowledge, as described by Schwab (1974), Houli (2007) states that teachers should not only be able to know the truth in their subject knowledge but also to be able to explain why a theory is valid, in what cases it is not valid, what limitations there are and how it is related to other theories; i.e. the teacher needs a deep understanding of their subject in order to be able to fully transmit the knowledge to their students.

The lack of teacher expertise is evident in the classroom, no matter how much teachers want to believe the opposite. The students tend to notice it very quickly and there is the danger of losing their respect towards the teacher, making the teaching and learning process difficult. Watters (2013) states her support for the student-led learning environment but she also comments on the loss of teachers’ authority within the classroom in favour of the importance of student voices and experiences. According to reports from teachers, Watters (2013) writes that students tend to resist critical feedback or evaluation, preferring the idea that all opinions are equally valid, and questioning the expertise and subject knowledge of their teacher.

Moreover, a teacher who knows their subject well is confident enough to transmit this confidence to their students. Brophy (1991, p352) argues that:

…where (teachers’) knowledge is more explicit, better connected, and more integrated, they will tend to teach the subject more dynamically, represent it in more varied ways and encourage and respond fully to students’ comments and questions. Where their knowledge is limited, they will tend to depend on the text for content, de-emphasize interactive discourse in favour of set work assignments, and in general, portray the subject as a collection of static, factual knowledge.

**Classroom activities and infrastructure**

Comparing how the teaching takes place in the two countries, we see a great difference. In the UK, the classroom is very well structured providing the students with a variety of facilities and resources (Interactive whiteboards, Powerpoint, videos, audio material, printed material, etc.). Plenty of activities (group activities, interactive, presentations, games, etc.) take place, transforming the environment into a pleasant and creative experience.

The corresponding situation in Greece is very limited. The classroom set up is the traditional one, usually hosting 25-30 students. There are no teaching assistants. The traditional white board is used, while the IWB has just recently been introduced and not all schools have it. All lessons take place in the same classroom. The activities are few, if at all, and the lessons have no variety. Clearly and unfortunately, Greek teaching limits students’ creativity and the learners are easily bored.

**Student’s feelings**

How do the students feel about mathematics? How do they feel about their learning of mathematics?

Evgenia’s action research (Anagnostopoulou, 2013) showed that UK students do not feel confident with mathematics. Mathematics is considered a difficult subject that only clever students can understand. It is ok if they fail unless a certificate is required; in this case they will almost always do what is necessary just to obtain the required qualification. Low levels of confidence and self-esteem are related to their mathematics background knowledge. A lack of determination is evident and UK students rely on others for their learning (the system, the teachers, the class); they are not determined to take control of their own learning. They clearly lack an intrinsic motive. They do not seem to have been taught the power of mathematics, how to love and understand it, so they look confused at why they have to learn it and what is the use of it in their lives. Those who like mathematics feel that they are taught less than they would like.
A previous action research project undertaken by Evgenia in Greece, concluded that the Greek system of education leads to mathematics expertise but creates a negative psychology, overall in the person. If the students fail to understand the subject, they are criticised as not worthy or lazy; so they struggle more towards an achievement and they end up very stressed and depressed. The Greek students lack an intrinsic motive as well, because all their efforts are directed towards proving their value to the society rather than their own knowledge acquisition.

**Teacher’s feelings**

What about the teacher’s feelings?

In the UK, teachers generally live their teaching role and like their job. However, they often feel very hard pressed as there is too much to do outside the class which usually involves bureaucratic procedures. They are allocated too many responsibilities and roles on top of their teaching, leading to great pressure and stress. The teachers’ salaries are considered fair and above the EU average. Teachers in England only have to work for five years to get to the top of the basic salary scale, whereas in Greece, as in most other European countries, teachers have to work over 20 years to get to the top of the scale.

The present situation in Greece is much influenced by the economic crisis, but in general Greek teachers think they are not treated fairly. Having waited too long on a list, often as much as 7-10 years, to get a teaching post, due to competition, they end up in a job which is not at all well paid; on top of that, a high level of expertise is expected from them without getting practically anything in return. They are not allocated non-teaching time as in the UK. Meanwhile waiting, they are seeking teaching posts in the private sector where the selection method is completely unfair. Most teachers, especially in the area of mathematics, are unemployed due to high supply. The consequence of going through a difficult situation is that when a teacher actually gets a post, they treat it as ‘just a job’ and they do not usually give their best self.

**Market Competition and Social Trends**

In the UK, the social trend is that not everyone needs to go to higher education. People usually cover the places that the market needs. About 75% of the students are in full time education. 40% of them carry on to ‘A’ Levels; just 13% of the students do A or AS mathematics, with only about 2% taking it to a high level. Gove (2011) states his concerns:

> Only half the population has even basic maths skills, we are producing only about a quarter to a third of the number of pupils with the maths skills that our universities need, and economic trends mean that this gap will, unless we change, get wider and wider with all that entails for our culture and economy. (¶p47)

Although the qualifications for a market post in the UK are in compliance with the post, in Greece the qualifications for a post are higher that what actually the post requires making the market more competitive. This is one of the reasons why the majority of Greek people proceed to higher education. Another reason is the social trend of “you should have a degree to be worthy”. It is a mainstream mentality; after secondary school the next step is the University.

**Conclusion**

A summary of the above discussion is presented in table 1 on the next page.
We have seen the two educational systems and we discussed their upsides and downsides. So, now the question is: How do we improve the teaching and learning of mathematics to reach its full potential? How do we achieve a learner who is proficient in Maths but also has the confidence and belief in themselves? Michael Gove (2011) states his concerns as well as future plans about mathematics and science in the UK:

While other countries have raced ahead we have, in the words of the OECD’s Director of Education, ‘stagnated.’… And when I see the pace at which other countries are transforming their education systems to give more and more of their students mastery in maths and science, it only reinforces my

determination to reform our system here so our children can have access to the essential knowledge which truly empowers. (p24)

**Recommendations**

**Stick to the theories.**

The gauge in Figure 1 should point at the centre. In other words, the theories are there: Dewey, Piaget, Vygotsky, Rogers and many others have talked about how students learn. The educational practices, such as Bloom’s Taxonomy and Howard Gardner’s theory of multiple intelligences, are there for us to use in order to account for the students’ different learning styles. All we have to do is apply these theories in practice and not just leave them in the books. We may probably need to refresh our knowledge concerning the theories, as it seems that in practice we usually forget what is meant by a learner centred system; it is the system where the student is the centre of their learning. Only when students take responsibility for their own learning, will they acquire an incentive and intrinsic motivation.

**Build a strong knowledge background basis.**

The curriculum should clearly be reformed to a more challenging one, even in the Primary School years. We must build a strong basis and provide exciting and appropriate learning opportunities so that the learners can gradually advance in mathematics without any gaps in their knowledge. Gove (2011) states:

> If we are to keep pace with our competitors, we need fundamental, radical reform in the curriculum. Unless we dramatically improve our performance, the grim arithmetic of globalisation will leave us all poorer. (p28)

Also, some policies should be revised to include less bureaucratic work for teachers so that they can focus more on their teaching work. Ticking the boxes does not always mean that we do the right thing.

**Increase teacher expertise.**

Students deserve to be taught by experienced teachers with profound subject knowledge. If we want to be inclusive, we need to also include the students who have a thirst for learning and seek information beyond what is in their curriculum. A teacher with confidence in their knowledge can provide these students with the right answers rather than avoiding the questions.

**Improve learners’ resilience.**

Create independent and responsible learners. Encourage individual study. Appropriate homework is very beneficial especially for the learners’ confidence and self-esteem.

**Use creative resources and activities.**

Create a pleasant and engaging learning environment but also one that is appropriate to their level and age. Overly simplified activities and resources can be fun but can also be boring and criticised as meaningless. Mathematics can still be easy and fun without being trivial. Sometimes entertainment can be found in progress alone.

**Give constructive feedback but be honest.**

Encourage students in their learning process but give them a clear picture of what they have achieved, how far they can go and how much effort is needed to progress further; because, if the students are not
good at something, we tend not to tell them but provide them with a lower qualification.

**Inspire the learners.**

Teach them the power and magic of mathematics. Inspire them to love mathematics rather than fear it. The answers to questions like: “Why do I need to learn this?” and “Where can I find that useful in my life?” should be self-evident.

We, the teachers, must remember that this is a learner centred environment and too much ‘nursing’, especially when we teach adults, should not be a part of it. We are there to facilitate and strengthen students in their learning process; like the story of the butterfly struggle, for example:

One day a boy found a cocoon of a butterfly. He took it home so that he could watch the butterfly come out of the cocoon. He sat and watched the butterfly struggling to force the body through that little hole. Then it seemed to stop making any progress. It just seemed to be stuck.

Then the boy being kind decided to help the butterfly. So he took a pair of scissors and snipped off the remaining bit of the cocoon. The butterfly then emerged easily. But it had a swollen body and small, shriveled wings. He expected that the wings would enlarge and expand to be able to support the body which would contract in time. Neither happened! In fact, the little butterfly spent the rest of its life crawling around with a swollen body and shriveled wings. It never was able to fly. A few days later, it died.

As the boy tried to figure out what had gone wrong his mother took him to talk to a scientist from a local college. He learned that the butterfly was SUPPOSED to struggle. In fact, the butterfly’s struggle to push its way through the tiny opening of the cocoon pushes the fluid out of its body and into its wings. Without the struggle, the butterfly would never, ever fly. The boy’s good intentions hurt the butterfly.

The boy learnt that struggling is an important part of any growth experience. In fact, it is the struggle that causes us to develop our ability to fly.

As teachers our gift to our students is stronger wings…

Mathematics has been a very important part of our civilisation from time immemorial. Michael Gove characteristically states that “the emergence of the first, truly great, Western civilization, in the scattered city states of Ancient Greece, was intimately connected with the first systematic thinking about reason, logic and number” (2011, p9).

Mathematics is not an abstract notion. It includes the energy to serve people. It can be used for very powerful reasons and purposes. We should not devalue or limit it. Our mission is to use it accordingly for our benefit, giving it the place that it deserves in our civilisation.

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Abstract
Card activities are increasingly chosen by adult numeracy teachers as alternatives to traditional worksheets and word-problems. Their effectiveness is usually theorised in cognitive terms, focusing either on the affordances of tasks such as sorting, categorising and matching for promoting understanding of mathematical concepts (Swan 2006), or on the benefits of multi-sensory approaches for reinforcing learning (Henderson 2012). In this paper, I argue that card activities also bring benefits within affective, critical and social domains of learning. I draw on social practice and multimodal literacy theories – which suggest that the style and physical format of written texts are associated with certain settings and practices – and apply these to learning materials. Thus while conventional worksheets of word-problems are strongly associated with an accepted set of responses in the mathematics classroom, alternatives such as card activities can disrupt learners’ prior expectations of how they should respond, allowing them to engage more critically with the meaning and relevance of their learning to everyday life.

