FROM 'WORK-AND-WALK-BY' TO 'SHERPA-AT-WORK'

Paul Drijvers considers teaching practices in mathematics lessons with computers.

Nowadays, many technological means are available to support teaching, such as the interactive whiteboard, class sets of laptop or netbook computers, and high speed internet access. For mathematics education there are advanced software packages for geometry, algebra, calculus and statistics, which in many cases are available on line at no cost.

The actual integration of these technological tools in everyday teaching, however, is not a trivial task. If a teacher wants to use ICT in a lesson, there are often – at least in the Netherlands – practical barriers to overcome. Furthermore, pedagogical questions arise, for example the relationship between the use of a tool, and the 'traditional' use of book, paper, and pencil, and the classroom organisation required. The question, therefore, is how teachers can exploit the potential that technology offers in the day-to-day classroom reality.

To answer this question, I investigated how four Dutch teachers used technology – computers in particular – in their classrooms. I analysed their classroom organisation, pedagogic approaches, and teaching practices, as well as the relationship between their chosen technology and their views on mathematics, education and technology. This article draws a first inventory of these teaching practices, as it results from two projects which are described elsewhere (Drijvers *et al.*, 2010; Drijvers, in press). Both projects made use of the Freudenthal Institute's Digital Mathematics Environment DME. The first project[1] focused on the function concept in grade 8 and used *AlgebraArrows* as a central application. The second project[2] focused on practicing algebraic skills in grade 12.

Seven teaching practices

Through an analysis of video recordings of mathematics lessons in which computers were used, I identified seven typical teaching practices that were used more, or less frequently by the four teachers involved. The first concerns a classroom organisa-

tion in which students work individually, or in pairs, an organisation which is used frequently in Dutch mathematics lessons. The other six are forms of whole-class teaching.

1 Work-and-walk-by

A teaching practice that is observed frequently is one we called *'Work-and-walk-by'*. In this practice students work individually, or in pairs, with the computer. The teacher walks by and monitors student progress. The teacher can take the initiative, by looking at the screen and asking for additional explanations, or they can leave the initiative with the students, and just react to questions.

Of course, we recognise this teaching practice from regular lessons, in which teachers also 'circulate', while students work on tasks from the textbook. However, there are differences. A practical difference is that many computer labs are quite narrow, which makes it difficult to pass by all students and to watch their screens. Compared to students working in their textbooks, on the other hand, it is easier to get a global overview of all student screens. Also, more than its textbook variant, this teaching practice puts high demands on the diagnostic skills of the teacher: if a student raises a question, does the underlying problem have a mathematical or a technical basis, or maybe both? A quick look at the student work on the screen, in combination with the student not always appropriately phrasing the question should clarify this. Flexibility and imagination are required from the teacher, and of course – as is the case in regular lessons – this does not always work out well.

As an example of such a mismatch, we observed a grade 12 student who was stuck when she had rewritten the equation $^e\log(x) = -5$, and asked for help. The teacher understood this as a mathematical issue and walked to the whiteboard, where he wrote down $^2\log 8$. He asked the student for its value and she correctly replied 'three'. Then the teacher continued with $^e\log(x) = 5$, which was

also solved by the student. When he returned to the student, it turned out that the problem was not a mathematical one, but rather how to enter 'e', the base of the natural logarithm, in the digital environment.

This observation illustrates that the *Work-and-walk-by practice* is more complex in a computer lesson than in a regular lesson with textbook, paper and pencil.

2 Technical-demo

A second teaching practice which was observed frequently is the *Technical-demo*. This practice comes down to the teacher showing in a whole-class group how certain technical procedures can be carried out with the software. Rather than the mathematics being central, the goal is that students, when they work individually with the software later on, will not encounter too many technical obstacles, which might prevent them from concentrating on the mathematical content.

