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METAPHORS AND CULTURAL MODELS BRIDGE THE GAPS IN COMMUNICATION BETWEEN WORKERS AND OUTSIDERS

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This paper develops the argument in Williams and Wake (2002) about the nature of the resources that can support workers and outsiders in 'bridging the gap' between mathematics practised in the workplace and College mathematics. We noticed in our Maths at work project that when workers try to explain their mathematical practices to outsiders, breakdowns arise when crystallised or reified mathematics has to be justified. We present here briefly some examples in which workers spontaneously used metaphors and models which facilitate explanation and communication. We analyse these resources, drawing on Lakoff and Johnson (1999) and Lakoff and Nunes (2000) in substance and approach.

INTRODUCTION

This short paper provides further theoretical development of the ideas in Williams and Wake (2002). We argued there that the differences between workplace practices and College practices can be explained by the different structures of their activity systems, and that breakdown moments arise in discourses between workers and outsiders because of this. In the latter paper we argued that metaphors and models sometimes have a significant role in helping workers to explain their mathematical practices to researchers and students, thus 'bridging the gap' in understanding that previous researches have highlighted (e.g. Williams et al, 2001; Pozzi, et al 1998,). Several examples were given there drawing on transcripts of discussions at length: we will touch on these in this paper, but just sufficiently for our main purpose which is to develop our theoretical understanding of productive discursive manoeuvres.

THE COMMUNICATION METAPHOR IN PROGRAMMING

First, we recall that mathematical practices in workplaces are shaped by their 'activity systems', by the tools, rules, division of labour, and especially the 'object' of the activity: production of goods and services (Engestrom and Cole in Kirschner and Whitson (Eds) 1997; Williams et al., 2001). Among these practices we include discursive practices, which may include the use of gestural, figurative and mathematical signs. The Cultural Historical Activity Theory point of view of Cole, Werstch, Engestrom, etc builds on the Bakhtinian and Vygotskian tradition in emphasising that discourse is mediated by semiotic 'tools' (such as languages) according to social rules (such as discourse genres) which are socio-cultural-historical products. Thus we find communities engaged in working practices using genres of 'mathematics' in very particular, specially adapted ways which relate to the historical development of a particular productive process.

These special genres of mathematics may seem to mathematicians to be 'special' and, at least initially, mysterious because mathematicians are used to speaking a normative, academic mathematical genre, considered to be THE language of mathematics. But academic genres of mathematics are special in their own way, too, structured by the activity of 'schooling', whose object is explicitly some kind of 'learning', conditioned by all kinds of special rules of assessment, and divisions of labour in the academic institution.

In previous work we showed how an Activity Theoretic analysis of the systems of work and College could help to explain why difficulties in understanding occur, and hence 'breakdown moments' may arise in discourse between worker and 'outsider' whether it be researcher-teacher or student. When breakdowns occur, we look for 'repairs', and study these as possible resources for problem solving, teaching and learning: hence the interest in metaphors and cultural models here as such resources.

A fine example from our case studies involves a metal workshop where Steven uses a machine tool to punch holes in and 'nibble' metal plates. The tool is controlled by a program which Steven writes specially for each task, converting a specimen diagram of the necessary 'development' (faxed through with the order) into a program which will cut the necessary shapes from bare metal.

One line of his program reads as follows:

X 25. Y 172.5 T12 G90

Probably the reader can discern some mathematically suggestive elements here, especially given some hints: there are commands for the drill to 'move' through certain distances across and up, and the selection of an appropriate tool with which to cut a hole. Presumably the author of the programming language in use here was a 'mathematician', making use of notions of Cartesian axes for describing vectors on which the movement is based: in this sense mathematics is crystallised in the language, and to some extent therefore hidden.

