Maths at Work

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1 Introduction

This section deals with some questions concerning the import of mathematics from authentic workplaces into classrooms and addresses some of the problems that arise when you try to let classroom meet workplace. It seems that there is a lot more involved in this than just finding good examples from different workplaces.

What is meant by workplace in this context? It is not specialised workplaces like the ones where engineers or scientists work. I refer to workplaces where the employees do not have a great deal of mathematical training as part of their education. Perhaps their education is not even formal – at least regarding mathematics. It might be craftsmen, shop assistants, people in all kind of service trades, skilled as well as unskilled workers: In brief all kinds of occupations you come across in everyday life.

2 Mathematical awareness: Recognising mathematics

You need a bridge between the very abstract and specialised mathematics you find in textbooks and the sort of activities non-specialists can relate to. Not as much in the form of a specific curriculum but rather an attitude and a habit of recognising mathematics in the form in which it shows up wherever it is being applied.

Some teachers asked at a factory if they could pay a visit to see what kind of mathematics was applied in daily work. “Oh, you’re welcome to visit us. You can have a member of our staff to guide you around, but concerning mathematics we have to disappoint you: We don’t use maths here.”

This is a typical reaction when you ask non-school people about their application of mathematics. It may even be a response from engineers who certainly often apply mathematics. Why this seemingly lack of logic?

Perhaps the concept of focal knowledge together with problems concerning formalisms can bring some clarification to this. First let us have a look at focal knowledge.

2.1 Focal knowledge: Mathematics in and out of focus

An important point when you are dealing with mathematics outside classrooms and textbooks is the question of where the focus is. The concept of focal knowledge can perhaps clarify aspects of this. To my knowledge it was the philosopher Michael Polanyi who was first to point towards this aspect of knowledge. From Sveiby [2] a short description of focal knowledge is cited below:

»Tacit and Focal Knowledge
In each activity, there are two different levels or dimensions of knowledge, which are mutually exclusive: Knowledge about the object or phenomenon that is in focus - focal knowledge. Knowledge that is used as a tool to handle or improve what is in focus - tacit knowledge. The focal and tacit dimensions are complementary. The tacit knowledge functions as a background knowledge which assists in accomplishing a task which is in focus. That which is tacit varies from one situation to another. For instance, when reading a text, words and linguistic rules function as tacit subsidiary knowledge while the attention of the reader is focused on the meaning of the text.«

When you are executing lots of workplace tasks, the focus is on the objects you handle and the practical problem you have so solve. Although mathematical procedures may be integrated in the actions, focus is not on mathematics if everything works out as expected.

An example: I’m sitting here writing this text on my computer not bothering about the functioning of the computer and the programmes that make everything go the way I expect. Now I want to include a picture in my text, so I want to click the icon for importing pictures into my Word document. Having just shifted to a new version of Word (from 2003 to 2007), I realise that the well-known icon is not to be found where it used to be. I have to turn focus away from my writing and concentrate on the functioning of my new version of Word, open help files, etc. Knowledge about the software is now in focus, and in fact one has to be disciplined not to drift away into exploring the software instead of writing about focal knowledge. Back to the matter at hand.

Another example: Many years ago before net banking was introduced, I sent a filled-out giro form to the post office intending to pay the amount of DKK 19.25. At the post office the form was read by an optical machine, and I could hardly believe my own eyes when a couple of days later I saw that there was a great minus in my account. Looking into details I found out that the optical machine had read my 19.25 as 1925. The mistake was mine. Using American textbooks in my daily work as an educator of engineers, I had got into the habit of using a decimal point (.) as the American standard is. But the Danish postal service used the Danish standard: a decimal comma (,). So the optical reader was not programmed to check for any other use of number notation than the Danish standard. My focus now moved from paying my bills to being careful about notational systems for numbers.

2.2 Classroom versus everyday-life mathematics

Another reason why mathematical activities outside classrooms go unnoticed may be that mathematics is integrated in different contexts and formalisms than you find in textbooks. In the classroom you do a lot of exercises having more or less fixed methods for finding solutions and unique answers. Outside the classroom the mathematical problems are integrated in complex settings where you have to formulate problems for yourself from the practical problems in focus. Furthermore you are the one who are responsible for ensuring that solutions are acceptable within specific limits of tolerance. There is no answer book to consult and no teacher to ask.

3 Example: The raised garden bed

Fig. 1 The raised garden bed one year after designing and constructing

A gardener wants to construct an unusually shaped raised bed for growing flowers in a garden. This involves a lot of steps which you never come across in textbook problems during maths lessons.

At first you have to decide what kind of shape you want. You may make some informal drawings on location to have a first idea. Then you have to make a working drawing in a suitable scale:

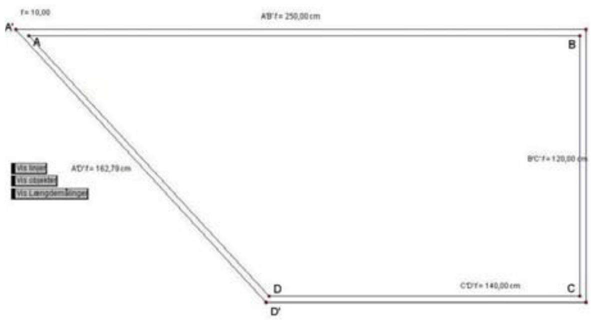

Fig. 2 Sketch for the garden bed drawn with Geometers Sketchpad

This involves geometry. Contrary to lots of textbook-problems you have to take into consideration the thickness of materials. You are dealing with very long and slim rectangles and trapezoids.