An example of such a *Technical-demo* was observed when a teacher explained to her grade 8 class how to work with the applet *AlgebraArrows*. The teacher demonstrated how to connect operations into chains, how to enter numerical values as well as variables in the input box, and how the applet then calculates the output value for you.

To carry out such a *Technical-demo*, a computer screen projection facility is needed, and the setting in the computer lab should be such that all students have a good view of the central screen. Depending on the arrangement in the computer lab, this can be problematic. Furthermore, as a teacher, one has to be skilled enough to simultaneously operate the computer and explain the techniques to students. And, finally, pedagogical preparation is needed to ensure that appropriate information is provided to the students at the right moment, so that what they receive prepares them for the subsequent tasks, but they are not overwhelmed by an 'overdose' of buttons and menus.

3 Explain-the-screen

Like a teacher may use a blackboard for a mathematical explanation in a regular lesson, the projected computer screen may evoke whole-class explanation of a mathematical concept or method in a computer lesson. We called this teaching practice '*Explain-the-screen*'. The screen that forms the starting point of the explanation may have different origins. It can be set it up by the teacher during the lesson preparation, so that the explanation can be completed efficiently, but will be less dynamic. Or, if it is possible to centrally display individual student work, the work of one student

can be taken as a point of departure. This may enhance student involvement. Finally, the screen can be set up during the explanation, which is dynamic, but also demands more skill and confidence from the teacher: if there is a technical hitch in front of the whole class, the teacher may regard this as embarrassing, and it may distract from the mathematical goals of the explanation.

Compared to the traditional '*Explain-the-board*', the '*Explain-the-screen*' practice requires specific skills from the teacher. In a practical sense, it is important during the explanation, that the teacher is not 'hidden' behind screen and keyboard, as this will hinder communication with student. The interactive whiteboard has much to offer here.

As an example of the '*Explain-the-screen*' practice, we observed a teacher in grade 12 using one student's work on a specific task – see *Figure 1* line 1 – to explain that solving an equation of the form $A^2 = B^2$ by expanding brackets is not appropriate – *Figure 1* line 2, but in most cases this can be done more efficiently by rewriting it as $A = B$, or $A = -B$ *Figure 1* line 3.

$$(5x - 5)^2 = (4x - 2)^2$$

$$25x^2 + 25 - 50x = 16x^2 + 4 - 16x$$

$$5x - 5 = 4x - 2 \text{ or } 5x - 5 = -(4x - 2)$$

*Figure 1:
'Explain-the-screen'*

4 Link-screen-board

We speak of a '*Link-screen-board*' teaching practice if a teacher in a whole-class setting uses both the projected computer screen and the traditional board, and takes care to intentionally connect the two. The goal is to enhance the transfer between what happens on the ICT-screen and the conventional mathematics of board, book, paper and pen. This avoids a situation whereby in students' minds the 'world of computer mathematics' remains unrelated to the 'ordinary' mathematics, such as that which will be assessed during a written test, for example.

A practical condition for this teaching practice type is of course that the board is not completely used for the screen projection. Furthermore, it requires that the teacher is able to combine both old and new media, and to integrate them in a natural way while keeping the mathematics coherent.

Figure 2 shows an example. Two grade 8 students used the applet *AlgebraArrows* to create two arrow chains that result in the same table of output values, as was asked in the task. After discussing
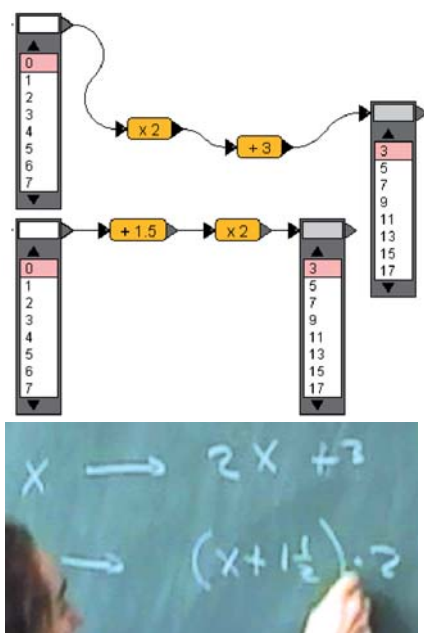
*Figure 2:
Link-screen-board*

their screen, the teacher walks to the board beside the projection and copies the two arrow chains and raises the question of why the two output tables are the same. While copying, the teacher makes a transition to the conventional arrow notation for functions. Expanding the brackets in the second expression leads to the algebraic proof.

