"IT'S NOT JUST MAGIC!" LEARNING OPPORTUNITIES WITH SPREADSHEETS IN THE FINANCIAL SECTOR

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In the research project "Techno-mathematical Literacies in the Workplace" we have carried out case studies in several industry sectors to characterise employees' need for functional mathematical knowledge mediated by tools and grounded in the context of specific work situations. We have subsequently designed learning opportunities which we have tested and revised as part of design-based research. This paper gives examples from three financial companies in which we have used spreadsheet-based learning opportunities to support employees in their understanding of the (for them) hidden mathematical models on which pension investments and mortgage illustrations are based.

TECHNO-MATHEMATICAL LITERACIES

The "Techno-mathematical Literacies in the Workplace Project" [1] is investigating the combinations of mathematical and technological skills that people need in workplaces. We are investigating different industry sectors (manufacturing and services) and we focus on employees at "intermediate" skill level, typically non-graduates with at most A-level qualifications. In the financial context, this includes sales agents, customer enquiry agents and first-line managers in such areas.

This research follows on from a previous project (Hoyles et al., 2002) which put forward the idea of "mathematical literacy" as a growing necessity for successful performance in the workplace. In the current project, we are using the term "Techno-mathematical Literacies" (TmL) as a term to describe functional mathematical knowledge mediated by tools and grounded in the context of specific work situations. The prefix, "techno", emphasises the mediation of mathematical knowledge by technology, and the plural form of "literacies" hints at the breadth of the knowledge required in the context of work.

FROM ETHNOGRAPHY TO DESIGN RESEARCH

The project's research methods combine ethnographic studies with design-based research. We have used ethnographic techniques to identify the mathematical practices in companies; we aimed to understand the work process and to describe the techno-mathematical aspects of the practices that we observed. One of the results of this was a set of real contexts and situations in which we identified how employees' TmL could be improved. In the financial companies, this was mainly in customer-facing situations such as in sales teams and customer enquiry teams (see Kent et al., in press). Working with percentages and compound interest underlies almost all financial mathematics in the areas that we observed; yet very few of the employees we interviewed demonstrated a basic understanding of what we considered to be the essential mathematical features of the financial products they were dealing with.

Their mathematical knowledge was generally fragmented: in a striking example, sales agents in a mortgage company admitted they had never thought about a potential relationship between monthly and yearly equivalent interest rates, not even to the extent of "approximately times 12". They tended to see the different interest rates as labels (annual rates are labels attached to mortgages, monthly rates are labels attached to credit card or loan debts), with any relationship between them being devolved to the (mostly invisible) knowledge instilled in the IT system.

The current phase of our research is concerned with developing learning interventions that can support employees in developing the TmL that are useful in their work. In collaboration with companies and industry sector experts, we carry out design experiments (cf. Cobb et al., 2003), which are characterised by cycles of preparation, design, evaluation and revision of what we call "learning opportunities" in collaboration with workplace trainers. Within the financial sector, we have carried out three cycles of design experiments in two pensions companies (*Cycle 1*: 3 times 1.5 hours with 8 people, customer enquiries; *Cycle 2*: 3 times 2 hours with 4 people, sales support administrators) and one mortgage company (*Cycle 3*: 2 days with 6 people, telephone-based mortgage sales).

DESIGN PRINCIPLES

Rather than thinking of training as transmitting our mathematical knowledge to employees and managers in companies, we prefer to think of learning opportunities as "boundary-crossing" activities involving the participants and ourselves (cf. Tuomi-Gröhn & Engeström, 2003). The notion of boundary crossing builds on Star and Griesemer's (1989) notion of a boundary object, an object which serves to coordinate different perspectives across communities of practice. For the purpose of our research we think of employees, managers and ourselves as different communities with different agendas, experiences and formal knowledge that each brings to the situation. Our challenge is to characterise how techno-mathematical knowledge is exchanged across boundaries.

