Mathematics in the world of work

Each of the examples below illustrates a use of mathematics in a different workplace.
Read through each and make notes below of how the use of mathematics in each is different from the way it is learnt in school.

Example 1: Railway signal engineer.

(This is an edited extract from: Wake, G. (2014). Making sense of and with mathematics: the interface between academic mathematics and mathematics in practice. *Educational Studies in Mathematics*. doi: 10.1007/s10649-014-9540-8 Published online: 15 February 2014)

The case study summarised here brought together a group of students following a pre-vocational engineering course, their teacher, and a researcher to investigate the work of Alan, a railway signal engineer.

During a visit of the group to Alan's workplace, he described and illustrated how he calculates the speed at which trains should travel on a stretch of track. As part of this work, Alan decides where to position the speed boards that indicate to drivers the maximum speed at which they should travel as they head toward an impending signal at which they may have to stop.

http://commons.wikimedia.org/wiki/File:Newark_North_Gate_railway_station_MMB_04.jpg

The gradient of the track is an important factor in the calculations Alan performs: Because of the momentum of the train, a downhill gradient will require a greater stopping distance, and so a greater distance between speed board and signal, whilst for uphill gradients the reverse is true. Consequently, Alan needs to calculate the average gradient over a stretch of track. He showed the students the example from the training manual (see Figure 1). Having calculated the average gradient for the stretch of track, Alan goes on to use the chart in Figure 2 to determine the distance between signals and speed boards for trains of varying maximum speed limits. Alan knows when using the chart that, for safety reasons, he should always use the maximum possible speed for the types of trains that will use the track, and the gradient which is least advantageous for stopping the train.
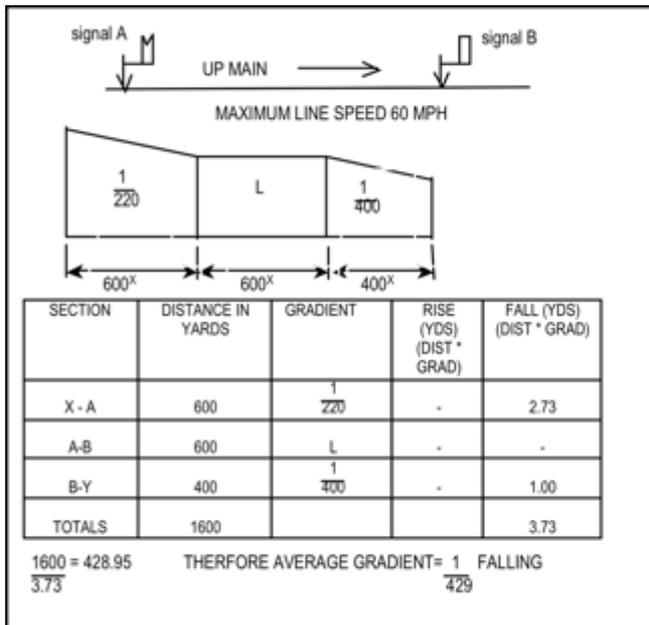
Figure 1. Example of average gradient calculations from railway signal engineering training manual (Note the use of superscript x, as in 600^x, to indicate yards, an imperial unit of distance).

Figure 2. Railway signal engineering chart used to determine the distance required between signals and speed boards.

It was clear that Alan does not need to think hard about all this. He knows to find the two values of gradient included in the table between which his calculated gradient lies, and then to use the value from the column in the table "to the right," thus leaving a "margin for error" for safety. Follow-up discussions with the group of students who visited the workplace highlighted the major misunderstandings they had in relation to gradients.

The students first of all investigated how to find the distance between the stop and the warning signals (speed boards) using a gradient of *1 in 433 rising* that appears on a plan of a section of track (Figure 3).

> Student 1: Yeah, or 1 in 433 - and it is *rising* - it couldn't go that high could it?
> Student 2: I don't know how they use it. [referring to Figure 3]
> Researcher: well look, ok… have you got any idea (to S2). Here you've got *level*, here you've got 1 in 200, and here you've got 1 in 100 [indicating the column headings]. But we want 1 in 400 so what do you think we might do?