5 Discuss-the-screen

The '*Discuss-the-screen*' teaching practice depends on the teacher using the output on the screen to set up an interactive class discussion on the mathematical content. As was the case in the '*Explain-the-screen*' approach, such a screen can be prepared beforehand by the teacher, or can be the result of student work. The main point is that the screen can serve as a point of departure and can invite a mathematical discussion.

Of course, we all experience interactive whole-class discussions from regular lessons. Compared to that, student input while discussing the screen may lead to immediate changes on the screen. The dynamic feedback that technology affords can be exploited to test students' hypotheses, or to underpin their claims. This immediate use of the technology during the discussion requires mastery of the tool by the teacher.

An example of a '*Discuss-the-screen*' practice is a whole-class discussion in grade 8 on different ways to use the applet *AlgebraArrows* to find a break-even point in the context of two mobile phone offers – see *Figure 3*. Methods that were brought to the fore included searching in the table of output values, finding intersection points of graphs, to just calculate some function values, and solving the corresponding equation with paper and pencil. This

whole-class discussion capitalized on student hands-on experience and provided insight in the 'big picture' of the targeted learning process.
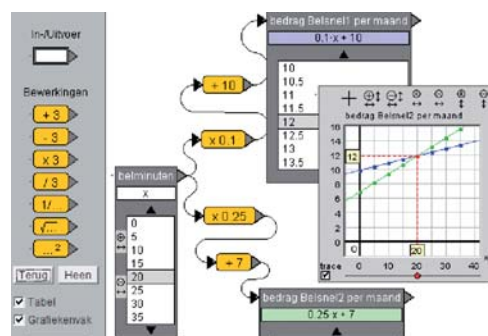

Figure 3: Discuss-the-screen break-even points

6 Spot-and-show

The label '*Spot-and-show*' was attributed to a specific teaching practice, in which ICT allows the teacher to access digital student work while preparing the lesson. During planning, the teacher spots something special in the work of one student, such as a remarkable mistake, a misconception, or a surprisingly original solution. The teacher decides to exploit this during the lesson and shows the student's work to the whole class by means of a projection. Next the teacher may ask the student to explain their approach or reasoning. Peers can comment, and the teacher can explain why they consider this particular solution worth showing.

In a regular lesson, the teacher also gets an impression of student progress, for example by looking at exercise books while they are working individually. However, it is not always possible to refer to this paper evidence outside the classroom, so here is a specific opportunity offered by technology. Of course, the classroom culture should be such that students do not object to their work being shown. In our experience, this was not an issue, and in some cases students even asked to have their work shown.

An example of '*Spot-and-show*' was observed in grade 6. Students had compared dot graphs of the
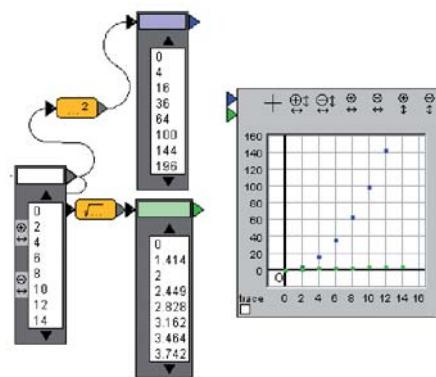

Figure 4: Spot-and-show a misconception

square and the square root function – see *Figure 4*. While answering the question what was remarkable in this comparison, was that one pair of students had typed in the digital environment: 'And the square of a number is always right above the root'. The teacher wanted to highlight that the value of the dependent variable is always positioned vertically above the value of the independent, and that this has nothing to do with the type of function involved. So, the teacher projected this answer in the classroom. After a whole-class discussion, one of the students said: "That's because the line underneath, that's got a number on it, which you take the square root of and square, so it's on the same line anyway."