Introduction
An on-going challenge in adult mathematics classrooms is making mathematics relevant to learners’ lives. Traditionally, word-problems have been used in an attempt to present learners with realistic contexts from everyday life. However, research shows that learners rarely engage with the contexts provided (e.g. Cooper & Harries, 2002; Wyndham & Saljo, 1997; Verschaffel, De Corte & Lasure, 1994; Mukhopadhyay & Greer, 2001).

In this paper I examine possible barriers to learners’ engagement with these contexts. I present transcripts of classroom discussion to illustrate how adult learners responded to two different classroom activities, both of which presented them with socio-critical contexts. Using social practice theories as a framework, I analyse the extent to which the features of the mathematical learning materials used in each activity served to encourage greater learner engagement with context. I conclude by discussing implications for practice, including the tensions involved in preparing learners for formal assessment.

Background
The Problem with Word-problems
The mismatch between classroom mathematics and everyday numeracy practices has been well-documented through ethnographic studies of how children and adults use numeracy in their lives. These have included studies of: children selling water-melons and sweets in Brazil (Carraher, Carraher & Schliemann, 1985; Saxe, 1988); adults grocery shopping and weight-watching in the USA (Lave 1988); adults working as market traders, fishermen, builders, carpenters and farmers in Brazil (Nunes, Schliemann and Carraher 1993); and young unemployed adults in Australia (Johnston, Baynham, Kelly, Barlow & Marks, 1997). The common theme emerging from these studies was that the situated numeracy practices undertaken by participants were fundamentally different from classroom mathematics. The real-life problems to be solved were generated by participants...
themselves, and were structured in terms of goals to be achieved, rather than mathematics, with social relationships central to many practices. Participants who struggled with written problems in the classroom were found to perform competently within these meaningful situations.

Attempts to embed classroom learning into contexts more relevant to learners’ lives have often proved unsuccessful, particularly the word-problems which dominate many mathematical learning and assessment activities, and which aim to present realistic situations such as those associated with money, measurement or employment. The limitations of traditional word-problems as a genre are explored, for example, by Gerofsky (1996; 1999), who critiques their typical three-part structure, generally consisting of: a “set-up” to establish a minimal story-line; items of numerical information; and one or more question(s). The problem is normally expected to contain two numbers to be combined using addition, subtraction, multiplication or division. As Evans and Tsatsaroni (2000) point out:

A student doing a calculation in shopping has different purposes and constraints than when they are doing it in the mathematics classroom. The calculations have to be more accurate in the classroom, because that is what is required, or what it takes to keep the teacher happy, and because this is what is a valid answer in school assessment practices. (p. 59)

Social Practice in the Mathematics Classroom

Social practice perspectives recognise literacy and numeracy as embedded in people’s lives in domains of practice such as home, work or the community. The ideas were first developed through studies of literacy in use in a variety of communities, for example by Scribner and Cole (1981), Heath (1983) and Street (1984). Literacy is not regarded as a set of autonomous skills, to be learned in school and transferred unproblematically to other contexts, but as an ideological practice, which “encompasses the knowledge, feelings, embodied social purposes, values and capabilities that are brought into play through the reading and writing of texts” (Mannion & Ivanić, 2007, p.16). Literacy is seen to be practiced differently in different domains, only one of which is the domain of formal schooling (Gee, 1996; Barton & Hamilton, 1998; Crowther, Hamilton & Tett, 2001; Papen, 2005).

Many of these ideas have since been applied to numeracy (Baker, 1998; Johnston and Yasukawa, 2001), including the recognition that numeracy is embedded in social practice and that certain domains of numeracy and mathematics are more highly-valued by dominant discourses than others (Coben, 2002). According to Street, Baker and Tomlin (2005) numeracy practices involve “the conceptualisations, the discourse, the values and beliefs, and the social relations that surround numeracy events as well as the contexts in which they are located” (. 20).

Such perspectives have tended to focus on the mismatch between classroom mathematics and everyday numeracy practices, and there has been a tendency to categorise classroom activity as conforming to an “autonomous” or “skills” model (Street, 1984; Green and Howard, 2007). In this paper I recognise the classroom itself as a site of social practice, and examine the literacy and numeracy practices which take place within it.

Multimodal Literacies

Studies of literacy as multimodal recognise that readers and writers of texts will respond differently to the affordances offered by the modality and materiality of a text; for example to texts on paper, computer screens, or cards (Jewitt & Kress, 2003; Pahl & Rowsell, 2006; Gillen & Hall, 2009). Kress, Charalampos, Jewitt and Ogborn (2001) stress the additional scope for semiosis through bodily interaction with physical written materials as they are handled, owned and manipulated by learners.
Learning materials in adult numeracy classrooms in England frequently take the physical form of A4 (21.0mm x 29.7mm) photocopied worksheets – to such an extent that the phrase “death by worksheet” will be recognised by many practicing teachers, though scholarly research on its ubiquity is hard to find. In recent years, however, teachers have been encouraged to use alternative formats to supplement, if not displace, the A4 worksheet, such as cards and mini-whiteboards. Although a few teachers have been using card activities for much longer, the practice became widespread following the dissemination of learning materials and training (DfES, 2005; 2007), based largely on research by Swan (2000; 2006). Swan’s research focused on the cognitive affordances of cards, which allow learners to develop a deeper understanding through activities such as sorting, ordering and matching representations of mathematical concepts.

In this paper I suggest that card activities not only bring benefits in the cognitive domain, but also in social, critical and affective domains of learning, through their potential to disrupt traditional classroom expectations and practices.

**Methodology**

This paper presents data collected in two adult numeracy classrooms in England, in which learners’ naturally-occurring discussions were audio-recorded as they worked together in small groups to solve mathematical problems (Oughton, 2009; 2012). The audio-recordings offer close insights into how the learners responded to the fictional contexts in which classroom mathematics problems were set.

**The classroom, the learners and the teacher**

The participating classes (both taught by the same teacher) took place in two adult community education centres which offered free literacy and numeracy provision to any adults lacking qualifications in those subjects. The classes each comprised between eight and twelve learners, aged between 20 and 55 years old. As a requirement of the provision, all learners were working towards the National Certificate in Adult Numeracy at either Level 1 or 2.

Working in small groups, the learners undertook a variety of mathematical learning tasks, ranging from conventional worksheets of word-problems (in preparation for formal examinations) to innovative card activities. The learners supported each other during all these activities, calling on the teacher’s help only as a last resort. Participants were audio-recorded (with their informed consent) during their usual classroom activities and no intervention was requested for research purposes.

While I would resist the notion of a “typical” classroom, experience as a teacher-educator in this sector leads me to suggest that these classes were by no means untypical. Broader ethnographic accounts of similar classrooms may be found in Appleby and Barton (2008), Rhys Warner and Vorhaus (2008) and Cara et al. (2008).

**Data collection and approaches to analysis**

Mobile phones were used as audio-recording devices, placed unobtrusively on classroom tables. Since learners usually brought their own mobile phones to classes, they had become “part of the

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72 I do not refer here to playing cards (though these can have their place in mathematics classrooms), but to any learning material or activity presented on cards small enough to be handled and manipulated by learners. This may include, for example: question and answer pairs; representations of mathematical concepts; or quantities for manipulation. Uses might include matching, sorting, ordering, or – as in the example presented in this paper – random selection and allocation.

73 Level 2 is equivalent to the target level for 16-year-olds completing compulsory schooling in England. The National Certificate in Adult Numeracy has now been superseded by the Functional Skills Mathematics qualification, discussed below.
furniture” and participants tended to ignore them. Labov (1972) furthermore suggests that speakers’ discourse becomes more natural when they are intensely engaged, as the learners were in their mathematical problem-solving. Learners seemed quickly to forget that they were being recorded, and their talk appeared to become naturalistic within a few minutes. Eleven hours of recorded discussion was collected over two terms. The audio recordings were then transcribed for analysis, using field notes to enrich the transcription where relevant.

Analysis focused on how learners related classroom activities to their everyday numeracy practices, and the relevance that these seemed to have in their lives. Codes were drawn up to identify and categorise ways in which learners responded to the contexts in which mathematical problems were set. Samples of the learning materials used in each activity were also collected, and analysed to examine the structure, modality, tenor and materiality through which the contexts of mathematical problems were presented to the learners.

Data from the classroom

Two illustrative extracts have been selected from the data. The first is representative of the learners’ response to a traditional word-problem, although the context provided is one which might be expected to produce a more a socio-critical response than most. The second is a rarer example, in which the learners responded very differently to the problem they were posed. It may be regarded as a “telling case”, which allows “small facts get in the way of large issues”, and has the potential to disrupt generalisations by showing that alternatives are possible (Mitchell, 1984; Hannerz 1987, p.556).

Episode 1: Percentages word-problem

Five learners, Ruth, Dawn, Gemma, Jackie and Charlotte74, were working together to solve the traditional word-problem shown in Figure 1. This was one of ten similar percentages word-problems on an A4 worksheet, intended as preparation for examination at Level 2. Answers to all questions were included on the reverse of the sheet, but the learners assiduously avoided looking at the answers provided until they found their own solution and were ready to check it.

