From the classroom to the workplace and back again: Developing an understanding of numeracy teaching

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In this report I explain my research into how numeracy skills are developed in both workplace and education contexts. One aspect of the research is the development of a model of analysis that I use to work with teachers to identify and reflect upon the numeracy skills, knowledge and processes used in the contexts of education and the workplace. The paper explains the origins of the model of analysis through my work with the NHS, then its use when working with Cake Bake Company, and finally with trainee numeracy teachers. This report details how the model can be used in a variety of workplace scenarios to analyse the numeracy skills and knowledge being used and how trainee teachers used the model to develop their thinking about numeracy teaching in context. In the methodology I briefly summarise my personal journey from teacher trainer to researcher / teacher trainer as the development of this model has been influential in my understanding of both aspects of my work.

Introduction

Learning and developing skills in the context of the workplace has a rich and varied background of research. The recent focus in the UK on the links between education, training and economic success has resulted in policy and funding being channelled into developing workplace skills (Leitch, 2006). In response to this policy shift I have had the opportunity to work with and train people from a range of contexts in the workplace and in education.

During this time I developed a model of analysis to try to further understand the challenges to teaching and training in the workplace and developing numeracy skills and knowledge. It was originally used to aid my own understanding but I now use it with numeracy teacher trainees to help analyse the variety of challenges faced when trying to teach numeracy skills and knowledge in a workplace context, in a classroom, in a college.

The original model of analysis emerged from a process of analysing the skills required by nurse tutors and mentors who wanted to support their student nurses to improve their numeracy skills in clinical settings. This year I used the model for further research in different contexts: in a large cake baking company and with a group of teachers on a numeracy specialist teacher training programme.

I also include a literature review on workplace learning theories. This is a brief review, but one I am building upon. As the philosopher Lyotard wrote “We always begin in the middle” (Lyotard, 1992). The report also contains the findings from the Cake Bake Company, including both employer and employee perspectives, and the responses of the trainee numeracy teachers to the model. The discussion with the

teacher trainers took place as part of their numeracy specialist teacher training programme within a section on contextualised and workplace learning.

Methodology

While originally developed in 2008 the model was further redrafted after discussions with peers at the 15th Adults Learning Maths (ALM) conference. London South Bank University then funded research into the model to test its adaptability to another workplace setting, a cake baking company, and to further test the response to the model by a group of trainee numeracy teachers. This paper is one of the forms of dissemination agreed. The funding from the university had two aims: to further my research but also to further me as a researcher. This could be viewed as successful on both counts I am now studying for my doctorate and my use of the model has further evolved beyond this paper.

This research was in two parts. Part one was an ethnographic approach to research interviewing the employer at length, visiting the factory and interviewing the team leaders from the production line. The interviews discussed the maths used to help understand better the changes needed on a production line, including a spreadsheet that helped with calculating cake costs. These interviews were written up and shared with the employer and team leaders to ensure accuracy.

Part two was research carried out with a group of trainee numeracy teachers. They were given a presentation on the development of the model and then asked to fill in questionnaires as part of the research. The questionnaires were given out a week later so that the trainee teachers had time to reflect on the content of the presentation in relation to their own work and to an assignment they had to write for their training programme about numeracy in context.

Theories of learning within education and the workplace

There is a great debate about the value and ethics of teaching mathematics in a vocational setting, or numeracy skills in the workplace. Are teacher trainers developing teachers who, as Robert Reich identified, create a workforce whose members participate in the global economy and are able to create solutions to problems that currently do not exist with technologies that have not yet been invented? (Reich, 1992) Or are we developing teachers who are dealing with current numeracy skills demands, developing the skills needed to gain a job during the current economic recession?

In this report while recognising the tension existing in the UK between vocational and academic studies, I am not able to do justice to all aspects of the debate exploring the social, economic, philosophical and historical basis of teaching and training in the workplace. However as a researcher I build on a perspective that recognises education can enable people to change their lives. Wedege (2000) in her research links mathematics, technology and the concept of democracy as possibly enabling “a personal competence that changes inability to initiative and power”, considering the development of numeracy skills to enable people’s lives in the sense that Paulo Freire (1985) used when discussing teaching literacy.

Exploring the value placed on learning in the contexts of education and the workplace I am interested in the ideas developed by D’Ambrosio (2001), who sees mathematics,

or numeracy, as a function of life, culture, values, language recognising that it helps us prepare for the 21st century workplace.