7 Sherpa-at-work

The final teaching practice was fairly rare, but is nonetheless an interesting one. The basic idea is that the teacher invites one of the students to use the technology, either seated behind a computer, or in front of an interactive whiteboard, so that all students can see which actions the student carries out. The student may be asked to carry out actions by the teacher, that will support the teacher's explanation or the whole-class discussion. The student is like a '*Sherpa*' who carries the water for a mountaineer, and the teacher benefits from the student's work while concentrating on other tasks, such as explaining, or managing the discussion – Trouche, 2004. This setting increases student engagement, as students may identify with the volunteer, or the 'victim', who is manipulating the buttons. An additional advantage is that this practice provides the teacher with feedback on the level of mastery that students have in operating the software. A variant of this practice is letting the student manipulate the technology to show and explain their solution.

An example of the '*Sherpa*'-practice was observed in grade 8 and concerned the task shown in *Figure 4*. The student who is in front of the smartboard in *Figure 5* had to draw the two graphs, explain the difference between the two and, according to guidelines provided by the teacher, carry out some modifications.
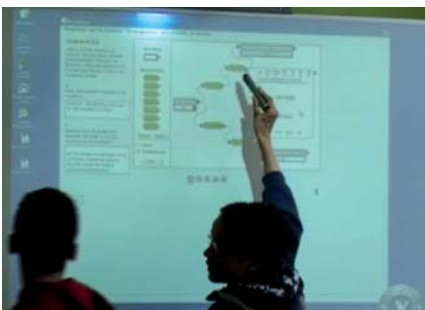

Figure 5: A student at the board

Four teachers

The seven teaching practices were identified while analysing video recordings of lessons by four teachers. Between these four teachers, the frequencies of these teaching practices differed considerably. These differences relate to the personal view of each teacher on mathematics, education, and the role of technology therein.

In lessons by the first teacher – let us call them teacher A – '*Discuss-the-screen*' and '*Sherpa-at-work*' were relatively frequent. These are practices in which students have an important voice. This meets teacher A's view that interaction is important in education, and that ICT is a means to enhance this. For example, in an interview after the teaching sequence, they say:

> … "*so you can have discussions with the students using the images that you saw on the screen, … that makes it more lively*"

In the post-sequence questionnaire that teachers filled in, teacher A agrees with statements such as 'The use of ICT gives the teacher more possibilities to build on students' ideas during whole-class discussions', and 'The use of ICT creates shared images and experiences which one can discuss with the students'. This explains the preference for student-centred teaching practices, in which interaction plays an important role.

In the lessons of teacher B '*Link-screen-board*', and '*Spot-and-show*' are relatively frequent. The first one is mainly used to 'translate' the mathematics as it appears in the applets to the mathematics of paper and pencil. Teacher B's primary concern is the mathematical goal, and students see ICT as a means to achieve this. In their opinion, the students' experiences should not be limited to the technological environment. The teacher explains that they use the '*Link-screen-board*' to:

> … "*take distance from the specific ICT-environment; otherwise the experience remains too much linked to the ICT.*"

Teacher B finds it important to treat misconceptions and original solutions in the classroom situation. Therefore, they appreciate the opportunities technology offers to spot student work while preparing the next day's lesson:

> "*The DME is convenient to see what students do; you can exploit this in the lesson.*"

Teacher C has a preference for '*Technical-demo*', and '*Explain-the-screen*', which were relatively frequent in their lessons. These preferences follow from a concern for weaker students: the teacher considers it important that students know what is expected of them, and that students are able to work on the computer tasks without technical

obstacles. Only then can technology be a suitable means to support learning. In the interview, teacher C describes herself as a 'typical teacher for mid-ability students' who strongly believes that such students benefit from clear demonstrations and explanations in a structured and stepwise approach. Furthermore, she likes to be in control of what is happening in the classroom. The teacher strongly agrees with the statement '*As a teacher, one has to tell students clearly what they should do with ICT*', which matches with her prioritising '*Technical-demo*'.