In explaining the last command, G90, which is baffling to the researcher, Steven says:

> G90 switches it back to thinking from nought-nought.....
> ... So from here it's thinking 'Oh, I'm going from nought nought, I'm going to go one hundred and seventy two and a half up, twenty five in

Steven's use of a metaphorical device (- it's thinking, 'Oh, I'm going...' -) here in explaining the instruction G90 is of interest here. Speaking formally he might have said something like "The subroutine G90, according to the manual, resets the machine to move through coordinates set from relative to absolute references for the vector commands X and Y." Instead, and quite typically of our case studies, he adopted a metaphor which we can describe as 'computer-machine = servant', 'programmer = master', 'program = series of orders'. Thus, a program = 'a series of orders communicated to a servant to understand and act on'. Related-metaphors include: the conduit metaphor for communication (Reddy, 1993), and the brain-computer metaphor. These metaphors and analogies involve many 'entailments' in Lakoff and Johnson's sense, such as: the machine is 'thinking', instructions have to be 'interpreted' and 'understood', and so on. Indeed, it would be impossible to discuss programming without deploying terms such as 'language', 'interpreter', 'memory': whose meanings have been constituted by the *interaction* of their meanings in the original (source) and computer (target) frame (see Black, 1962; 1993 for more on the interactive theory of metaphor).

In the above case, Steven understands the function 'G90' as an 'instruction' to the machine thenceforward to 'interpret' movement 'commands' differently, i.e. to 'think from nought-nought'. Thus he sees it as changing the machine's ('it's') way of 'thinking'. He may be aware that it is a subroutine, and even how this routine works, but if so he gives no indication of this: he speaks of it as any other instruction, its meaning is in its functional role, expressed effectively through the metaphors employed.

What is more, this way of speaking and thinking seems to the researcher perfectly clear and unproblematic: we suggest that this metaphor is a 'cultural model', i.e. it is a widespread, 'intersubjectively shared' way of speaking about programming, machines and so on within our particular culture. Such models are effective as a means of communication as well as a means of thinking about programming. (Holland and Quinn, 1989; Lakoff and Johnson, 1999). In the above example, Steven explained to the outsider how the command G90 functions, and rather than reach for a formal mathematical or programming exposition, he did so metaphorically, calling on a widely shared cultural model, i.e. a shared way of thinking and talking about programming. In the next example, we will look at a case of breakdown in which such an appeal to a cultural model seemed critical.

THE TIME-LINE MODEL FOR ESTIMATING GAS CONSUMPTION

We illustrate the power of grounded metaphorical models by way of a second example, in which a mysterious spreadsheet formula is explained by its author, an engineer in a power plant who is responsible for estimating the plant's 24-hour gas consumption based on consumption during the working day. A breakdown occurs when the researcher fails to follow the explanation of the times and readings involved, particularly the use of T2 and TIME4 in the formula:

{{{{{"2nd INTEGRATING READING"-"0600 INTEGRATING READING"}+{{{"2nd INTEGRATING READING"} – {"1st INTEGRATING READING"}}/T_2}*TIME4}}/100000}/3.6*CALCV*1000000/29.3071}

The formula uses 3 meter readings, *A* taken at the beginning of the gas day ("0600") and two others, *B* and *C*, ("1st and 2nd Integrated Readings") taken a short interval ($t=T_2$) apart just before the estimate is calculated. The estimate is calculated using the linear formula:

Gives the actual volume of gas used up to the time the estimate is calculated

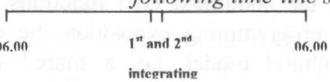
$$C - A + \frac{C - B}{t} \times T$$

T represents the time remaining of the gas day (T_4) – multiplying by the rate of gas use gives an estimate of the gas that will be used during this period.

This is added to the amount

Gives the average rate of gas consumption over period of time t

The worker makes the construction of the formula clear by recourse to drawing a timeline, on which he marks the instants during the 'gas day' when readings have been taken, and gestures to the intervals between these points on the time-line as time-intervals T2 and TIME4 which are used in the construction of the formula.

	Transcript	**Commentary**
Kate	... So T_2: that's the *time*? So is it the time from first to the last, or is it a combined...	*inquiry about T2's: still confused*
Dan	Because you've already got ... All I'm interested in, is Let me draw it out ...	*Dan is lost for words... draws the following time-line sketch:* 
Dan	The gas day: 0600 ... reading 1, ... reading 2, ... end of gas day ...	*'gas day' is 0600 – 0600 next day*
Dan	You've got a reading *there (1)*, and you've got a reading *there (2)* ... so subtract one from the other, and you know how much you've used *there (3)*....	*Gestures to points and intervals on the line... (1) i.e. first 06.00 reading (3) i.e. interval between first 06.00 reading and 2nd integrating reading*

This time-line model is a special case of the number-line model that Lakoff and Nunes (2000) analysed and claimed to be one of the big four 'grounding metaphors' underpinning arithmetic. The 'blending' of space and time, with the blend of numbers as collections of objects/sets and numbers as measures (in the 'measuring stick' metaphor) afford powerful entailments which include the following:

- Life (and hence the gas day) is a journey: with source-path-goal.
- Time is a 'path' along a line through space.
- Instants in time and gas readings are 'points', and intervals between them are both intervals in time and quantities of gas consumed.