It seems to me that the willingness of the employer in the Cake Bake Company to engage the workforce in developing an understanding of the usefulness of the spreadsheet to inform decisions around production may reflect this perspective on learning for work. On the other hand it may simply be a drive for greater profits. However in this case it was not necessary to develop the skills of the workforce to increase the profits and it seems to reflect more the underpinning philosophy of one of the directors to the company, who had a career in education before she started the company.

Exploring the teaching and learning of numeracy in variety of social contexts also includes such notions of 'crossing borders' (FitzSimons, 2004) and recognising that the social context is an inherent aspect of numeracy teaching and learning, that numeracy is a function of mathematics and its social context.

A study by Lave and Wenger (1991) discusses the concept of 'situated learning' as 'legitimate peripheral participation' in 'communities of practice' as ways of conceptualising the process of development of expertise in practice. Wenger described the concept of the 'community of practice' in more theoretical details as being a group of people who regularly engage in an activity in pursuit of some jointly–negotiated enterprise, "thereby developing a shared repertoire of ways of going about things that is constituted in the ongoing process of the communities of practice" (Tusting and Barton, 2003, pp17). The development of the spreadsheet certainly informs the 'community of practice', in this case the cake baking team. By using the spreadsheet the team leaders in particular developed the 'shared repertoire' of ways of going about making cakes. The spreadsheet helps the team to understand the impact of changes on any cake in production and enables team leaders to give informed instructions and work in a more efficient way.

Research by Resnick (1989) into situated learning and the differences between ways of learning through apprenticeships in the workplace and ways of learning in school is useful to consider when working with the model of analysis. Resnick found "in schools people are expected to learn individually. Yet in work and personal life, most mental activity is performed in the context of some shared task that allows mental work to be shared over several individuals." (Resnick, 1989 p12) Resnick, and Griffiths and Guile, identify shared tasks that almost always involve the social nature of informal learning distinguishing it from formal learning. Formal learning is more individual, purely mental, resulting in generalized concepts. It is second hand as well as decontextualised and needs motivation. The informal is collaborative, leading to highly specific forms of reasoning and skills. It has 'real content', is first-hand and comes easily. (Griffiths & Guile, 1999). The development, use and understanding of the spreadsheet certainly fits into the informal category as described, however some definitions of informal also describe this learning as "unplanned or incidental" (Tusting and Barton, 2003, p26). The spreadsheet at the Cake Bake Company does not fit into that category. The spreadsheet was specifically developed by the employer to improve understanding of production for the members of the team.

Also relevant to this use of the spreadsheet in the workplace is the research carried out by Hoyles, Noss, Kent, Bakker and Bhinder (Bakker, Hoyles, Kent, & Noss 2004,

Bakker, Kent, Noss, Hoyles and Bhinder 2006, Hoyles, Noss and Kent 2007), who researched the mathematical skills used in developing and using IT tools to make the workplace more efficient. In this context the use of a spreadsheet is to inform the decision-making process in the cake baking company and it may be described as an example of a 'boundary object', "an object that can serve to coordinate different perspectives of several social worlds or communities of practice" (Bakker, Hoyles, Kent, & Noss, 2004, p. 4.)