![Image of a worksheet](image.png)

Figure 1. Extract from *Skillsworkshop* worksheet on percentages (*Skillsworkshop* 2007, original emphasis)

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74 Names of all participants are pseudonyms.
Extract 1:

1. Ruth [paraphrasing from worksheet] Right, 220 fatal accidents
2. 55 of 'em on building sites.
3. [reading from worksheet] “What percentage of the total fatal accidents?”
4. Dawn Right, so you’ve got 220
5. Over 55
6. No, no, it’s the other way round isn’t it?
7. Gemma Is it the other way round?
8. Dawn I don’t know
9. Ruth [reading from worksheet] “What percentage of the total fatal accidents?”
10. Dawn Yeah, it’s – I think it’s that way
11. Jackie Which way?
12. Gemma Is it the other way round, yeah?
13. Dawn I think so
14. Ruth 55, yeah, over 220, and then
15. Dawn Yeah, so you’ve got to cancel that down
16. Ruth And how d’you do that then?
17. Dawn Five’ll go in to it, won’t it?
18. [whispered] Five, ten, fifteen, twenty
19. Ruth (…) is eleven
20. Dawn Yeah. How many fives into 220?
21. Ruth Well fifty’s ten, a hundred is twenty
22. [laughing] 150 is what, thirty?
23. Forty, forty-four
24. Forty-four?
25. Charlotte Yes
26. Ruth So it’s eleven forty-fourths? [laughs]
27. Jackie Oh, no
28. Ruth We surely can get lower than that
29. Dawn Yeah, so
30. Charlotte Because eleven
31. Dawn Yes, eleven – I’ll go into forty-four
32. So it’ll go in one, and four, so it’s a quarter
33. Charlotte Yeah
34. Ruth Hang on a minute, whoa, whoa, whoa
35. Now you’ve got me now
36. Gemma Do you know your eleven times table?
37. Ruth Eleven, twenty-two, thirty-three, forty-four.
38. Dawn So eleven’ll go in –
39. Ruth Hang on, hang on
40. How do we suddenly –
41. Because I would have been thinking, what does that, and that, go into?
42. What goes into both of them?
43. Dawn Yeah, yeah
44. Gemma Eleven
45. Jackie So it’ll just be one, won’t it? Because only one eleven goes into eleven.
46. Ruth Yeah, I’m with you, I’m with you
47. The bottom is forty
48. Dawn Eleven’ll go into itself once
49. And it’ll go into the bottom (…)
50. It’s a quarter
51. Ruth Yeah I’m with you
52. So you’ve got your job back now
53. Dawn Right, okay, I’m happy now
54. Ruth [laughing] Good
55. Charlotte So that’s twenty-five percent
56. Ruth So that’s one quarter
57. Right
58. [The learners then move on to the next problem on the sheet.]

I have included the learners’ entire discussion on this problem in order to illustrate a pattern which recurred throughout the data I collected; that learners extracted numerical information from the word-problem and carried out their calculations, without appearing to respond at any point to the context in
which this problem is set. This is particularly striking when that context might be expected to provoke concern, shock, or at least a query as to its validity.

Lines 1-14 are concerned with reading the word-problem to extract the relevant numerical data and mathematical relationships. Although Ruth reads aloud the potentially emotive words “fatal accident” three times (lines 1, 3 and 9), the learners focus only on the numbers, grappling with the difficulties of which is the denominator. Ruth’s paraphrasing of the question in line 1-2 suggests her understanding of the narrative, but she does not reflect aloud on its significance.

From line 15 onwards, the learners respond to the problem merely as an instruction to find 55 as a percentage of 220. Once Gemma has made her case that 220 should be the denominator rather than the numerator, the learners’ discussion is solely of arithmetic through to the correct solution at lines 50 and 55, centering largely on the identification of eleven as a common factor.

Rather than responding to the construction industry fatalities context, the learners respond to the expectations of the word-problem genre. For example, they show familiarity with conventions of simplified numerical relationships; in line 27, Ruth recognises that 11/44 is unlikely to be the correct answer, even though she has not yet spotted the equivalence to a quarter. On obtaining the correct answer, checked using the answers provided, the learners show satisfaction, a sense of resolution, and mutual congratulation (lines 50-57).

**Episode 2: Wages cards**

The second episode was part of an activity to demonstrate how the mean of a data set can be distorted by outlying values; in this case how the mean salary in a small company might be distorted by one very high salary. The teacher asked each learner in the group to select and keep a card at random from the set of shown in Figure 2.

![Wages cards used in Extract Two](image)

**Figure 2. Wages cards used in Extract Two**

No other details (for example, roles or job titles) were provided on the cards or by the teacher. Nonetheless, the learners spontaneously seized the opportunity to role-play, using their knowledge of typical salaries to match the cards to employee roles:
Their spontaneous role-play suggests that the learners felt unconstrained by the expectations of more traditional classroom activities. They demonstrated a playful creative knowingness about wage distribution and a satirically mocking and critical attitude to wealth. Judith’s mocking remark in line 30 is not, of course, directed at Abigail, but at individuals who earn high wages, and the shared laughter allows all learners to show solidarity in their relationship to higher earners. In line 32 Abigail ostensibly imitates a happy complacency which those on high wages might be supposed to feel, while at the same time the overtly stylised tone distances her from those she is imitating. She reverts to a more natural and very quiet tone as she dismisses the personal value of wealth in line 34.

Significantly, the role-play enables them to make more critical sense of the eventual conclusion about how the mean has been distorted (Extract 2b below). Note the learners’ knowing laughter in response to the teachers comment in line 15, as they identify themselves and each other with the wages on their cards:

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<table>
<thead>
<tr>
<th>Extract 2a:</th>
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</thead>
<tbody>
<tr>
<td>1 Teacher:</td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
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<tr>
<td>4</td>
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<td>5</td>
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<td>6</td>
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<tr>
<td>7</td>
</tr>
<tr>
<td>8 Donna:</td>
</tr>
<tr>
<td>9 Judith:</td>
</tr>
<tr>
<td>10 Donna:</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>13 Teacher:</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>15 Donna:</td>
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<tr>
<td>16 Sally:</td>
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<tr>
<td>17</td>
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<tr>
<td>18 Donna:</td>
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<tr>
<td>19</td>
</tr>
<tr>
<td>20 Teacher:</td>
</tr>
<tr>
<td>21 Judith:</td>
</tr>
<tr>
<td>22 Teacher:</td>
</tr>
</tbody>
</table>
| 23           | And we’re going to calculate what the typical wage from our (…)
| 24           | So what have you got there? |
| 25           | [overlapping talk and chairs banging] |
| 26 Donna:   | ? |
| 27 Donna:   | Ten thousand [pounds] |
| 28 Sally:   | Twelve |
| 29 Teacher: | Twelve thousand |
| 30 Judith:  | Miss Moneybags here |
| 31           | [laughter] |
| 32 Abigail: | [in “posh” sing-song voice] I have a hundred thousand |
| 33 Donna:   | The director. You’re the director. |
| 34 Abigail: | [quietly] I wouldn’t know what to do with it anyway |
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Note also how this activity does not have a pre-defined “right” answer; it depends on the number of learners participating and the wages they randomly select. The teacher must therefore work together with the learners to calculate the mean value (lines 1-10), and the mean value is not an exact figure but the result of a slightly messy calculation, as are solutions in real-life.

**Analysis from a social practice perspective**

*The social context of the classroom*

The numeracy problems in both the above episodes were presented in contexts which might be supposed to be of socio-critical significance to adult learners: in the first case, employee safety in the construction industry; and in the second, wealth distribution and the distortion of statistical measures. Yet only in the second did the learners respond to the context provided.

It becomes important at this point to interrogate what is meant by “context”. Dowling (2001, p. 20) describes how attempts to set classroom mathematics problems in supposedly real-life contexts merely “mythologise” the practices they are supposed to represent, while Evans and Tsatsaroni (2000) warn of the dangers of “an overly simplified notion of context as a ‘thin veneer’ of applicability, that only seemed to make ‘word-problems’ in the classroom different from abstract calculations” (p.56). (original emphasis)

I argue that the context in which the learners are practicing numeracy is not that of the construction industry and its fatalities, nor of wage distribution in small companies, but the adult numeracy classroom together with the discourses and structures which regulate it (Papen, 2005; Oughton, 2007). The classroom should be seen as a site of social practice in order to examine the literacy and numeracy practices which take place within it.

Thus in my analysis below of how learning materials are used in the classroom, I take into account features of the classroom as summarised in Table 1 below, drawing on Chouliaraki and Fairclough (1999); Street, Baker and Tomlin (2005); and Barton and Hamilton (1998; 2000).
Table 1. The Social Context of the Adult Numeracy Classroom: Key Elements

<table>
<thead>
<tr>
<th>Physical setting:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A classroom in a dedicated adult community education setting</td>
</tr>
<tr>
<td>Surrounded by educational resources such as whiteboards, textbooks and educational posters</td>
</tr>
<tr>
<td>The materiality, modality and mediation of the learning materials</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Historically and socially situated:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The <em>Skills for Life</em> infrastructure – classroom activity is planned around the curriculum, qualifications and targets</td>
</tr>
<tr>
<td>Relationships with other learners and with the teacher</td>
</tr>
<tr>
<td>The cultural capital associated with success in mathematics</td>
</tr>
<tr>
<td>Mathematics qualifications as a gateway to employment</td>
</tr>
<tr>
<td>Learners’ own history of schooling</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learners’ social purposes – long term:</th>
</tr>
</thead>
<tbody>
<tr>
<td>To obtain a qualification needed for work or further study</td>
</tr>
<tr>
<td>To help own children with their schoolwork</td>
</tr>
<tr>
<td>For personal fulfilment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learners’ social purposes – short term:</th>
</tr>
</thead>
<tbody>
<tr>
<td>To obtain the “correct” answer – usually the one given on the answer sheet</td>
</tr>
<tr>
<td>To support each other in solving the problem</td>
</tr>
</tbody>
</table>

The classroom context can be seen to be strongly associated with the curriculum, accreditation and school mathematics. Thus any artificial “context” provided by the learning materials needs to engage the learners sufficiently to disrupt these dominant discourses of the classroom.

**Literacies and the Percentages Worksheet**

This worksheet was downloaded by the teacher from the *Skillsworkshop* website, through which teaching resources are contributed by volunteers and made freely available to teachers. The following is therefore *not* intended as a critique of the website, the worksheet nor its author, but a comment on the curriculum and accreditation structures and discourses of which it is part.

Although this was a word-problem, it was less conventional than some. It referred to a specific year (most word-problems use, anomalously, the present indicative tense) and presented numerical data which, if accurate, might be regarded as a cause for social concern. On first listening to the audio-recording, I was initially surprised (and, admittedly, shocked) at the casual way the learners repeated the phrase “fatal accidents” without responding to it. Their response appears to conform to what Street (1984) would describe as an “autonomous” model.
The percentages worksheet itself was a single A4 sheet, photocopied in black and white, and presenting ten mathematical word-problems. The A4 format is very commonly used in classrooms throughout all educational stages in England, and learners would have encountered similar materials both in their own schooling and in the homework their children bring home from school. The title of the worksheet, **Percentages – Level 2**, is strongly classified and framed by curriculum area and level (Bernstein 2000). The word-problems on the sheet conform to the genre commonly found in classrooms and assessment materials. Most make anomalous use of the present indicative tense, and present the typical three-part structure: a “set-up” to establish an arbitrary scenario; items of numerical information; and a question, reinforced using bold type. Answers are given on the reverse, together with hints on carrying out the necessary calculations. Advice is given on examination preparation, emphasising that learners need to work out answers without a calculator; a constraint which would not apply to real-life numeracy problems. The answers are neat and familiar percentages (unlike the intermediate answer of 11/44 obtained by the participants in Extract 1), and they are understood to be exact, correct and non-negotiable. Thus this format will be firmly associated with the classroom and formal learning.