|	
S1:	double it [indicating value in 1 in 200 column].
S2:	yeah double it…
R:	….double the distance would make it *huge* wouldn't it? Yes, if you doubled … like 60 miles [per hour]… we're working along this line here… So 1 in 200 is 1061 if you *doubl*ed it, that would be 2100 – well…. but on the level it's only 1100?
	…if we could slot in another column there between 1 in 200 and? Yes?
S1:	I would just take the higher gradient … or erm…
R:	Or you could…oh you see, you could…erm. Ah, he [Alan] mentioned something about always using the one to the *right*, didn't he?…
S1:	right yeah
R:	so, where are we then? Which… I can't read that. What value have you got?
S1:	1165
R:	that's 1165… what are they … they're yards[1]. Right, so what we've got to find out *now*, is…whether it is actually 1165 …
S2:	times 2
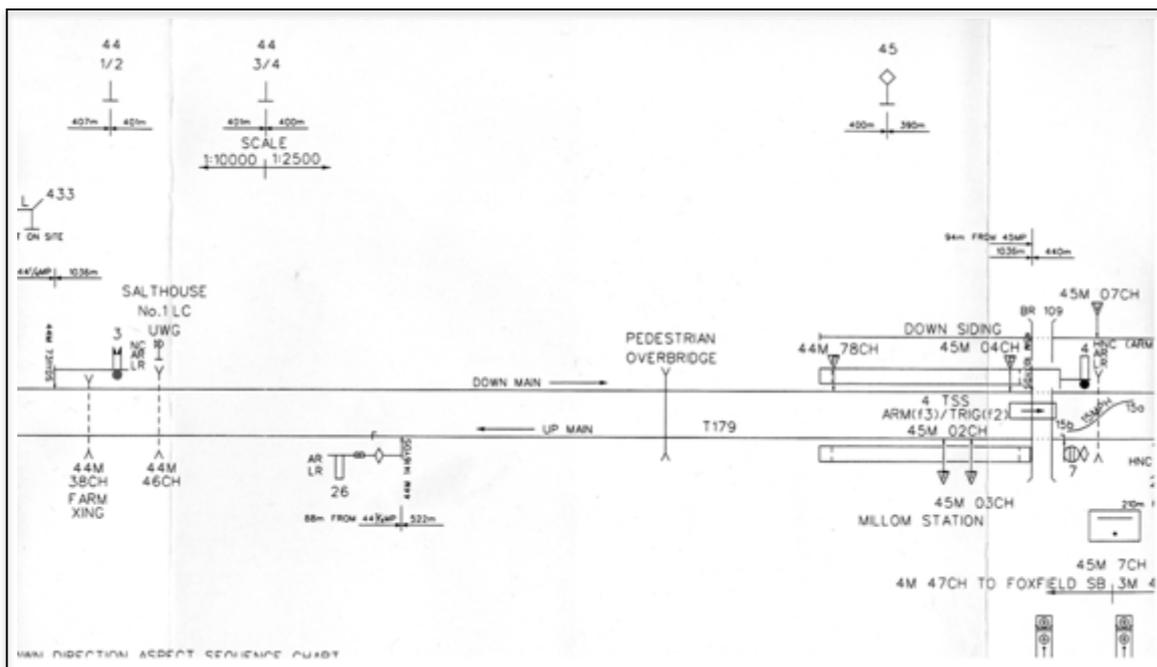
Figure 3. Railway signal engineering plan of a section of railway track.

As Student 2's final comment indicates, his initial belief that a gradient of 1 in 400 somehow requires doubling values associated with a gradient of 1 in 200, seems intuitive and a deeply ingrained misconception common to these students.

Equally problematic was the students' understanding of the training calculations of Figure 1 that

---

[1] Yards are an Imperial measure of distance still used throughout the railway industry and other transport systems in the UK. One yard is a little shorter than one metre.

show how to find the average gradient over three of sections of track. Alan explained that such averaging needs to be performed prior to using the chart in Figure 2. The brief extract below from the transcript of the discussions between researcher and one student from the group illustrates how the student struggled to make sense of the process.

R: Yes… So can you just explain what's going on in there [indicating the Table in Figure 1]?

S: … used different gradients for each slope and he's averaged it out…

R: yes can you sort of explain the detail …

S: you started adding them together - adding the gradients together and divide by two.

R: Perhaps if we describe what each column is doing

Here, the student appears to associate finding an average with the school mathematics procedure of "adding the values together and dividing by the number of values" – presumably, in this case, ignoring the level section of track. The ensuing discussion was lengthy, requiring the researcher to explain the basic concept of gradient by drawing diagrams that illustrated "for every 220 it goes along, it comes down 1, so when you've gone along [the track] 220 it's come down 1".

Example 2: Power plant engineer

Consider this formula /model in a single cell of a spreadsheet developed by an engineer in a power plant. He uses this to predict the gas required by the plant over a twenty-four hour period:

{{{{{"2nd INTEGRATING READING"-"0600 INTEGRATING READING"}+{{{"2nd INTEGRATING READING"} – {"1st INTEGRATING READING"}}/T2}*TIME4}}/100000}/3.6*CALCV*1000000/29.3071}

Example 3: Punch press operator

Consider the activity of a worker who works with technical drawings supplied by customers to produce a programme to drive a punch press that stamps components from sheets of metal. The programs he develops are particularly idiosyncratic; they result in command lines such as

" X 25. Y 172.5 T12 G90".

Here "T12" designates the tool to be used whilst X and Y axes are unconventionally developed from an origin in the top left of a metal sheet with X being positive in the direction left to right, and with Y being positive in the direction from top to bottom.

http://commons.wikimedia.org/wiki/File:Amadapunch.jpg

The instructions G90 and G91 flip between absolute and relative referencing in this coordinate system.

Example 4: Finance clerk

We investigated finance office workers analysing performance data in a medium-sized retail company. Here researcher and workers struggled to make sense of an indicator "debtor days". This particular indicator is used to give an indication of how long customers are taking to clear their debts and is found using the formula:

"debtor days = (outstanding debts / annual turnover)*365".

The worker who calculated this measure each month, although having a sense of what the measure conveys, was not able to make sense of how the measure related to the data involved. The researcher and office manager, however, were able to gain an understanding by substituting the simplified values, "annual turnover = 2 million [pounds]" and "outstanding debts = 1 million [pounds]" giving "debtor days = 182.5" or half a year. This, therefore, gives an indication of how long customers are taking to clear debts. Perhaps the confusion was compounded because the worker actually knows exactly how long each customer takes to clear each individual debt associated with their purchases.