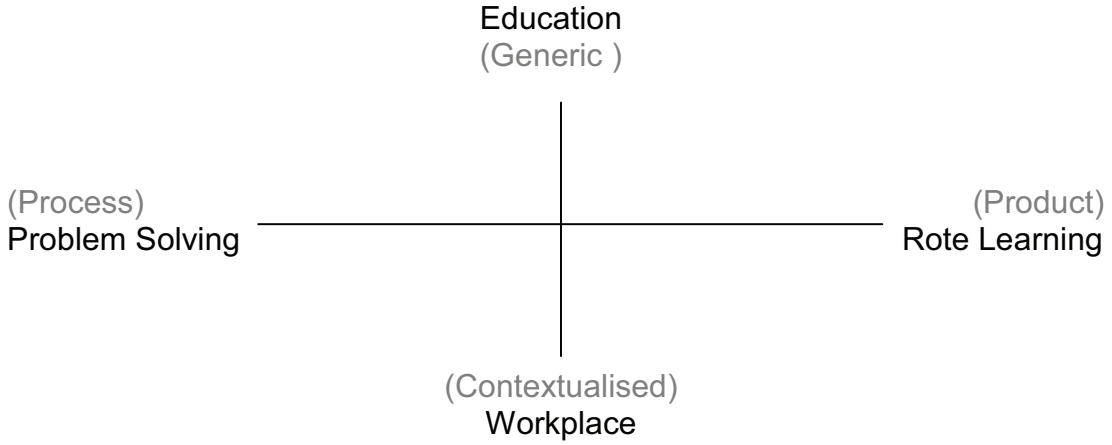
The Model of analysis

The model of analysis was initially developed to explore the relationship between the learning of numeracy skills and the context of the learning, in particular, the contexts of education and the NHS. (Kelly, 2008).

The model was used to differentiate between the social context of learning on the vertical axis and the approaches to teaching and learning numeracy skills on the horizontal axis. The vertical axis represents the contexts of education and workplace, while the horizontal axis represents a continuum from rote learning to problem solving approaches to numeracy teaching.

The model was developed to try to help explore how numeracy skills and knowledge were currently taught in the classroom and in the workplace. The further research was to explore the transferability of the model to another industrial context and to assess its usefulness to trainee numeracy teachers when considering approaches to teaching.

Diagram 1 Model of analysis for workplace



The vertical axis represents the world of education above the horizontal axis and the workplace below. The horizontal axis represents a continuum of numeracy approaches to teaching and learning, with rote learning on the extreme right and process / problem solving approaches on the extreme left. The axis itself represents a continuum of approaches between these two; for example, a fraction calculation will be at the opposite end of the axis to a mathematical process of understanding, e.g. ratios and proportions, and its application to a variety of contexts. Moving from Product to Process implies movement from right to left along a continuum of teaching approaches.

Thus the model can help to identify teaching and learning approaches in different contexts, enabling judgements as to the most appropriate one for a particular

numeracy skill. For example, it may be appropriate to learn generic fraction skills at school, while adult workers may find more value in a workplace problem solving approach. Educators can move around the axes as they adapt their approaches.

Context 1. Nurse Lecturers and Mentors supporting numeracy skills in a clinical setting

What are the practical implications for educators? Consider the following problem from a training session to help Nurse Lecturers and Mentors better support their trainees' numeracy in a clinical setting.

> You need to prepare an injection of 0.75mg of digoxin.
>
> The stock solution has 500mcg in 2ml. How many millilitres do you draw up? Show how you would carry out the calculation

Asked how to solve it, participants identified four methods.

> For information: mcg = microgram; 1000mcg = 1 milligram (1mg); 500mcg = 0.5mg

Method 1. What you want (0.75mg), divided by what you have got (500mcg or 0.5mg), multiplied by the volume (2ml). Answer: 3ml to get 0.75mg

This is the standard formula given to trainee nurses for situations when they have a prescription for a drug supplied in phials. This formula is learned by rote. It is specific to the clinical context, not transferable outside it and often not fully understood by those using it.

In the model that emerged from participant discussion in the session (see figure 1 below), this method is placed in the bottom right quadrant: it is contextualised with a specific answer (i.e. 'product').

Method 2. 0.75 mg is prescribed but the medicine phials are produced in amounts of 0.5mg. 0.5mg = 2ml (concentration in one phial). 0.25mg = 1ml. 0.75mg = 3mls

To deliver 0.75mg of the medicine the nurse will need to deliver 3mls of the solution, or 1.5 phials.

The mathematics for this calculation is based on ratio and proportion. This approach can be used and applied to many different contexts. (A common use of this approach is in the calculation of VAT). This calculation is transferable to many contexts and generic in its applicability. This method goes in the top left-hand corner of the model.