The teacher inevitably had a mediating role as she distributed the worksheets, which reinforces this classification and framing. Her introduction was couched in terms of a forthcoming examination, the National Certificate in Adult Numeracy at Level 2 (the “it” in line 6 refers the examination itself):

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75 Note that this is not due to the intrinsic nature of the format, but its association with school classrooms. Colleagues who were teaching in the sector at the time recall worksheets first being introduced as a revolutionary and flexible alternative to textbooks (my thanks to David Kaye for this insight).
Extract 3

Teacher: Right, the sheets I’ve got

I’ve got quite a lot of different ones really here

Do level two if you think

Have a go at level two questions

Cos it’s coming up in two weeks time

Literacies and the Wages Cards

Given this analysis of how the worksheet reinforced the classroom context, which features of the cards used in the second activity might have encouraged the learners towards a more socio-critical response? The activity was closely mediated by the teacher, who created a subjunctive mood by inviting the learners to imagine themselves in a different situation: “They’re meant to be, er, your wage. We’re all working, all working in a factory or something,” (Extract 2a, lines 2-3). The first and second person pronouns (your, we’re) serve further to engage the learners in identifying with the position of employees in the factory. The cards (Figure 2) were laminated and tactile, and only slightly smaller than a bank note or a wage slip. The tactile quality seemed to give each participant a sense of ownership (c.f. Kress et al., 2001) and their random distribution may be seen as mirroring perceived randomness in wealth distribution.

In contrast to non-negotiably “correct” answers on the back of the percentages worksheet, the result of calculating the mean wage was not known, even by the teacher, at the outset. The answer depended on the number of learners participating, and their random selections from the cards. The teacher encouraged them to calculate the mean without an electronic calculator, and was obliged to do the arithmetic along with her learners. The result involves division by seven and, in contrast to the round, tidy answers on the percentages worksheet, is a messy, inexact number, as are solutions to numerical problems in real-life. In another parallel with real-life problems, the teacher concludes that they do not need the exact answer in order to draw their conclusion; a value accurate to the nearest £1,000 is sufficient to see that the mean has been distorted by one very high wage, and is not representative of the other values.

Discussion

As a former adult numeracy teacher myself, I am aware that mathematics does not have to be functional to be meaningful to learners. Learners may study mathematics for its own sake, to help their children or for a qualification (Swain 2005). Nonetheless, since functionality is, at present, central to policy and accreditation in England, it is worth considering whether this enforced emphasis succeeds in making classroom mathematics more relevant to learners’ lives.

I have outlined how the real and present social context for the classroom is dominated by curriculum and accreditation constraints and expectations. Thus for learning materials to be effective in engaging learners with the fictional contexts they present, they must be powerful enough to disrupt the dominant expectations of the classroom.

In Episode 1, the textual features of the percentages worksheet: its mediation by the teacher in terms of exam preparation; its A4 format; its layout, tenor and content; are strongly associated with
the discourses of the mathematics classroom and serve to reinforce learners’ expectations about how they should respond. They ignore the construction industry context and strive to obtain the correct answer.

By contrast, in Episode 2 the random distribution of the wages cards by the teacher; their physical possession by the learners; and lack of known “right answer” appear to disrupt the classroom context, and the learners’ expectations about how they should respond. They thus identify themselves with the wages indicated by their cards; assign themselves roles; simulate mockery or complacency; and laugh in resignation at the apparent injustice of the unequal wages. The wage card activity is not only effective cognitively in helping learners understand the concept of the mean, but it also brings benefits within critical and social domains of learning.

This paper presents just two examples of numeracy classroom activity, and does not attempt to make specific recommendations for practice. Nonetheless, single cases have the potential to disrupt over-generalisation and to demonstrate the ways in which superficially similar situations can differ from each other.

The following table summarises the characteristics which appeared to make the learners respond differently to these two learning activities and the texts associated with them. By developing learning materials which feature more of the characteristics apparent in Episode 2 (wages cards), teachers may be able provide classroom activities which are more meaningful to their learners and relevant to practices outside the classroom. Some of these characteristics have previously been found effective in encouraging learners to relate classroom mathematics to everyday numeracy practices, by changing the subject of word-problems from the third person to the second person (PALM, 2008), or the conditional “would” instead of the present indicative typical of traditional word-problems (Oughton, 2009).

<table>
<thead>
<tr>
<th>Table 2: Key characteristics of learning materials</th>
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<tbody>
<tr>
<td><strong>Word problems</strong></td>
</tr>
<tr>
<td>A4 photocopied sheet – associated with schooling</td>
</tr>
<tr>
<td>Introduces fictional third person</td>
</tr>
<tr>
<td>Present tense, indicative mood - states a “fact”</td>
</tr>
<tr>
<td>One pre-defined “right” answer</td>
</tr>
<tr>
<td>Answer is “tidy” (e.g. 25%)</td>
</tr>
<tr>
<td>Exact answer required</td>
</tr>
<tr>
<td>Reinforces the classroom context</td>
</tr>
</tbody>
</table>

**Final word: The issue of formal assessment**

While Table 2 offers tentative recommendations for developing learning materials, one issue cannot be ignored. The achievement of formal qualifications remains a primary aim in many adult mathematics classrooms. This impetus comes partly from the learners themselves, who may need a qualification to progress in work or further study, and is also imposed by policy; funding is dependent on the successful achievement of qualifications.

At present, the most common qualification taken by adult numeracy learners in England is Functional Skills Mathematics at Level 1 or 2. The assessment for this qualification does indeed
represent an improvement on its multiple choice predecessor, the National Certificate in Adult Numeracy. Many of the questions have several stages, and are designed to assess reasoning and problem-solving skills rather than a single right answer. Some awarding bodies (for example AQA and OCR) provide a separate data booklet in which candidates must look up numerical information in order to solve the problems.

Nonetheless, barriers remain which reinforce the classroom context. The assessment materials still take the ubiquitous form of word-problems presented on A4 sheets, and where data booklets are provided they take the same format. The word-problems themselves generally introduce a superficial scenario, an arbitrary fictional third person, and are written in the present indicative tense.

The question of whether formal written examinations are the best way to assess adult learners’ numeracy skills is beyond the scope of this paper. Nonetheless, I argue, so long as this form of assessment prevails, it will present a barrier to learners’ full engagement with context and relevance in their numeracy learning.

References


TEACHER AS RESEARCHER: ACTION RESEARCH IN THE CLASSROOM

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Abstract
At ALM-19, the research topic group sessions focused on the conference theme of “synergy between parts,” where the “parts” are research and practice. Practitioner attendees expressed an interest in conducting classroom research but frustration due to their lack of knowledge concerning the research process. During a separate conference presentation that summarized twenty-first-century dissertation research on adult mathematics education, one attendee lamented the seeming lack of proactive research projects that investigate solutions to known problems.

The need to move the adult mathematics education research agenda forward would seem to be a critical moment for ALM. The organization now has two decades of published material about research and practice in editions of our journal and proceedings. Our members have been actively engaged in national research projects around the globe. This presentation will discuss the methods of action research described earlier at ALM-3 (Safford, 1997). Examples of teacher-as-researcher from national projects will be identified. Attendees will be invited to share their action research experiences and to identify additional projects of which the presenter might not be aware.

Introduction
The impetus for this research stemmed from three separate roots. During the two sessions of the research topic group at ALM-19, practitioners expressed frustration that they have no time to incorporate research in their work. At the same time they acknowledged the fact that knowledge of existing research was vital to improving classroom practice. An attending researcher pointed out that projects need not be large in scale and that any teacher could be a researcher in some small and focused way.

At a separate session where indexed research published since 2000 was summarized, a researcher lamented that we are not initiating groundbreaking research as a community practicing in the field of adult mathematics education. In the earlier years of the organization there were several national projects in our field, but those have dwindled and few new ones have commenced in the last five years. This might be due to the lingering global recession but might also be attributed to fickle political agendas that shift focus over time. Reflecting the theme of the conference, it is appropriate that we unite to promote research with or without government support.

The final momentum for the session was a personal one. As a university lecturer I experience continual frustration when reading assignments are not completed. Daily assigned work includes both textual material to be read and problems to be solved. The problems are usually attempted, but the readings lie fallow. This impedes student learning and slows progress during lectures as questions are asked that would have been answered within the assigned reading. This presented an ideal situation for an action research project to track an intervention.
Methodology

This project was not intended to include an exhaustive literature review. Rather, it was hoped that some of the research published since 2000 would inform my proposal and could be adapted to fit the task I hoped to undertake. At an early ALM conference (ALM-3), I had presented a paper on this topic (Safford, 1997), and the principal source was a text by Hopkins that had been published in 1985, ALM. Most three decades ago. A search of two major online booksellers was initiated in order to locate recent texts on action research so that the impact of technology over the intervening time, 1985 to the present, could be used to update the older framework of action-research data collection.

At the same time, the databases of the Education Resources Information Center (ERIC) were queried for full-text records meeting the descriptors “action research” and “adult mathematics education.” No results were found. That second search argument was amended to “adult education,” and 50 records were returned. Finally, the second argument was amended to read “numeracy,” and 21 records were returned. These 71 abstracts were then reviewed individually to eliminate overlap and to determine their usefulness for the enterprise I was undertaking. Full texts of those documents that looked as if they might be useful were then read completely, and an annotated bibliography took shape. Forty-two papers were read by the time the presentation was finalized and the ALM conference took place.

Action research

The concept of action research is generally attributed to work done by Kurt Lewin and John Dewey in the 1940s. Lewin’s interest was that of a social scientist, not a classroom teacher, and his focus was conflict resolution. His description of the process of action research is somewhat general. Lewin speaks of a “circle of planning, executing, and reconnaissance or fact-finding” (Lewin, 1948, p. 206) as a method for conducting social research, in particular, intergroup relations. John Dewey, an American education reformer, upheld the connectivity of research and practice with his view that learning is social and experiential. Dewey questioned the growing movement, still prevalent today, of evaluating social experiments using natural science methodologies.

This tension between methodological poles has plagued the acceptance of action research as a viable research technique. Generalizability is highly prized in the educational research community, and the subjective, qualitative nature of action research renders the results locally appropriate, at least initially. Replication can dampen that objection, but that process requires multiple settings with identical agendas. The individual nature of an action research project counteracts replication unless several individuals are struggling with the same issue. This presentation aspired to promote just such an alliance, as the problem and the student population crosses international borders, if conversations with colleagues are any indication.