Teacher D limits their teaching practices to the '*Work-and-walk-by*' format, leaving the initiative to students. Whole-class teaching practices, or more directive approaches where students work individually were hardly observed. During the interview after the teaching sequences Teacher D indicated that their approach was similar to their behaviour in normal lessons:

"My lessons consist of students working. I refrained from explaining a chapter. The kids are just listening passively, and at the end of the lesson I learned a lot, and they just said 'yes'. I prefer the kids act, and raise questions based on their actions."

Altogether, we notice that for each of the four teachers involved there exists a clear relationship between the teaching practices they favour on the one hand, and their views of mathematics, education and the role of technology therein on the other.

Reflection on the seven teaching practices

This inventory of seven teaching practices does not, of course, pretend to be exhaustive, and is specific to the type of technology used, and to the four teachers involved. Also, it is somewhat superficial, as the focus is on external characteristics of the teaching practices, and not on their intrinsic quality or content.

This being said, there are some aspects in the inventory worthy of note. First, there is a distinction between the first teaching practice in which students work individually or in pairs – '*Work-and-walk-by*', and the others, which concern whole-class teaching. In our projects, we mainly focused on whole-class teaching, as it is important to exploit, make explicit, and reflect on students' individual hands-on experiences. Just having student's work individually may be less efficient. We do have the impression, however, that teachers are less drawn to whole-class teaching in a room with computers than they would be in a regular lesson. Whether this is caused by computer labs being less appropriate for whole-class teaching, or by a lack of

confidence in their own technological skills, or by the idea that students should primarily work with the technology themselves, is not clear.

A second aspect is that some of the identified teaching practices are strongly teacher-centered, whereas others are more student-centered. In '*Technical-demo*', and '*Explain-the-screen*', the teacher controls what happens, whereas students have much more influence in '*Discuss-the-screen*', or '*Sherpa-at-work*'. The choice between more teacher-centered, or more student-centered practices, seems to relate to the degree to which the teacher feels a need to have control. In computer lessons in particular, this need may be significant.

A third aspect we noticed was that the identified teaching practices differ in their degree of ICT-specificity. The '*Work-and-walk-by*' practice is a common format that is closely related to a similar practice while students work on tasks in the textbook. '*Technical-demo*' is specific for the use of technology, but not for one type of technology in particular. The '*Spot-and-show*' practice requires teacher access to digital work done by students, and thus puts specific demands on the technology used.

The fourth and final aspect is that of time: the teaching practices fit specific phases in the learning process. '*Technical-demo*' is appropriate when students start to work with a new type of technology, or when new techniques are needed. While students are working with ICT, '*Work-and-walk-by*' may fit. To summarize the results of the individual work, '*Explain-the-screen*', '*Link-screen-board*', and '*Discuss-the-screen*' may all be suitable teaching practices. The same practices, like '*Spot-and-show*', and the '*Sherpa*'-arrangement, may be used while discussing homework.

Conclusion

These findings may not seem very surprising, but I consider them to be important. Indeed, the step from regular teaching to teaching with computers, or technology in general, is not easy for many teachers. Therefore, it is important to know more about ways in which mathematics teachers can make this step, and about the type of support they might need during the process of transition. An ongoing project called Edumatics[3] aims to respond to such needs through the design of online modules for mathematics teachers' professional development on the issues addressed in this article.

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