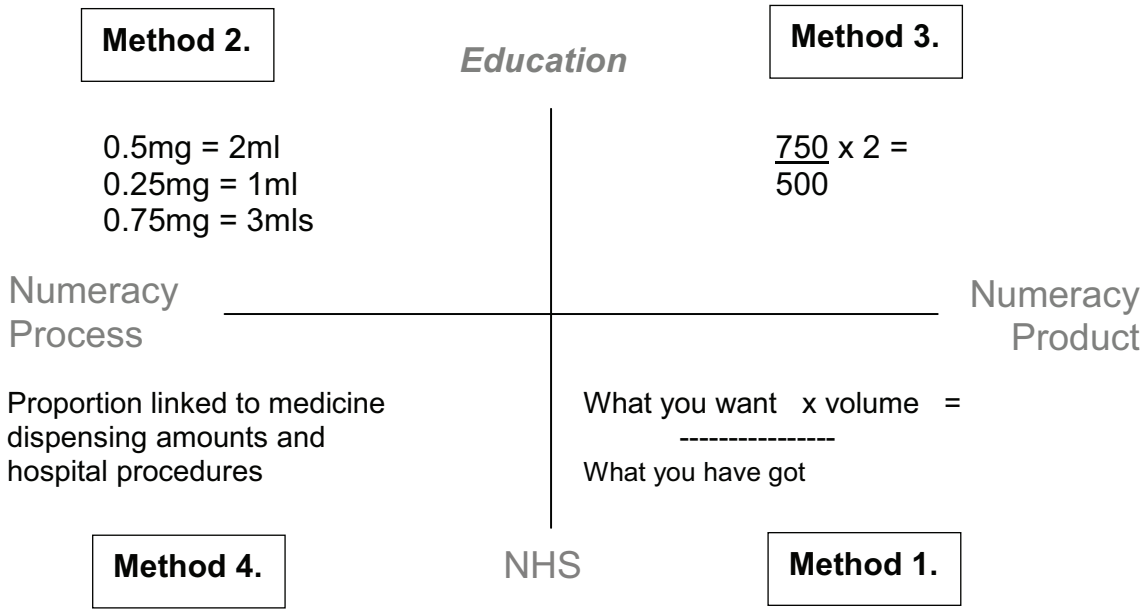
Method 3. Three divided by two times two.

This method uses Method 1's approach, but without units, reducing the calculation to a simple fraction with a simple number answer. This method goes in the top right-hand corner of the model: generic (no units) and no context.

Method 4. Treat the calculation as a word-based problem, linked to delivering medicines according to the procedures used specifically in that hospital or organisation.

This method goes in the bottom left-hand quadrant: a process for calculating the medicines, but totally context-driven.

Diagram 2 Model of analysis for workplace numeracy



This example shows the relationships between the different aspects of calculations and contexts. Where learning is a fundamental part of the calculation in one context, Education, it may not obviously inform the same calculation in another context in the workplace, in this case, the NHS.

It also shows the different methods that can be used to solve a single problem.

Context 2. The Cake Bake Company

'Workers with understanding make good judgements'

Director of The Cake Bake Company.

The question: How do you enable a team on a production line to work with greater understanding and make good judgements?

The director of the Cake Bake Company, an independently run company, wanted the team on the production line to have a better understanding of how decisions made further up the production line impacted on waste and hence profit. She felt that when involved with large-scale production it is important for the workforce to appreciate:

- how the ingredients costs are calculated,
- the timing on the production line,
- the pace of production,
- the impact of wastage on costs and outputs

Thus gaining a better understanding of the cost of the production process would help them to identify priorities for action, enabling the team members to make better, more efficient judgements about the running of the production line.

The employer felt that it was useful for the team leaders, at the very least, to understand some of the implications of ingredients ratios, pricing, timing, pace and waste.

According to the employer the accountant's information shows ingredients to be 55% of costs of sales, gross wages are only 15%. It is therefore worthwhile trying to reduce costs in the interest of efficiency.

The spreadsheet as a tool to increase understanding and change behaviour

The ratio of cake mixture can change quite regularly depending on orders, availability of ingredients, prices and demand. Obviously some ingredients are more expensive than others so some understanding of the implications of changes to production is important to reducing waste and making a profit.

The director of the Cake Bake Company produced a spreadsheet to try to help that understanding and appreciate some of the implications of their work on the costs and quality of the final product.

The spreadsheet had several headings including ingredients, weight of product, and cost of product. The calculations on the spreadsheet included cost per ingredient, total cost per cake mix and the individual cost of producing each cake.

Diagram 3 Exemplar Spreadsheet

Windsor cakes - Batch of 20,000

Ingredients	weight	costs	cost per ingredient
Flour	20 kgs	3.42 per kg	68.40
sugar	-	-	-
Oil	150 tonnes	-	-
Water		-	-
	Total cost of mix =	-	

***Cost of one cake** = Cost of (cake mix – wastage)

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number in batch

Each type of cake e.g. lemon sponge, had a separate column with different colour code, so the spreadsheet included the mixtures for all of the cakes on the production line.

