Techno-mathematical Literacies in the Workplace

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What are the combinations of mathematical, statistical and technological skills that people need in their work? The type of people we have in mind are those at "intermediate" level, typically non-graduates with A-level qualifications or equivalent who may be working as skilled industrial operators or supervisory managers. This question was central to the Mathematical Skills in the Workplace project, previously reported in this newsletter [1, 2]. That project concluded with the idea of "mathematical literacy" as a growing necessity for successful performance in the workplace. The Techno-mathematical Literacies in the Workplace project [3] was established in October 2003 to investigate the nature of mathematical literacies in more detail, by a two-stage process. First, to survey the mathematical work being done by intermediate-level employees in a sample of companies. Second, to design and test "learning opportunities" for employees that focus on those "Techno-mathematical Literacies" (TmL) which we find to be important from the initial survey. Ultimately, the intention is that our research findings will not fizzle away, as tends to happen with fixed-term projects, but that the learning materials we produce can continue to be disseminated and developed in the post-16 education and training sector. One avenue for this that we are working on is to incorporate our ideas into NVQ frameworks for the several industry sectors that our investigations focus on: Packaging, Pharmaceuticals, Manufacturing and Financial Services.

What are Techno-mathematical Literacies?

First, we should give some illustration of what we mean by the term Techno-mathematical Literacies (TmL). We use the term as a way of thinking about mathematics as it exists as part of modern, increasingly IT-based workplace practices. Part of the reason we felt the need for a new term is to avoid the baggage which goes along with the term "numeracy", which pervades educational discussion of mathematics, and also to avoid the (apparently) simple term "mathematics" for which many people in industry, both managers and shopfloor employees, might have misunderstandings based on their school and later life experiences. Beyond this, we are convinced that the idea of literacy is really crucial: individuals need to be able to understand and use mathematics as a language which will increasingly pervade the workplace through IT-based control and administration systems as much as conventional literacy (reading and writing) has pervaded working life for the last century.

Compared with past requirements for general mathematical literacy in the workplace (being able to calculate and estimate), what is now required is something considerably more complex: we consider TmL as combinations of mathematical, IT and workplace-specific competencies that demand an ability to deal with models and to take decisions based on the interpretation of abstract information. Of course, such understandings have always been required of relatively few, highly trained employees. But IT brings unprecedented complexity to workplace systems, and it involves an increasing number of people to engage with IT systems and to interpret their outputs, both qualitatively and quantitatively.

Here are two examples which contrast the presence and absence of TmL in workplace situations. Firstly, when talking to managers in a pharmaceutical company about control charts such as in Fig 1, one of them told us about an operator who did not spot a trend in a control chart.

Interviewer: *I can imagine that an operator could see a trend within those limits and maybe be able to predict, if this trend is going on – We are going to have a problem in one hour's time.*

Manager: *That is exactly what we tell them to do. We had a very expensive example where an operator didn't spot a trend. We have 30 positions for capsule filling, and for 4 hours one of those positions was creeping more and more out of control. After 4 hours and 10 minutes the damn thing fell apart, which cost £8,000 and took the machine out of service for 24 hours. So that is an example where an operator was not looking at the statistical data accurately enough. It was overfilling, and there was a reason for it. The reason was that the thing was coming loose; it was sitting high and getting overdose – and we could use the data to show that there was a trend.*

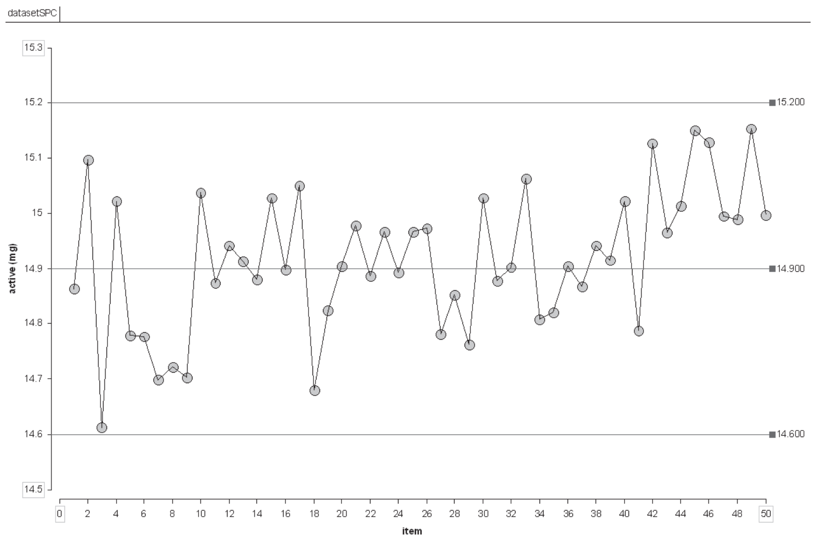

Fig 1 A control chart with 14.9 mg as the target value of active drug, and 14.6 as the lower control limit and 15.2 as the upper control limit. This is not a real data set, but one we might use for a learning opportunity to discuss trends in SPC charts (created in TinkerPlots [4]).