A second feature of action research has made it suspect in the United States. In some societies, the characteristics of the research have mingled with political issues, and its tenets have been applied to organize and develop grassroots reform movements. This “participatory action research” reputation colors the viewpoint of the American research community and introduces a level of distrust for an otherwise respectable technique.

There is a chance that action research’s time has come. In the United States there is a growing emphasis on learning outcomes in the collegiate classroom and the formative assessment of same. This author would argue that action research is the perfect tool to achieve that assessment, since a primary goal of the methodology is the formulation of classroom intervention and the assessment of the resulting outcomes.
The action research cycle

Defining the problem: The action research cycle begins with the identification of the problem to be confronted. A list of questions that the researcher might pose to him/herself could be:

- I would like to improve the …
- Some people are unhappy about …
- What can I do to change the situation?
- I am perplexed by …
- … is a source of irritation. What can I do about it?
- I have an idea I would like to try out in my class.
- How can the experience of … be applied to …?
- Just what do I do with respect to …? (Hopkins, 1985, p. 47)

A form of the first and third questions would fit for the project that triggered this presentation. “I would like to improve the completion of reading assignments by my students” or “What can I do to change the situation in which my students are not completing their reading assignments?” serve to frame my “burning issue.”

Gathering the evidence: Once the research question has been framed, a decision must be made as to the data-gathering tools that are appropriate to the task and fit within the institutional boundaries. A major difference between this presentation and that delivered at ALM-3 is the explosion of technological tools available in the classroom and over the Internet. The classroom management system provided by my institution offers online collaboration, blogs, discussion boards, journaling, surveys and pools (not sure what these even are), and wikis. Any of these can be used to record student input over a semester.

Audio and video equipment have also taken a giant leap forward in the intervening years since the earlier conference. Students possess phones and tablets/pads that allow them to record events as they occur as well as reflections after the fact. Interviewer and interviewed need not even be in the same hemisphere—they can teleconference using Internet services such as Skype™. The researcher can dictate field notes or journal remarks using a voice-to-text software. Finally, archival data is often available as a database or spreadsheet that can be sorted or queried to researcher criteria.

Analysis of the data: The two major types of analysis are quantitative and qualitative, although they are not, and should not be, exclusive of each other. Action research, by its nature, leans in the direction of qualitative data: interviews, journal entries, and field notes. A project, however, might begin using a quantitative tool. Using my own project as an example, the preliminary study should survey students about the amount of time spent reading each week and could include an attitudinal instrument. The results of these are sometimes surprising and indicate a situation that differs from that which the instructor perceived.

Some, if not most, of the drudgery involved in tabulating data is alleviated by software. Statistical packages tally results and perform any statistical test the researcher desires as well as graphical representations of the results. On the qualitative side of the board, themes and trends can be identified and summarized. These aids are invaluable and free up the researcher to examine the results and draw conclusions. They should, however, be used prudently. There is value in reading the raw data, in listening to the subject’s voice. Nuances can surface that software may obscure.
Writing conclusions and recommendations: The action research cycle ends, and then begins again, with a review of the findings that emerge from the analysis. What conclusions do you draw from them? Patterns should surface that will prompt future action. If the intervention has had the desired effect, then plans for future incorporation need to be made. If not, can it be altered and the new version tested? Whether accepted or amended, a new action research cycle then begins.

Caveats

Before beginning a project, institutional restrictions need to be investigated. Privacy is always a concern and some institutions may not permit the use of surveys or student work because of undue influence on student or instructor attitude. It is important to check with your institutional review board, if one exists, to determine your institutional boundaries before planning the project, as many of the data-gathering tools are limited or prohibited if student work is outlawed.

Research of any kind takes time, and the analysis of the results will entail work on your part and perhaps on the part of colleagues if you involve them in the gathering or analysis of the data. The old expression “Don’t bite off more than you can chew” is an appropriate warning. A grant-funded project with funds for stipends allows the expansive effort that a solitary classroom investigation cannot.

Finally, the results may not be positive. The goal of your intervention is the improvement of student classroom experience, but the findings may reveal neutral or negative results. Do not be discouraged. The American inventor Thomas Edison is often quoted on the perception of failure. Two such quotes are "I have not failed. I've just found ten thousand ways that won't work" and “Just because something doesn't do what you planned it to do doesn't mean it's useless” (Bellis, 2014). While you certainly wish to avoid ten thousand repetitions of the action research cycle, each repetition enlightens your practice.

My action research project

Statement of the Problem: Each academic year (two consecutive semesters) I am the lecturer for a mathematics course that addresses the mathematics content in the United States elementary school system (students age 5 through 14). The students in the class are prospective teachers. We meet three times a week for 1 hour and by year’s end have experienced roughly 80 class hours. Class sessions are a mix of lecture and mathematical activities pursued by pairs or groups of students who then share their solutions with the class.

One hour of reading is assigned as homework after each lecture. This is generally from the textbook we are using but occasionally is a newspaper article that is pertinent to the course. Students take a weekly quiz that reflects the work of the previous week. The quiz material is drawn from the lectures, the textbook, and the mathematical activities. It is frequently obvious that the students have not done the assigned reading. Over the course of their careers they will have to read and comprehend textual material as curricula or their grade assignment change. A major goal of my course, therefore, is to pilot them through the process of reading technical literature with understanding.

A Research Plan: During the coming academic year, 2013–2014, the weekly quiz will be based exclusively on the material in the readings. There will, of course, be overlap, as the lectures are tied to the readings and contain similar content. The quiz questions, however, will draw from details contained in the readings but not necessarily highlighted in the lectures. Early in the semester one lecture will focus on the reading of technical literature with suggestions as to how to proceed.

Periodically, class time will be devoted to informal discussion about difficulties encountered when reading the assignments with student input about successful coping strategies. My perception of the
reasons for noncompliance with the assignments range from lack of time and general reading comprehension issues to the suspicion that students entering tertiary education are still mired in an objective learning perspective with the belief that knowledge is external, not constructed by the individual.

The first iteration of the action research cycle will take place during the 2014–2015 academic year. Obviously the intervention cannot be predicted completely at this point, as the plan will reflect the findings of the 2013–2014 inquiries. I anticipate, however, that it will be a two-pronged approach with a “learning to read” component applied using a scaffolding approach. The weekly quiz will include a reflective question that will require students to interpret the readings rather than replicate information. At my institution, student work cannot be used directly in research projects. As a result, the actual repository for data will be an instructor journal that reports the results of the intervention.

**Advice from research:** Not surprisingly, the literature review produced no one research article providing advice that directly addressed my project. A few were irrelevant and others provided marginally useful information. As is so often true of research, many of the articles addressed one facet of the project while also imparting information that is peripheral to the task or just fascinating in its own right. For example, an article on professional development in a law firm contained a clear and precise history of the practice of law in England (Gold, 2007). The following sections convey ideas garnered from seven of the papers that may prove fruitful to my project.

**Action Research**

In 2009 Jim Parsons and Phil McRae presented a paper about a large-scale longitudinal study done in Alberta, Canada, as part of an effort to improve education in districts across the province. While the paper is not a “how to do action research” document, it delves into the philosophical justification for conducting action research as it describes the interplay between the external research project Alberta Initiative for School Improvement (AISI) and a Masters of Educational Studies program at the University of Alberta. Embedded in the description of the authors’ work are periodic impassioned arguments for recognition for AR in the educational research community as well as the founding tenet of ALM, that practitioners are researchers and researchers need to be rooted in practice.

In an article by Capobianco, Lincoln, Canuel-Browne, and Trimarchi (2006), the authors address two points that are key to my project. The first is the tension between scientific training and the value of qualitative data and methods. In this article, Trimarchi states:

> As an experienced research technician, I had set up controlled experiments, run multiple trials, and collected clear-cut, obvious data. I found it difficult to transfer my empirical and experiential knowledge of scientific research to that of my own action research (Capobianco et al., 2006, p.68).

Her feelings are echoed by co-author, Canuel-Browne when she says:

> As a scientist, my initial exposure to action research did not come without its struggles. Qualitative research is often dismissed in science. Aspiring scientists are grilled for quantitative data. During my first experience with action research, it took me weeks to come to terms with using qualitative data, and yet with some reluctance, I found a way to address my concern. I used scores from student tests and quizzes to lend credibility to my concern for quantifying my data. I just had to have some graphs in my results! (Capobianco, et al., 2006, p. 69)

The second point was one of assessment strategy. Trimarchi wanted to evaluate the success of what she termed “interactive lectures” (Capobianco, et al., 2006, p. 68), and she devised multiple tools including:
instructing students to write reflective responses to questions posed throughout a lecture, assessing students’ understanding formatively via quick check ins, and asking students to compose a letter to the teacher depicting the main points of the lecture (Capobianco, et al., 2006, p. 68).

A Sample of interventions

An article by a group of faculty at University of Massachusetts–Amherst (Beatty et al., 2008) reported progress and initial insights gleaned from an action research intervention with middle and secondary school science and mathematics teachers. The intervention itself was technological in nature, a classroom response system (CRS), but the theory that supported the research, the design and implementation of the project, and the resulting recommendations have a broader application for in-service mathematics education professional development. The piece that I chose to apply was the use of a focused question to survey student responses and to open a classroom dialogue. This is a cousin to the way that I generally open class, but in light of the planned emphasis on student reading and reflection, it prods me to replace those opening questions with others closely tied to the reading assignment.

Farrell (2008), in a brief directed toward teachers of English language learners (ELT), expounded on the theoretical background for reflective practice and stressed the need for all teachers to reflect throughout their careers. He says:

> Reflective practice occurs when teachers consciously take on the role of reflective practitioner, subject their own beliefs about teaching and learning to critical analysis, take full responsibility for their actions in the classroom, and continue to improve their teaching practice (2008).

Farrell bases his vision of reflective practice on the work of Dewey, while the practical applications reflect the constructivist theories of Piaget and Vygotsky. The use of a teaching journal, the data collection tool that I plan to use in my project, is discussed at length in the brief, and links to other journaling sources should be helpful as I move forward in the next academic year.

Inglese (2011), in a paper that also reports action research in an ELT class, speaks of the paucity of research on teacher reflective journals. His paper includes a literature review of the sources that he discovered, followed by a summary of his own project using a journal to record and then reflect upon innovations that he used in his Asian university class for English learners. He cites Farrell, the author of the paper discussed above, and I plan to look into his list of citations to gain background into the use of a reflective journal in a university setting.