Impact of spreadsheet calculations in the work place

The value of this spreadsheet from the Employers perspective is that it not only allows the costs of production to be easily calculated but also allows the implications of changes in ingredients and wasted cakes to be quickly understood by team leaders.

Thus the impact of an increase in the price of one ingredient can be quickly understood. The implications may be that the cake becomes too expensive to sell with the current mixture. Decisions then need to be made: Shall we reduce that ingredient or consider how else we can absorb the cost? For example, shall we trade off some oil for water? This may save money in ingredients but will also have an impact on the shelf life of the cake so the quantity and rate of sales must be understood.

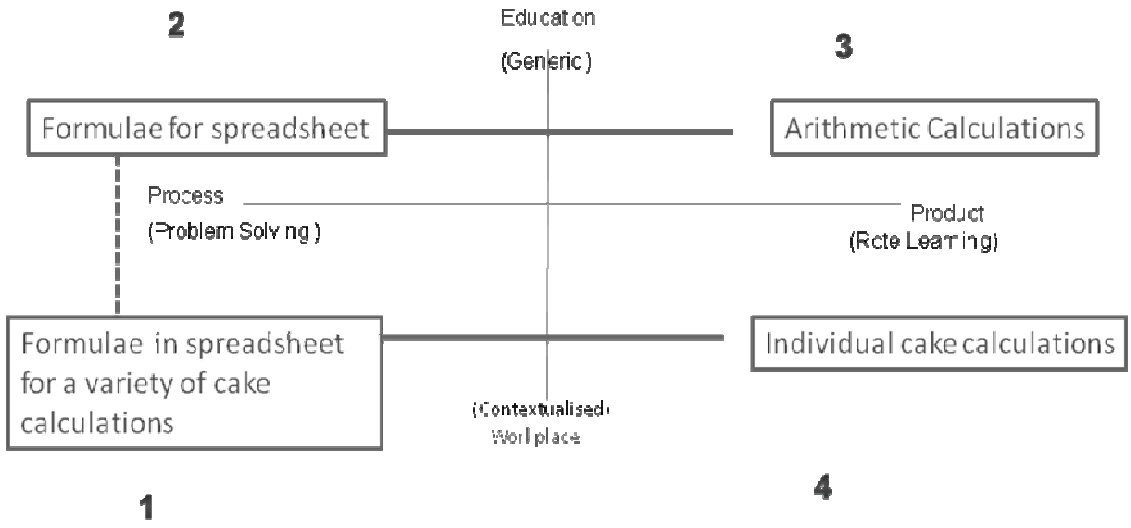
This level of discussion and inclusion in decision-making for the cake production may be possible without the spreadsheet, but in this case the spreadsheet acted as a tool to aid understanding and did have an impact on behaviour, for example, enabled the team leader to prompt others in the team to ensure ingredients were scraped out of containers reducing waste.

Prior to the explanations of the costs of baking, all of the calculations for the costing of production were carried out by hand by the director and kept in a file. One motivation for sharing the spreadsheet was that one of the team leaders wanted to get a computer at his home and wanted to know how he might use it. The director used this opportunity to discuss the cake costings with the employee. He said he had an understanding of the costs of some the ingredients before he saw the spreadsheet but it helped him get a real overview into the impact of price changes on the costs of production.

Analysis of the numeracy skills and knowledge in the spreadsheet for the cake baking company

The calculations in the spreadsheet for one cake could easily sit in quadrant 4 – contextualised and set of numeracy calculations - the single product. However once the calculations are put into a spreadsheet and extended to other cakes and their ingredients, the calculations move into quadrant **1** in the workplace context, now using a set of numeracy processes adapted to all cake mixtures.

Diagram 4



The arithmetic calculations within the spreadsheet; for a single cake multiplying one set of numbers by another, adding a column of numbers, and dividing the total by another number fits well into quadrant **3** the numeracy product in a generic context. This learning can all take place in the numeracy class where generic skills can be taught.