This approach has several implications. One is that we use real artefacts that we try to "unpack" with the participants; they learn to construct, for example, annual pension statements or mortgage illustrations that otherwise only appear as numbers on their computer screens as if "by magic". Another implication is that we take seriously participants' concerns about the meaning of any numbers, charts or graphs within their work context. We do not just ask them to reason about the underlying mathematics but also give them opportunities to connect work-related and mathematical reasoning. In this way we intend to focus on mathematical models and structures (such as compound interest) that can bring coherence to what is otherwise perceived as a plurality of different and unrelated elements. Additionally, we intend to facilitate boundary crossing by adopting a constructionist approach in the learning opportunities that allows participants to express their ideas through the use of appropriate tools, and in so doing open windows onto their thinking (Noss & Hoyles, 1996).

FROM PERCENTAGES TO MULTIPLYING FACTORS

The first activity of each cycle was intended to generate surprise and motivate the mathematical habit of making percentage calculations with multiplying factors (i.e. "times 1.08" instead of "plus 8 %"). We did not observe this habit in any of our ethnographic interviews, although it is a simple and powerful way of understanding how money grows. In particular we wanted to make use of it for dealing with models based on compound interest in later activities. In the context of a shopping trip to New York, we asked the employees to consider buying a camera for $250, get 15% discount on this price, and having to pay 8% sales tax. The question concerned the order in which tax and discount were applied; the shop manager first subtracted the discount and then applied tax, but customer wanted him to do it the other way round in order to get "more discount". (This situation is based on the example called "Warehouse" in Mason, Burton, & Stacey, 1985.)

Out of 20 persons, only two suggested that the price would be "about the same". One interesting observation was that participants intuitively situated this problem in a real world context whereas we mainly interpreted from a mathematical perspective as a way of discussing the equality of 0.85*1.08 and 1.08*0.85. For example, one experienced customer enquiry agent insisted that only one way could be *legally* correct, an interpretation which simply did not occur to us in designing this activity: "the 8% tax has to be on the price paid, so customer is not right." Apart from the argument of getting more discount, there seemed little reason for thinking mathematically that one or the other way would lead to a lower or the same price. When one participant checked the two options with a calculator, he said that "the numbers come out the same", but then accused us of "cooking the books" by choosing these particular numbers! It turned out that this activity worked well in many ways: participants brought contextual reasons to this mathematical problem, they were surprised, were able to model it in Excel and wanted to know why it worked out mathematically liked this. Moreover, in using Excel to model the situation, they were able to investigate the equality of the two methods as a *general rule* (i.e., working for any price, discount rate, or sales tax) and so not arising from any particular "cooked" figures.

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Statement date: 24 April 2005

Date of birth: 19 April 1961 Pension age: 60

Your fund value at the statement date is: £14,223 , no additional premiums to be paid

Projected benefits at pension age:

	Lower rate (5%)	Mid rate (7%)	Higher rate (9%)
At age 60 your fund would be	£31,000	£41,900	£55,600
This could buy a pension annuity of (see note 3)	£838 pa	£1,970 pa	£3,780 pa
OR			
A tax-free lump sum of	£7,760	£10,500	£14,100
and a pension annuity of	£629 pa	£1,480 pa	£2,840 pa

These are only examples and are not guaranteed - they are not minimum or maximum amounts. What you will get back depends on how your investment grows.

Figure 1. Example of a pension statement without monthly premiums

RECONSTRUCTING A PENSION STATEMENT WITH EXCEL

For the major activity in the pensions companies (Cycles 1 and 2), we invited participants to reconstruct an annual pension statement. Each year pension companies send out pension statements to their customers, which tell them what their current fund value might be at the time of retirement based on projected percentage growth rates. Since pension plans are usually invested in a mixture of equities, bonds and property the projection by a constant rate of compound interest is actually a fiction which not all customers appreciate. Figure 1 is an example of a statement we used in the sessions.