Turner (2012) detailed an action research methodology that she utilized in a graduate course on research methods. One goal of her course was the development of a literature review by the students, an effort that forced them to learn to read research articles in educational journals. She based her efforts on Vygotsky’s zone of proximal development, which in her words is “that difficult, itchy place where students are challenged but not overwhelmed” (p. 69). Turner accomplished her task by using what she termed “baby steps,” where assignments were scaffolded and the level of difficulty increased using “small, incremental steps” (p. 65). While her goals, and therefore steps, are different from mine I believe that the idea can be adapted and plan to attempt to do so.

Whannell, Whannell, and Allen (2012) explored the use of action research to improve self-efficacy in students in a tertiary bridging program. They describe the dilemma as:

> A particular problem which appeared to be hindering these students to successfully transition into the bridging program was their lack of knowledge of what was required to be a successful student in terms of academic and study behaviours. (p. 40)

The intervention they undertook was included in the first 6 weeks of the bridging program and, similar to Turner’s approach, was an exercise in scaffolding theory, advice, and specific assignment tasks in order to guide the fledgling students toward successful academic behaviors.
Conclusion

Action research appears to be an appropriate tool for improving the reading comprehension of the students in the preservice mathematics content course. Students do, however, need guidance as they move from novice to apprentice readers and a structured approach that blends lecture, modeling, and formative assessment may be the path to success. The journal articles contained helpful suggestions for developing an intervention, as well as references that may provide additional insights. My personal journey as practitioner-researcher will be facilitated by the labors of these earlier explorers. Hopefully, the wheel will be improved, not re-invented and, contrary to the old adage, I can learn from the mistakes (and successes) of others.

References


SECTION 3: Abstracts, Presentations, and Handouts

[Presentations are available at www.ALM-Online.net]
Section 3: Abstracts, presentations, and handouts

GIVING ADULT LEARNERS A ‘HEAD START’: MEASURING THE EFFECT OF A PRE-UNIVERSITY MATHEMATICS PREPARATION COURSE ON ADULT LEARNERS’ SELF EFFICACY

Lisa O’Keeffe
University Of Bedfordshire, England
[and]
Patrick Johnson
University Of Limerick, Ireland

In August 2008 the Mathematics Learning Centre (MLC) at the University of Limerick (UL) initiated a one-week mathematics foundation course entitled ‘Head Start Maths’ to provide mathematics revision for adult learners about to embark on science or technology degree programmes.

The objective of ‘Head Start Maths’ is to revise mathematics fundamentals before the commencement of third level education to lessen the workload and anxiety levels of adult learners in the early stages of their studies. Negative preconceptions are of major concern with adult learners, both preconceptions of mathematics in general and also of their own abilities. Further to this, research has shown there is a relationship between self efficacy and performance which suggests that learners with higher levels of self efficacy will persevere for longer with challenging tasks. Due to the impact that self efficacy can have on adult learners the authors decided to investigate via Pre and Post testing if there is a correlation between participation in the ‘Head Start Maths’ programme and a change in self efficacy level.

NARRATIVE LEARNING TRANSITIONS: DIALOGUES ABOUT MATHEMATICS LEARNING WITH ADULT LEARNERS

Dr Javier Díez-Palomar
University Of Barcelona, Spain

Learning is a personal process which is shaped by the context of adult life and the society in which one lives. When a person decides go back to the school, there must be a range of reasons that explain such a decision. Narratives bring to the researcher an amalgam of interdisciplinary analytic lenses to understand more deeply why adult learners decide to expand their learning.

The objective of this study is to draw on adult learners’ biographies to generate a deeper understanding of the multiple dimensions underlying individual approaches to learning transitions. I focus on mathematics learning courses. Using life histories I draw on learners’ voices to discuss critical moments in their lives to understand why they decided to participate in learning activities in mathematics. I explore with them their wishes, their challenges, their fears, in learning mathematics in an adult school. I use conceptual tools such as individual learning trajectories and critical ownership to analyse in depth adults’ learning experiences. I also use the dialogic learning approach to elucidate how adults overcome particular challenges in learning mathematics.
USING FRACTALS AND CHAOS TO DEVELOP DEEPER MATHEMATICAL EXPERIENCE AND IDENTIFY IMPLICATIONS FOR LESSON PLANNING

David Tennant

A group of students in their final year of a Secondary Maths Teacher Training Programme,
University of South Wales, Wales

Secondary school final year trainee teachers in mathematics undertake an action based research project during their last block of school experience. They take the non-curricular topics of fractals and chaos within mathematics, research the deeper theory behind these and use what they discover to develop a lesson suitable for 11-16 year olds. The lesson is then delivered in school and evaluated.

This workshop will briefly introduce the benefits of this sort of assignment for the trainee teacher and their learners, and provide an overview of the amazing variety of lessons that have resulted. Three trainee teachers will then present some of the work they have undertaken and delegates will have a chance to try some of the resources developed for secondary school lessons.

It is not uncommon for the trainee teacher to modify their view on how learners learn while conducting this action based research. Delegates will be given time to question the presenters on the outcomes.

NUMERACY AT WORK

Anna Gustavsen
Vox, Norwegian Agency for Lifelong Learning, Oslo, Norway

Tanya Aas
Vox, Norwegian Agency for Lifelong Learning, Oslo, Norway

A lack of Numeracy skills may negatively affect quality of life, labour market possibilities and participation in lifelong learning for the adult population. In Norway, there is significant political interest in basic skills. The long-term goals are avoiding social exclusion, improving chances of entering into or staying in the labour market, and building stepping-stones enabling the individual to go on to more education.

We will present examples of good practice and methods used in courses in Numeracy at the workplace. We have developed job skills profiles that describe basic skills that are part of working practice, and are based on competence objectives. Employers can ascertain what skills need to be strengthened, and employees can see what type of training they need in areas of reading, writing, verbal communication, Numeracy and IT skills. The profiles can be adapted to individual and local needs. They describe the link between basic skills and the employee’s actual work tasks, and make it easier for the training manager to devise appropriate courses.

The job skills profiles can be found here: http://www.vox.no/no/global-meny/English/Basic-skills/Framework/ In our workshop the participants will be able to make their own profiles for job skills in Numeracy.
A CHANGE OF ATTITUDE? EXPLORING UNDERGRADUATES’ PERCEPTIONS OF LEARNING MATHEMATICS

Karen Wicks
University of Bedfordshire, England

The purpose of my research is to explore undergraduates’ perceptions in learning mathematics and issues surrounding mathematics anxiety. I currently work as a senior lecturer in mathematics on a BA Applied Education Studies course at a university in the East of England and the undergraduates on the course consistently identify the mathematics education units as those they are most concerned about.

Having established, through literature, a potential link between mathematics anxiety in teachers and the possibility that this anxiety could be passed on to children in their classrooms, my aim is to identify whether there may be any strategies that could be identified to support adults in overcoming their anxiety. To do this I tracked a sample of first year undergraduate students through their initial mathematics education unit, exploring perceptions before and after completion of this unit.

This session aims to present the initial findings of this research, to include factors that affect how students feel about learning mathematics and the strategies they perceive support them in their learning and potentially help them to address mathematics anxiety.

EXPLAINING WHY YOU’LL DO YOUR DOUGH ON COMMERCIAL CHANCE GAMBLING: ACTIVITIES FOR TEACHING ABOUT THE MATHEMATICS OF GAMBLING LOSS

Donald Smith
Sunshine House, Victoria, Australia

Commercial gambling opportunities are widely prevalent; on the high street, your computer and phone. While stronger restrictive regulation is called for, individuals may gain some protection from gambling promotion by having a better awareness of why they will lose their money. A comprehensive curriculum is needed which develops and explains the mathematics of chance gambling.

We show the most crucial mathematical facts about gambling and introduce a range of activities which may be adopted across numeracy curricula. Step by step, together, we develop the probability concepts and understandings, without which it is difficult to argue that adults gamble with informed consent. The game Lucky Colours of Sunshine will be reprised from previous years with additional concept-anchoring activities and analysis suggested. The mathematics education community’s response to the growing scourge of gambling induced suffering is indeed a ‘critical’ moment in all senses of the word.
PROPOSING A PROJECT TO EXPLORE NUMERACY PRACTICES FOR ADULT ENGLISH LANGUAGE LEARNERS IN THE UNITED STATES: WHAT ARE KEY AREAS FOR CONSIDERATION?

Dr. Anestine Hector-Mason
American Institutes for Research, Washington DC, USA

This presentation is based on a proposal to advance numeracy practices for adult English language learners (ELLs) in the United States through an integrated project design. The American Institute for Research (AIR) is interested in exploring the literature on adult numeracy and ESL, and using the findings derived from this effort to generate theoretical papers in order to advance discussions within the field and with subject matter experts through a qualitative study that identifies promising practices that can be further examined in future scientific studies.

The aim of this work is to help to produce a comprehensive body of information that will advance numeracy practice with ELLs in the United States.

A SNAPSHOT OF THE CURRENT USE OF TECHNOLOGY IN ADULT MATHEMATICS EDUCATION IN AN IRISH CONTEXT

Catherine Byrne
Institute of Technology Tallaght, Dublin

Dr Theresa Maguire
Institute of Technology Tallaght, Dublin

Dr. John J Keogh
Institute of Technology Tallaght, Dublin

[and]
Professor John O'Donoghue
University of Limerick, Ireland

Recent research of adult numeracy tutors in Ireland has shown that the use of technology to support teaching and learning has increased significantly over the last ten years. Currently, over 60% of tutors report that they use technology in their classrooms.

This paper will report on the findings of a national survey that explored the kinds of technology used, the way technology was used and the opportunities and challenges that using technology brings to the adult numeracy classroom. Further, the paper will discuss how tutors define Technology Enhanced Learning (TEL) and the support that they feel both they and their learners need to effectively integrate technology into their teaching and learning.
WHAT'S NEW ON BBC SKILLSWISE?

Michael Rumbelow
BBC, UK

As UK adult numeracy education undergoes some of the most radical changes in a decade, BBC Skillswise is also preparing to transform and move onto a new BBC Learning online platform.

In this session we will preview some of the pilot work going on at BBC Skillswise to support adults at ‘critical moments’ of learning and practising mathematical skills, including while on apprenticeships in workplaces and when applying functional skills in everyday life.

You can find out more about BBC Skillswise here: http://www.bbc.co.uk/skillswise/0/

USING MOBILE TECHNOLOGIES IN FAMILY NUMERACY

Karen Workman
Neath and Port Talbot College, Wales

[and]

Hilary Jones
Neath and Port Talbot College, Wales

The aim of the workshop will be:

- To share the journey of implementing mobile technology into Family Learning classes.
- To explore ways to make learning collaborative, challenging and creative using iPads.
- To provide carousel activities using iPads to engage and promote adult numeracy.