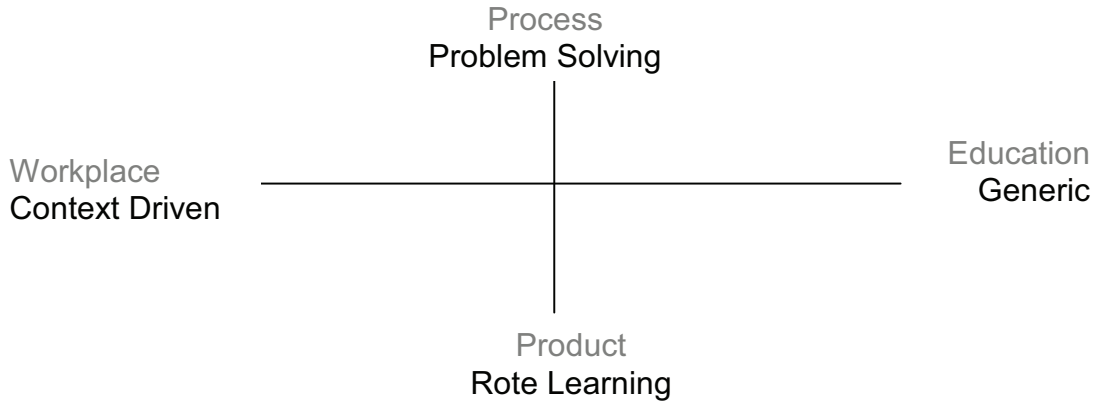
If the units are included to make sense of problem, the multiplication, addition and division calculations become part of the process for problem solving and it then fits into quadrant **2** - a generic approach, using a spreadsheet to support a problem solving approach.

The decision-making process in the workplace is also useful to understand in its complexity. Often work place scenarios are deemed as simplistic or are stripped of their complexity to concentrate on the numeracy skills thus losing the context. If the problem stays in the generic / numeracy product quadrant this may be true, if the context is removed for simplicity of calculations. However if the workplace context and the variables that fit into the production are understood, the calculations can inform a broader decision – making process within a different social context.

The employer's perspective on the model

When discussing the use of the spreadsheet and the purpose of the model the employer suggested a development to the model. She suggested that the vertical and horizontal axes should be rotated by 90 degrees to put workplace and education on the same level, rather than in a symbolic hierarchy with education above the workplace. This also allows the idea of processing information, or problem solving, to be above the horizontal axis and the simple product calculations to be below, introducing the idea of functionality above the axis and rote learning below.

Diagram 5



The removal of the visual hierarchy is useful for a number of reasons, not least because it made me reassess my value system and assumptions when devising the model. As the researcher I was very aware of the academic vocational divide in the UK education system, and had regularly critiqued a model that seemed unable to recognise the value of both. It would nevertheless seem that some of that value system prevelant amongst traditional UK academics had been absorbed. As Freire (1985) describes it, academic thinking can become 'domesticated' by the prevalent thinking of the dominant classes.

Impact of maths in the workplace

Both team leaders interviewed were responsible for different parts of the cake baking process. The team leader on the 'wet side" (pre-baking) was interested in the costs of the ingredients, particularly as he now had a responsibility for some purchasing as well. The team leader on the 'dry side'(post-baking), i.e. the cutting, packaging and labelling, said she was mainly focused on packaging and dates, but one of her main drivers was reducing waste.

The director regularly sat down with 'pen and paper' and the teams, and more regularly the team leaders, to work through costs of production and allow them to understand why changes had to be made to production practices. For example, there was a discussion about how waste had been reduced by reducing the size of cakes being cooked - so that the 'dry team' could handle and package the cakes properly. There was also a discussion about the recycling of packing and using surplus boxes for 'ends' of cakes that were sold off cheaper, rather than just throwing them away. These ideas came from the team leaders after discussions on the cost of packaging and reducing waste.

The director of the company had a philosophy of a 'no blame culture ' in the factory and was very keen for the workforce to engage with an understanding of the costs of production to enable them to see the impact of their work. She stated "she would not work with targets but wanted the team to work on shared knowledge". This inclusive approach to management, based on shared knowledge, encouraged and motivated the workforce to make suggestions for improving the production, quality and cost of the cakes.

This type of knowledge sharing relates well to the literature on informal learning where 'real content' - first-hand and easily understood - was used to inform decisions. The team and director had a 'shared repertoire' of knowledge around costings in their 'community of practice'. Interestingly the spreadsheet was introduced during these sessions as a response to a trigger outside the production line, but the director used the opportunity to further develop the understanding of the workforce. The most useful learning experiences were when they sat down with pen and paper and worked out the cost of changing production.