The example illustrates how machine operators have to monitor and interpret rather complicated statistical graphs, particularly to look for trends in behaviour. Note that we do not yet know for sure the reason for the breakdown in this case – whether it was negligence by the operator or a lack of ability to interpret the trend, which was (afterwards) visible to the manager. We do know that the traditional approach to statistical process control and the use of control charts generally seeks to "instruct" employees in techniques and rules for behaviour in a quite limited way. In such an approach, a control chart may end up as an abstract object that is not meaningful and functional in the workplace context ("expensive wallpaper", as some managers called it). Therefore, we are interested in the potential benefits of "educating" employees in a broader way to appreciate the mathematics and statistics which underlie the meaning of control charts, and begin to involve ideas of "problem solving" based on the use of data about the work process they know from direct experience.

The second example is a positive one – where a shopfloor employee used TmL to identify a production problem. In a packaging company making plastic film, one of the machines had problems. The extrusion machine, where plastic tubing is blown up into a bubble to stretch it, was not stable. A process engineer told us the following:

The bubble is normally really stable; it looks almost solid as you're looking at it. Occasionally we had periods where it would wallow in and out, it would burst and we couldn't find any obvious causes for that. One of our operators looked through the historic data, which is accessed through the computer control system … he scrolled through the various historic pages trying to find anything that had occurred at the time when we had the bubble instability…he went through all the graphs and tried to find anything that he thought looked 'odd' – that was his expression. Because he looks at graphs often, he has learned what looks normal, what's a normal fluctuation, and in his opinion when he looked at the graph of the film tension in one part of the machine it seemed that there was an abnormal pattern of fluctuation that corresponded to the moment when we'd had the instability in the extrusion bubble.

On the basis of the operator's observation, the process engineer initiated an investigation of one part of the machine. A set of sealed bearings that had not been looked at for many years was opened up and found to be worn out. They were replaced and the problem was solved.

What is striking about this example is that the operator concerned was "self-taught" in the use of the computer-based graphs – actually they are designed to be used for trouble-shooting of the machinery by professional engineers, and not for the use of the shopfloor employees.

The operator had learnt through long observation what is "normal" and what is "not normal" – something which few of his colleagues have taken the interest to do. Several questions arise: how should we characterise the mathematical ability which this operator has demonstrated (and are we sure it is the result of learning on-the-job)? How could this operator be helped to be even more effective in making use of data? How could his colleagues be encouraged to engage with and learn from data?

Using TmL to make the invisible visible

In our project, we have come to focus on the TmL involved in making invisible problems visible and coming to data-informed decisions. Making something visible depends on knowledge. In the first example, the operator might not have noticed a trend because he did not really know what the chart was showing. Perhaps he had just been told to stop only if there were points above the upper control limit or below the lower control limit.

In the second example, an operator used the graphs to see where the patterns of certain variables looked 'odd'. On the basis of the data, he was able to make visible the cause of a problem that otherwise would have been very difficult to locate (as you may imagine, the machine concerned has many thousands of working parts and several hundred control parameters).

The second example suggests the importance of a class of TmL which we call (provisionally) "situated modelling". We contrast this with modelling as normally understood in applied mathematics, where the model is a mathematical abstraction of the situation which can be understood independent from the context [5]. Based on the TmL found in several work practices we have come up with a provisional characterisation of situated modelling as consisting of two classes of TmL which could be summarised as "making the invisible visible" and "deciding action". The TmL of those classes are summarised in Table 1.

Making the invisible visible
- Posing a problem
- Identifying key variables
- Appreciating the need to quantify
- Systematic measurement and sampling
- Representing data
- Combining and coordinating different data sources to assess relative effects of key variables

Deciding action
- Interpreting, conjecturing and communicating with data
- Judging implications of possible decisions
- Deciding action based on information

Table 1 TmL for situated modelling in the work context

Developing Learning Opportunities

The project is now moving into a phase of research involving design and testing of multimedia-based learning opportunities to develop TmL. These will integrate multimedia presentation of episodes from workplaces with "open" IT models and simulations (that can be inspected and changed) of workplace systems. We will report on these developments in a future article for this newsletter.

References and Notes

[1] Davies, N. (2003). "Have you seen this? - Mathematical skills in the workplace". *MSOR Connections* Feb 2003, Vol 3, No. 1.

[2] Hoyles, C., Wolf, A., Molyneux-Hodgson, S. and Kent, P. (2002), *Mathematical Skills in the Workplace*. London: The Science, Technology and Mathematics Council. Download: www.ioe.ac.uk/tlrp/technomaths/skills2002

[3] The research project "Techno-mathematical Literacies in the Workplace" is funded by the UK Economic and Social Research Council as part of the Teaching and Learning Research Programme www.tlrp.org, Award Number L139-25-0119.

[4] Konold, C. and Miller, C. (2005). TinkerPlots. Dynamic Data Exploration (Statistics software for middle school). Emeryville, CA: Key Curriculum Press.

[5] For discussion, see Bakker, A., Hoyles, C., Kent, P. and Noss, R. (2004). Techno-mathematical Literacies in the workplace: Improving workplace processes by making the invisible visible. Download: www.tlrp.org/dspace/handle/123456789/119

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