We are numeracy teachers in an FE College who have been developing our own skills over the past year whilst studying the Level 5 Certificate in Teaching Adult Numeracy. We are ordinary teachers who are passionate about engaging hard to reach learners in innovative ways. We have been using mobile technology for 18 months and would like to share our experiences - particularly to demonstrate that you do not need to have high level IT skills to creatively and effectively embed technology into the numeracy classroom.

Family Learning aims to engage parents, grandparents or carers of young children who have not been involved in education for some time. It is designed to use the context of the child’s learning to teach both literacy and numeracy.

In this workshop we will show how embedding iPads into Family Learning sessions has enhanced the learning experience for both adults and children. We will demonstrate that effective principles of teaching - rich collaborative tasks, funds of knowledge and using ICT - are central aspects of our delivery.

We will provide practical activities for participants to discover many ways to use the iPad creatively to engage learners, promote numeracy and improve skills.
A CASE STUDY: SUPPORTING A DYSLEXIC/DYSCALCULIC STUDENT IN FURTHER EDUCATION

James Ruffell, Tower Hamlets College, London, England

This session will adopt a case study approach to consider strategies for supporting dyscalculic students in FE and will consider:
ASSESSMENT THROUGH EXHIBITION: AN INTERACTIVE DISPLAY OF WORK UNDERTAKEN BY GROUPS OF ADULT NUMERACY TEACHERS AIMED AT ENGAGING PARTICIPANTS, PROMOTING MATHS AND SUPPORTING NUMERACY LEARNING ‘IN SOCIAL CONTEXT’

Jo Hitchings, Rachel Earp, Jayne Cleary, Karen Workman, Hilary Jones, Lisa Rinaldi, Jess Bowen, Lisa Openshaw, Rachel Bastone, Andrea Neve, and Susan Roden with Janette Gibney, Joanne Harris and Judith Archer from USW Wales, Wales

As part of their final summative assessment for ‘Numeracy in Social Context’, new and in-service teachers on specialist Adult Numeracy teacher education programmes (L5 Cert/Cert Ed and PGCE) undertake a group exhibition task.

This ‘workshop’ will briefly introduce the rationale for this type of group assessment tool and then delegates will have the opportunity to look at and try a range of activities and resources exhibited by some of this year’s adult numeracy teachers. There will be a range of classroom and ‘street maths’ aimed at engaging participants, promoting mathematics and supporting numeracy learning ‘in social context’.

The presenting teachers will share some of the ‘significant moments’ they experienced in the course of the exhibition task. Delegates will be encouraged to reflect on their own responses to the activities, the exhibition format and the challenges and opportunities such a group assessment tool presents for learners, tutors and external assessors.

GCSE ENHANCEMENT PROGRAMME - UPSKILLING TEACHERS TO RESPOND TO POLICY CHANGES IN ENGLAND

Graham Griffiths

The post-16 GCSE\textsuperscript{76} Mathematics enhancement programme is a UK Department for Education funded project which supports teachers in developing their subject knowledge and teaching practice. The programme – devised by the National Centre for Excellence in the Teaching of Mathematics (NCETM) – is a response to a government policy change in which all young people (16-18) are engaged in mathematics and are expected to aim for the higher (A*- C) grades of the school leaving GCSE award. It has been estimated that there would need to be more than 500 extra mathematics teachers in order to deal with the teaching requirements. The enhancement programme has been devised to ‘upskill’ existing adult numeracy and functional skills teachers to deal with this challenge.

The workshop will outline some of the issues involved, describe the programme and discuss the outcomes from the pilot programmes run January to March 2013. Examples of the activities will be undertaken and discussed.

\textsuperscript{76} The General Certificate for Secondary Education (GCSE) is a school leaving qualification designed to be taken by school leavers at age 16 (but also by older, adult learners and sometimes by younger children).
USING DIGITAL TECHNOLOGIES IN THE CLASSROOM

Rachel Bastone and Kevin Lawrence
Ystrad Mynach College, Wales

Learners have become more and more expectant that digital technologies will be used as part of their teaching and learning experiences. This is driving teachers to consider how these technologies can be integrated into their teaching delivery in an effective, engaging and interactive way.

We are an FE College in the South Wales valleys and we are driving forward the use of technology within our teaching to enhance the learner experience.

This workshop aims to offer snapshots of a variety of maths/numeracy topics, demonstrating how staff and students have interacted with some of the technology based teaching strategies/resources. The resources will be available for participants to actively engage with and discuss.

We will include within the session the use of:

- Mobiles phones
- Tablets
- Augmented reality
- Interactive whiteboards
- Blogs and Forums

There will be opportunity for participants to engage in using the resources. In addition there will be facilities and short tutorials available to create simple resources using some of the technologies.

FROM ADULT NUMERACY TO FUNCTIONAL SKILLS: EXPERIENCES FROM AN ADULT AND COMMUNITY LEARNING SETTING

Helen Marsden and Bolaji Oluokun
Haringey Adult Learning Service, London, England

We teach Numeracy/Maths for the Skills for Life department within the adult learning service of a local government council in a deprived area of north London, UK. Our learners are aged from 19 to 70+ and range in level from Entry 1 to Level 1.

This academic year, 2012/13, in line with changes nationally, we prepared our learners for the first time for the new Functional Skills Mathematics assessments. In this paper we will record our experience of the transition from delivering Adult Numeracy to delivering Functional Skills to adult learners. We will describe the changes we made to the structure of our programme, look at some of the strategies we have used as tutors, attempt to convey something of our learners’ experiences and make some observations about the criteria and assessment items for these qualifications. The paper will include learner case studies and analysis of some of the emerging themes, outcomes from this first year and learning for next year.
TOPIC GROUP A: CRITICAL MOMENTS IN THE RESEARCH PRACTICE OF ALM

Dr Katherine Safford-Ramus
St. Peter’s University, New Jersey, USA
And
David Kaye
Learning Unlimited, England

This is the 20th conference for ALM and since ALM6 in 1999 a topic group has discussed a ‘theoretical framework for adult mathematics learning and teaching’. However even this was pre-dated by Tine Wedege’s paper ‘Could there be a specific problematique for research in adults’ mathematics education?’ at ALM 4 in 1997 and ‘ALM as a community of practice presented by Roseanne Benn, Juergen Maasz and Tine Wedege at ALM 5 in 1998.

From its origin, ALM set itself the task of bringing together research and practice and merging the roles of researcher and practitioner – the full name of the organisation being Adults Learning Mathematics – a research forum.

In this open discussion, we will re-visit the research principles of ALM itself. To begin, we will identify some critical moments from the history of ALM conferences and proceed to identify key objectives for ALM in the second decade of the 21st century. It is hoped that the resulting informal agenda for action will enthuse participants to engage in actions that will advance those objectives.

TOPIC GROUP B: MATHS AND DECISION-MAKING

Joan O'Hagan, Ireland with Graham Griffiths
Institute Of Education and Learning Unlimited
[and]
Rachel Stone
Sheffield Hallam University, England

The overall aim of this topic group is to get participants to think aloud about a range of connected issues about decision-making which I think adult numeracy teachers/researchers could work on, and about how we could also influence the work that is being done by cognitive scientists etc.
SECTION 4: Poster Presentations
NUMERACY IN VOCATIONAL LEARNING

Nuala Broderick,
University of Manchester, England

My current research sets out to explore whether a funds of knowledge theory which conceptualises literacy as a situated, social practice can be used as a lens through which to research young (16-18 year old) people’s every-day, informal experiences and uncover or ‘excavate’ (Johnson, 2005) the numeracy resources – the numeracy funds of knowledge - these young people bring to their vocational learning. It further seeks to identify how these learners’ informal/everyday numeracy practices are currently used by their vocational teachers and whether and how these funds of knowledge can be mobilised to support numeracy teaching and learning in the vocational classroom.

The poster presented on the next page is a summary of the research aims, my research activity to date and findings emerging from data collection so far.
Vocational Learners and Vernacular Numeracies
Funds of knowledge theory and learners’ everyday numeracy practices

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Research Questions
- What numeracy practices do learners engage in, in their everyday lives?
- What numeracy do learners need to succeed on their vocational programme?
- How are learners’ everyday numeracy practices, conceptualised as their ‘funds of knowledge’, used in their vocational learning?
- How can teachers use learners’ numeracy funds of knowledge in vocational and functional maths classes to support a more critical pedagogy??

Research Aim
- To explore whether funds of knowledge theory which conceptualises numeracy as a situated, social practice can be used to research learners’ everyday numeracy experiences
- To identify how learners’ everyday numeracy practices are used by vocational teachers and whether and how these funds of knowledge can be mobilised to support numeracy teaching and learning

Methods
- Focus group with two groups of Level 1 vocational students using stimulus prompts to gather data on everyday leisure activities
- Observations of vocational classes
- Observations of Functional Maths
- 1:1 Interviews with learners
- 1:1 Interviews with teachers
- Teacher action research activity

Students’ everyday numeracy practices

Learners’ vocational numeracy practices observed in hairdressing session
- Using computerised diary system
- Working with blocks of time when making appointments for clients
- Estimating amount of time needed for different lengths of hair and styles
- Setting timers when colouring hair
- Choosing different diameter brushes for different hair techniques
- Holding hair at right angles from the head when cutting or brushing
- Using the correct gradient when cutting or brushing
- Checking length of hair after cutting
- Using technology
- Asking clients about how much to cut
- Working out the cost and taking payments using credit/debit cards and cash
- Mixing colours in correct ratios
- Counting stock
- Talking to clients about achieving balance and symmetry

Interim Findings
- Students’ numeracy practices outside of formal learning are contextualised and situated in their everyday, lived experiences
- Students see themselves as experts in these practices but alienated from formal maths
- Vocational teachers unaware of learners’ numeracy skills and practices
- Few links made between informal and formal numeracy practices in class

References

Next Steps
Vocational teachers undertaking ‘change practices’ in their vocational classes.
As part of an assessment task on a Level 5 Teaching Adult Numeracy course this year, I was required to work with a peer partner to develop teaching and learning resources which would engage learners, promote mathematics and support numeracy learning. We also had to consider ethno mathematical approaches and sociocultural context.

We decided to research and develop a range of inclusive puzzles and games from around the world that could be used to engage learners in problem solving. The materials and activities were then used with our learners within a range of settings and formed the basis of a group exhibition, a peer presentation and a written rationale and evaluation.