Using an Excel spreadsheet, participants were asked to reconstruct these figures and to spot several errors we had deliberately inserted to make the task more interesting. They had to create formulae themselves for interest amounts and fund values for all the years up to retirement. Through the "dragging down" of formulae in the spreadsheet, the participants could get a feel for what happens without the need to use the standard compound interest formula (such as £14,223 * (1 + 5/100)^16). After they had reconstructed the simplest case, participants built up progressively more detailed spreadsheet models as the sessions progressed, incorporating more details such as premium payments and management charges.

The level of engagement with this activity was high, and participants evidently began to engage with the mathematical models underlying the calculations. One participant commented later, "it's not just magic… to me projections were just – someone gave you the figures over there and how they arrived at them was just magic! Now I can see what it is, it makes sense."

EVALUATION

The evaluation was based on questionnaires, a feedback discussion at the end of each course and interviews with individual participants a few weeks after each course. Generally, participants appreciated what they had learnt, but only a few of them had had opportunities to use the things they had learnt. One customer enquiry agent (Cycle 1) had done so: "I have used it talking to customers on the phone already, like the charges and all that, being able to challenge someone on the phone rather than do a referral [to someone who knows more about it]."

In the Cycle 1 interviews we did not use Excel, and we found that the feedback was somewhat superficial: it was difficult for the interviewees after three weeks to remember the details of what had happened in the sessions, and to explain themselves without the support of the software tool. This was evident for example in how they discussed the mathematical ideas underlying the shopping example (i.e. the equivalence of 0.85*1.08 and 1.08*0.85). For the second cycle we therefore decided to set a small task with Excel to explore participants' thinking around multiplying factors; we asked interviewees to construct a pension projection using a combined formula in a single column, rather than working out the sub-calculations across several columns. With a little guidance, these interviewees showed a good level of fluency *whilst working with the software tool*, which had not been evident in the first cycle by simply asking questions about multiplying factors.

In terms of learning outcomes, the two team managers in Cycle 1 felt more comfortable using percentages in spreadsheets and recording daily statistics on employees' performance. This impact of Excel had been an intended secondary outcome for us, since we believed that it was to a great extent the lack of an accessible mathematical tool that impeded their understanding of the mathematical artefacts in their work, and we hoped that the tool would unlock some of their implicit understandings and allow them to build new understandings. After Cycle 3, one employee regretted she could not use the spreadsheets as part of her daily work: for compliance reasons these first have to be "signed off" by another department. Without such a tool she felt she could not really use what she had learned. In other words, participants generally believed that having Excel as a tool had been central to much of what they had learnt.

CONCLUSIONS

We consider the boundary-crossing approach we have taken to be broadly successful. In the New York activity, both we and the participants altered our perspectives: *we* learnt to view the situation from a business perspective; *they* started to think about the underlying mathematics, in terms of multiplicative factors rather than addition and subtraction of percentages. In the pension statement example (and similarly for the mortgage illustration used in the third company), the statement functioned as a boundary object between the two communities: employees and researchers. From evaluative interviews and questionnaires we have gathered detailed feedback about

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the learning opportunities and mathematical artefacts that we chose, and how to refine these more effectively to the learning situations. For example, in the first design cycle, we learnt that we should focus more on communication rather than just structural understanding – underlining that communication with mathematical symbols is an important aspect of TmL.

In Cycle 3 (mortgages), we began to explore this idea in the form of role-playing scenarios in which participants answered inquiries posed by researchers acting as customers; the scenarios sought to pick on issues that took the participants beyond the comfort zone of familiar practice. The results are very provisional; yet it was clear that such scenarios were possibly the key boundary-crossing experience for the learners as they tried to relate the newly-experienced mathematics with the familiar practice of (in this case) telephone sales. From the company's point of view (the view of the trainer who co-designed and co-taught with us), the scenarios were also interesting because they suggested selling points for the company's mortgage products. This suggests that the TmL we had chosen to focus on (using percentages, interest rates, compound interest in a spreadsheet to reconstruct work artefacts) could point to a broader relevance in transforming practice.

NOTES

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