You have to decide on materials. Perhaps you may want to make changes in the construction when you see what you can get at the lumberyard. How much timber do you need to buy? What size do you need? What size is available? How many screws do I need to assemble the construction? What is the cost of the materials? How many hours will the work process last?

Then comes the whole question of the work process, e.g. cutting the material to size; this may demand supplementary drawings of which one is shown below:

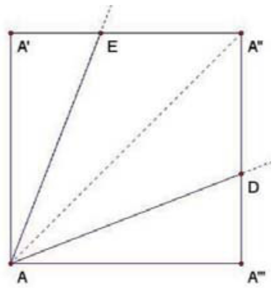

Fig. 3 Design and geometry of a corner

Fig. 4 The corner when finished

The work process will acquire tools quite different from the ones you are accustomed to in regular classrooms. Handling tools and materials may involve much more work and take much more time than the making of the drawings. This may result in the fact that the mathematical feature to some degree drifts out of focus.

Fig. 5 Tools and workspace

In addition, volume calculations may come into play to ensure that you have enough soil to put into the raised bed.

Fig. 6 Final stages of work

3.1 Tasks

From a description as the one above, you may extract different tasks for maths-teaching purposes. Such tasks will on the one hand be directly connected to the authentic problem and on the other hand look almost like textbook exercises. A great learning potential is involved if students practise the art of formulating suitable tasks from authentic contexts. In this connection they must bear in mind that part of the exercise is to be able to identify mathematics in disguise in contrast to the straight-forward, but artificial, exercises in the regular classroom.

[1] Make sketches and working drawings for your own version of a raised bed, drawn at a suitable scale.

[2] Make a budget for the whole project. Check the local do-it-yourself market for materials available and prices. Include pay for working hours, transport, etc.

[3] Make the relevant volume calculations to determine approximately how much soil is needed. Where do we get it from? Can we dig a hole elsewhere in the garden, or do we have to get it from somewhere outside with extra costs as a consequence?

If at all possible, you should complete the activities by actually building the raised garden bed of your own design. Opportunities for interdisciplinary approaches are right at hand.

4 Mathematics in non-classroom environment

Usually textbooks present mathematics categorised due to concepts such as numbers, algebra, geometry, functions, equations, etc. When mathematics is applied in different areas, it is not the pure concepts that are at work alone. When you go looking for mathematics integrated with human activities, categories proposed by Bishop [1] can be an inspiring guideline. The six categories are focused on human activities where mathematics typically show up, and they are: Counting, Locating, Measuring, Designing, Playing and Explaining.

Especially the first four are of direct interest in this connection, although the remaining two come up for instance in developing new concepts and when documenting methods.

Counting

Identify activities where counting and numbering are central. Choose activities you yourself are involved in as well as activities of professionals, for instance stocktaking in the nearby supermarket. What about statistics and the election for the EU Parliament? Special attention should be paid to the use of units which you cannot be careless about in work life. Only textbook mathematics does lots of exercises with numbers without units.

Locating

How do you manage to get people seated in the cinema or in airplanes? How do you find a specific address in a metropolis? How do employees in factories find objects in a warehouse? How do taxi drivers get around in big cities today?

Measuring

Who needs to do a lot of measuring? What does the tailor do when a customer needs a new dress? You want to order at carpet for the floor in your apartment, what must you do? What do professional carpet layers do?

Designing

The above mentioned example from the garden could be an instance of designing. Design and making of clothes, furniture, tools, houses etc. is a veritable treasure chest filled with instances of authentic applications of mathematics.

5 Automation of mathematical processes

Yet a reason that the role of mathematics may go unnoticed in a lot of contexts could be that a whole lot of mathematics today is built into machines. You do not actually see it.

"I don't know. I just type in the numbers and press enter." This was the title one of my students used for a synopsis at his exam. He had chosen to deal with financial mathematics – especially different models for calculating interest. The title came from an answer he got when asking a cashier in his bank what kind of mathematics she used in her job at the cash desk.

It lies at the core of a lot of the problems concerning making mathematics at the workplace visible that math is closely integrated in technological systems. In fact, the more mathematical processes are handled automatically, the more it enhances productivity, and work is done the faster and more efficiently. Furthermore, less human interference means less risk of making mistakes.

Those who deal with mathematical stuff that looks like the math you find in mathematical textbooks are the ones who invent, design and build the hardware and develop the software for computers, robots and other machines in use in modern society. It is tasks for specialists. You rely so heavily on the technological systems that you certainly not want any amateur to program the computers of the bank or the booking system for the airplanes or the computer numeric machines that cut out the wood for the windows to your house.

So should we cancel all teaching of mathematics except for some few chosen ones? How should we then in the first end find the chosen ones if not everybody in school did meet mathematics? And everybody should have some degree of knowledge of the role of mathematics in modern technological systems even though not everyone neither can nor shall be able to master all of the mathematics involved.

5.1 Task

[1] What would happen if the bar codes and optical readers with automatically data transfer to cash register disappeared?

[2] Take the till receipt from your latest shopping in the supermarket and imagine what had to be done manually to end up with a similar document.

References

[1] Bishop, Alan, Mathematical Enculturation, Kluwer Academic Publishers, Netherlands, 1991

[2] Sveiby, Karl E. Tacit Knowledge (1997) from http://www.sveiby.com/articles/Polanyi.html *(June 4, 2009)*