Consequently, every line segment is blended with a time-segment, a quantity of gas and a number, and Dan's gestures associate these implicitly with expressions in the formula. Thus the model affords a sensori-motor world of engagement, grounded in space-time image-schema with reduced need to call on concepts in formal language such as 'time interval' and 'instant in time' etc.

The number line then is conceptualised as a semiotic mediating tool through which a formula is associated with a 24-hour time line and the estimation of gas consumption. Its accessibility rests on its status as 'cultural' model, reasonably widely shared by those of us who are mathematically prepared: we can call this a mathematical-cultural model. This particular model proves particularly powerful due to its incorporation of metaphorical blendings, of space-time (linked to real-life is a journey/path) and of number (as collection of objects and measuring stick). It seemed in this case to help the researcher (and subsequently the student) to build a missing link in the chain of signs, that connect the symbols T2 and TIME4 in the formula with the elapsed times indicated by the workers' gestures to points and intervals on the timeline.

CONCLUSION AND DISCUSSION

We conceive of the 'bridging of the gaps' between mathematical practices and discourses (at breakdown moments) as the negotiation of a chain of signs, in the Peircean sense (see also Cobb et al, 2000, and Whitson in Kirschner and Whitson, Eds., 1997). The introduction of new semiotic mediating tools (such as metaphors) can afford 'new' links between signs which result in new chains and interpretants, and hence meaning and understanding. Workers, and perhaps informal 'teachers' and 'explainers' generally, seem to naturally appeal to or reach out to cultural models that can support such semiosis.

At the level of social languages and discourse genres, or Discourses in Gee's (1999) sense, we picture a landscape consisting of:

- workplace discourses (e.g. the 'gas day'),
- workplace mathematical discourse (e.g. the spreadsheet formula),
- formal academic-mathematical signs, (e.g. their academic uses as in our 'translation' of the spreadsheet formula above),
- everyday language including cultural models (e.g. metaphor, cultural models),
- physical signs in diagrams (e.g. the number line, points and intervals and labels),
- gestures, (e.g. pointing to a symbol in a spreadsheet formula, then to an interval of time on the time-line)

The workers and outsiders discussion constitutes a semiotic chain through signs within and between these domains: a successful conclusion of which may allow the outsider to arrive at an interpretant which is experienced as meaningful to them, (e.g. the formula comes to represent for the researcher a linear extrapolation of gas consumption quantities over time.) In such a hypothetical semiotic chain then, a breakdown can occur when the outsider experiences a failure to link: and a missing link may then be supplied by virtue of a mediating chain through a cultural model such as a number-time line.

We hypothesise that such appeals to cultural models may be available to individuals' internal cognitive conversations, on the intramental plane, just as they are in interpersonal conversation, i.e. in the interpersonal plane. In the two cases described above, for instance, it seems likely that the workers made use of the cited models and metaphors in their own personal work practice before the arrival of the researcher, i.e. when writing programs and when developing the formula for estimating gas consumption respectively. On the other hand, the interpersonal conversations may themselves be generative of new chains and meanings. A metaphor 'dawns' in the first instance without one necessarily being fully aware of all its potential for a full-blown analogy. (See Gentner and Jeziorski, and others in Vosniadou and Ortony, 1989, on the distinction between analogy and metaphor, a distinction Lakoff and co-authors do not uphold.) Thus the timeline begins perhaps as a 'bare' line, but then it is marked with various indications of instants and intervals, times and readings and the full implications of the metaphoric blend emerge. In general an analogy may subsequently emerge from a generative process (Schon, 1987) of interpersonal or intrapersonal conversation.

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