This poster (overleaf) on the next page gives a snapshot of how I undertook this task within my own practice context where I work with adult male numeracy students in a prison setting. The poster is a summary of the research aims, my research activity to date and findings emerging from data collection so far.
Section 4: Poster Presentations

Puzzles and games with adult male prisoners

Andrea Neve, HM Prison Usk/Prescod

Introduction
As part of a Level 5 Teaching Adult Numeracy course this year, I was required to work with a peer partner to develop teaching and learning resources which would engage learners, promote mathematics and support numeracy learning. We also had to consider socio-mathematical approaches and sociocultural context.

We decided to research and develop a range of inclusive puzzles and games from around the world that could be used to engage learners in problem solving. The materials and activities were then used with our learners within a range of settings and formed the basis of a group exhibition, a poster presentation and a written rationale and evaluation.

Figure 1: The maths games we chose to use with learners

Secret Code/Mastermind - Israel
Chinese Reverse - Britain
Tanagram - China
Tower of Hanoi - France
Matchstick puzzles - Britain
Horizontal - Vertical - Hurricane website
Achilles - Ghana
Mancala - Africa
Some cube - Denmark

Why games in numeracy lessons?
Games can introduce ideas in a different way and allow students to hide until they feel confident. They create discussion, are socially interactive and encourage mathematical talk. Games make learners work mentally whilst allowing them to solve problems in their own ways and many have few language barriers and are common to various cultures.

Our Exhibition topic and materials
Puzzles and games from around the world were chosen focusing on those which involved limited formal numerical skill making them accessible to most and playable on many levels. They were value-free, multicultural, socially acceptable and did not require previous knowledge. A positive focus on traditional games allowed for a limited access to technology in prison.

Puzzles and games in my classroom
Games chosen required only small physical actions, for example moving a counter, as I had small classrooms and learners with mobility difficulties. Games offered full information with no “luck” as this could be problematic (gambling) in the prison environment.

All the games needed safe, limited and inexpensive equipment so they could be loaned out.

Many prisoners had negative experiences in learning numeracy, and using puzzles and games to promote maths vocabulary and develop problem solving skills was successful with most learners. A small number of learners had experienced games through their lives but the majority had not. It was often necessary to emphasise learning outcomes in order to foster full engagement in tasks but most were receptive to a new approach.

Where learners initial numeracy levels were dissimilar, strategies were put in place to support learners playing the games (pair working, hints and tips, etc.). These worked really well and improved participation. Many prisoners were disengaged from learning and a key part of my classroom practice was developing their interest, enthusiasm and self-esteem whilst reducing stress and fear of failure. By playing games, my learners experienced interpreting rules, analysing strategies, generalising, summarising, proving and recording whilst actually enjoying themselves and having fun.

Figure 2: one of the puzzles on display during the exhibition

Conclusion
The enthusiasm and engagement that playing mathematical games engendered convinced me of the merits of such an approach with adult male prisoners. Having developed my confidence teaching with games, I intend to include this more widely in my classroom. Along with being a valuable teaching tool, the games widened participation and many became popular on the prison wing. We are now expanding the range of games for prisoners to borrow from the library.

Undertaking the Level 5 task of an exhibition and write up was for me a really stimulating new challenge that complemented the other assessment tasks and made a welcome change from academic writing.

References

Level 5 Unit 1 - Level 5, 2008

http://www.level5.co.uk/subject/mathematics/index/level5/5032/index.html

http://www.level5.co.uk/subject/mathematics/index/level5/5032/steam.html

History of maths
http://en.wikipedia.org/wiki/Mathematics

http://www.mathsisfun.com/history-of-maths.html

Conclusion
http://www.level5.co.uk/subject/mathematics/index/level5/5032/steam.html

http://www.mathsisfun.com/history-of-maths.html

By Andrea Neve | Usk Prison, Wales
SECTION 5: Miscellaneous
Mathematics quiz answers

Round 1 - Mathematics trivia and facts

1. If the length, width, and height of a rectangular solid box were each increased by 50%, by what percentage would the volume be increased?
   **Answer:** 237.5%

2. How many numbers between 1 and 1000 have at least one digit 9?
   **Answer:** 271

3. What shape does the equation \((x^2 + y^2 - 1)^3 - x^2 y^3 = 0\) make?
   **Answer:** heart shape

4. A googol is ten to the power of what?
   **Answer:** 100

5. What is special about the number 1729?
   **Answer:** smallest number which is the sum of two (positive) cubes in two different ways
   \[10^3 + 9^3, 1^3 + 12^3\]

6. What is special about a Reuleaux triangle?
   **Answer:** Has a constant width.

7. What is the phrase ‘may I have a large container of coffee?’ a mnemonic for?
   **Answer:** pi to 7 dp.

8. How many triangles are in the following? Answer: 48

9. Argentina uses the peso as currency which has the following coins: 5, 10, 25 and 50 centos. How many different ways are there of getting 50 centos. 25+10+10+5 is the same as 10+25+5+10.
   **Answer:** 11

10. What whole number is nearest to the sum of \(\pi, e\) and \(\phi\) (the golden ratio)?
    **Answer:** 7.
Round 2 – Mathematics and languages

Identify the languages the number words/numeral systems come from. Choose from the list below – note that there are 14 languages below – ie four of them are redundant.

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Armenian, Cantonese, Czech, Finnish, Gaelic, Hindi, Japanese, Korean, Persian, Polish, Swahili, Thai, Welsh, Yoruba

**Answers**

1. Polish
2. Armenian
3. Welsh
4. Hindi
5. Persian
6. Japanese
7. Yoruba
8. Cantonese
9. Thai
10. Finnish
Round 3 - Mathematics in the movies and TV

1. Which comedians calculated that 7 times 13 was 28 while ‘In the Navy’ in 1941?
   
   **Answer:** Bud Abbott and Lou Costello

2. Which 60s US TV series involved the rapidly breeding, hermaphrodite Tribbles who multiplied from 1 to 1771561 in three days?
   
   **Answer:** Star Trek

3. Which animated character spent time in Mathmagic Land in 1959?
   
   **Answer:** Donald Duck

4. In this 1994 film, Albert Einstein comes to the aid of a young garage mechanic (who has fallen in love with Einstein’s mathematically brilliant niece), by helping him to pretend to be a great physicist. Tim Robbins plays the mechanic who discusses Zeno’s paradox with Meg Ryan’s character. What is the name of the film?
   
   **Answer:** IQ

5. In this late 80s film, teacher Jaime Escalante encourages his Hispanic students to take the Advanced Place Calculus test. Inspired by real events, what is the name of the film?
   
   **Answer:** Stand and Deliver

6. Which performer plays a teacher in the 1958 film Merry Andrew who delivers a song and dance rendition of Pythagoras’ Theorem.
   
   **Answer:** Danny Kaye

7. In the second episode of a long running animated series set in fictional Springfield, this male character (voiced by actress Nancy Cartright) — day dreams of trains travelling in opposite directions (in a parody of mathematics problems) while sitting a school test. What is the name of the character?
   
   **Answer:** Bart Simpson

8. Fermat's Room (La habitación de Fermat) is a 2007 Spanish thriller film in which three mathematicians and one inventor are invited to a house and told to use pseudonyms based on famous historical mathematicians. "Fermat" (Pierre de Fermat) is the (apparent) host, "Galois" (Évariste Galois), "Oliva" (Oliva Sabuco) and "Pascal" (Blaise Pascal) are three of the visitors. What is the fourth pseudonym based on a German mathematician?
   
   **Answer:** "Hilbert" (David Hilbert)

9. Who is the director of the 1998 film entitled Pi in which Max Cohen is a number theorist who believes that everything in nature can be understood through numbers? (lenient on spelling)
   
   **Answer:** Darren Aronovsky

10. What is the name of the CBS television crime drama series produced by Ridley and Tony Scott in which mathematics is used to solve crimes? (Precise name)
    
    **Answer:** Numbers
**Round 4 - Mathematicians across geography and time**

Re arrange the following to get the names of some important figures in the history of mathematics.

1. up bratha mag (Indian – one part)  
   **Brahmagupta**
2. chevon khogle (Swedish – three parts)  
   **Helge von Koch**
3. pat yahi (Egyptian / Greek – one part)  
   **Hypatia**
4. needa stre crés (French – two parts)  
   **René Descartes**
5. josh hann (US – two parts)  
   **John Nash**
6. thailion wanor willamm (Irish – two parts)  
   **William Rowan Hamilton**
7. chimo chiz shiniuki (Japanese – two parts)  
   **Shinichi Mochizuki**
8. derrec obertor (Welsh – two parts)  
   **Robert Recorde**
9. yoteen hermm (German – two parts)  
   **Emmy Noether**
10. mavand reikor (Russian – two parts)  
    **Andrei Markov**

**Round 5 - Mathematics and music**

1. Who sang (and co wrote) the US/UK 1960 hit declaring that he did not know much about trigonometry or what a slide rule is for?  
   **Answer:** Sam Cooke (Wonderful world)
2. More recently, in 2011, who sang “I don’t know much about algebra, but I know one plus one equals two, And it’s me and you, that’s all we’ll have when the world is through”  
   **Answer:** Beyonce
3. Who sang the decimal expansion of pi as the chorus to a song, getting it wrong in the 53rd decimal place?  
   **Answer:** Kate Bush
4. The rapper Drake accompanied which singer with the following rhyme “I heard you good with them soft lips, Yeah you know word of mouth, the square root of 69 is 8 something, cuz I’ve been trying to work it out”?  
   **Answer:** Rhinanna (on What’s my name)
5. Now back to the 60s, who sang ‘Multiplication’? “Multiplication… that’s the name of the game!”
And each generation… they play the same!, Let me tell ya now: I say one and one is five, You can call me a silly goat! But, ya take two minks, add two winks, Ah… ya got one mink coat!”

**Answer:** Bobby Darin

6. Which Swedish band, better known for ‘All that she wants’ in the 90s, reformed recently and sang to their ‘Golden ratio’?

**Answer:** Ace of Base

7. Mos Def proved he could count on the b side ‘Mathematics’ which was also on his 1999 debut album. What was the name of the album?

**Answer:** Black on Both Sides.

8. The term math rock has been applied to a number of rock groups employing complex rhythms. Which Chicago based sound engineer and producer, a founder member of Big Black, is associated with the scene?

**Answer:** Steve Albini

9. Which performer expressed his concern that only a child could do ‘new math’?

**Answer:** Tom Lehrer

10. Douglas Hofstader made some links between mathematics, art and music in his 1979 book subtitled ‘The Golden Braid’. Who was the classical composer in the title?

**Answer:** Johann Sebastian Bach
### Names and contact details for ALM20 Participants

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