Context 3 Relevance to trainee numeracy teachers.

The model of analysis was also discussed with a group of trainee numeracy teachers who were undertaking a teacher-training programme to qualify to teach numeracy to adults.

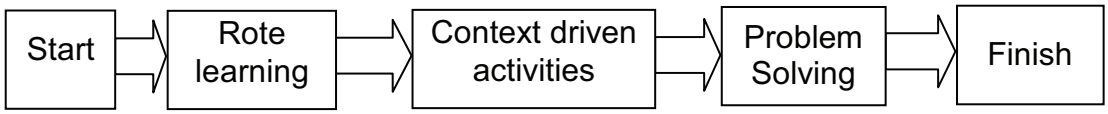
The group profile

The group consisted on 19 participants. four had been teaching less than 2 years, four had been teaching between 2 and 5 years and eleven, had been teaching more than 5 years. All had worked outside Education in a variety of jobs including: administration, pharmacy, finance, printing, social work and one had been an air traffic controller for 10 years.

Responses and discussions

No matter what length of service most of the respondents considered they always started their numeracy teaching was in the generic / education half of the model. Only a minority identified starting teaching in a vocational context. However a majority said they moved constantly into different quadrants of teaching approaches and contexts depending on their group of learners and the curriculum (functional skills was identified as a driver for moving into different contexts).

For example; one trainee described their general approach to teaching numeracy as



When asked if the group could use the model to analyse some numeracy teaching they are currently doing in context, nine (47%) described classes and scenarios using the terminology of rote, problem solving and context or describing the contexts. Four more made comments about moving around the model.

One was not teaching in a vocational context and three did not answer this question. Two of the three had been teaching for less than 2 years.

When asked how the model could be improved, reworked or adapted, most stated the model should reflect more movement. Words and phrases such as "fluidity, not pigeon holed, more overlapping areas", were used to describe the need to recognise the movement from specific answers to processes and from education to other contexts.

One suggested that it might be interesting to mark a point on the model every few minutes to show the movement of teachers from one quadrant to another throughout the lesson. Another wrote of 'unconscious" movement between quadrants, another spoke of a chronological time-line, another of Venn diagrams showing the overlap of contexts and methods.

Some spoke of using a web effect and others drew boxes on the diagrams to show areas of numeracy including all four quadrants.

Comments on Trainee teachers' responses

It was clear from the responses that trainees felt they moved around the model, using a range of different approaches to teaching numeracy during a single teaching session.

The responses indicated that the trainees had understood the concepts of types of learning from rote to process and that they had also understood the contexts. The respondents did not suggest changing the axes, so apparently accepted the continuums of types of learning and the difference in contexts for education and the workplace, they simply wished to animate the model.

Trainees spontaneously identified the time to contextualise and the lack of 'real" contextualised resources as a barrier to using the contextualised approach.

The value of the model in this teaching programme was that it gave a structure to the debate about context and transferability of skills between contexts. It recognised some of the complexity of teaching numeracy and allowed that process / product argument to be adapted to a context. It also enabled the teacher to further recognise and analyse the skills they use when teaching in a variety of contexts.

In conclusion

The model of analysis was adaptable to the further workplace context and useful to the trainee teachers' discussions on teaching and learning in contexts.

In both workplace and education scenarios the model was useful to consider the numeracy skills and knowledge used in the different contexts. It was also useful to further investigate the extent to which numeracy skills and knowledge can be separated from the specific workplace / vocational knowledge. Often the numeracy skills in the workplace context are hidden within the complexity of specific language of the workplace / vocational context.

For teacher training the model was also useful to encourage discussions on integrating and embedding numeracy into contexts and approaches to teaching numeracy skills and knowledge in a range of contexts. It also encouraged discussions on the variety of numeracy methods that can be used to solve a problem in the workplace or in a vocational context. It also opened up the opportunity to discuss the possibility, or not , of the notion of transferable skills.

The value of the model of analysis would be increased if further research was carried out to develop more workplace and vocational examples of numeracy skills analysis. Further research could be carried out with teacher trainers to develop the skills of

recognising the most appropriate contexts for developing numeracy skills and knowledge.

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