Title: Teachers Transforming Resources into Orchestrations

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Abstract: Nowadays, mathematics teachers are confronted with a myriad of resources that are available through technological means and through the internet in particular. However, teachers may perceive difficulties in orchestrating education which makes use of technological tools and resources. With instrumental orchestration as a theoretical lens, the main question addressed in this chapter is into which types of orchestrations teachers transform the technological resources. In the setting of a pilot teaching sequence in grade 12 on using applets for practicing algebraic skills, this question is investigated, through a case study of one participating mathematics teacher, through questionnaires among the 69 participating teachers, and through interviews with six of them. The results show that teachers privilege orchestrations in which students work individually or in pairs, at the cost of whole-class orchestration types. Within the performance of these student-centered orchestrations, we recognize elements already known from previously identified orchestrations. Compared to their regular teaching practices and their expectations before the pilot, the involvement in the pilot causes teachers to adapt their orchestrations during the pilot.

Keywords: algebraic skills; applets; classroom teaching practice; digital technology; instrumental orchestration; mathematics education; resources

Chapter 14

Teachers Transforming Resources into Orchestrations

14.1 Introduction

Nowadays, teachers are confronted with a myriad of both material and electronic knowledge resources available for mathematics teaching (Adler, Chapter 1). More and more, such resources can be accessed through technological means and are available on the internet (Bueno-Ravel and Gueudet, 2007).

However, resources do not transform teaching practices in a straightforward way. Documentational work, as part of the teacher's process of documentational genesis, is needed (Gueudet and Trouche, Chapter 2). Several studies show that teachers may perceive difficulties in orchestrating mathematical situations which make use of technological tools and resources, and in adapting their teaching techniques to situations in which technology plays a role (Doerr and Zangor, 2000; Lagrange and Degleodu, 2009; Lagrange and Ozdemir Erdogan, 2009; Monaghan, 2004; Sensevy, Schubauer-Leoni, Mercier, Ligozat and Perrot, 2005). Also, different teachers may adapt the same set of resources into quite different teaching arrangements (Kieran, Tanguay and Solares, Chapter 9).

As Robert and Rogalski (2005) point out, teachers' practices are both complex and stable. Building on this, Lagrange and Monaghan (2010) argue that the availability of technological resources amplifies the complexity of teaching practices and, as a consequence, challenges their stability. It is not self-evident that techniques and orchestrations which are used in 'traditional' settings can be applied successfully in a technological-rich learning environment. A new repertoire of orchestrations, instrumented by the available tools, has to emerge. This involves professional development of the teacher, in which both professional activity and professional knowledge may change. This process of transforming sets of technological and other resources into orchestrations is the topic of this chapter, which focuses on the question of how teachers orchestrate the use of digital resources in teaching practice and how these transformations of resources into orchestrations change over time.

14.2 Theoretical Framework

The main theoretical perspective that frames our investigation of teachers transforming resources into orchestrations is the notion of instrumental orchestration. It is widely acknowledged that student learning needs to be guided by the teacher through the orchestration (McKenzie, 2001) of mathematical situations (Mariotti, 2002). For example, Kendal and colleagues (Kendal and Stacey, 2002; Kendal, Stacey, and Pierce, 2004) showed that teachers privilege certain techniques for using technological tools over others and, in this way, guide the students' acquisition of tool mastery and their learning processes. To describe the teacher's role, Trouche (2004) introduced the metaphor of *instrumental orchestration*.

An instrumental orchestration is defined as the teacher's intentional and systematic organisation and use of the various artefacts available in a – in this case computerised – learning environment in a given mathematical task situation, in order to guide students' instrumental genesis (Trouche, 2004). We distinguish three elements within an instrumental orchestration: a didactic configuration, an exploitation mode and a didactical performance.

A *didactical configuration* is an arrangement of artefacts in the environment, or, in other words, a configuration of the teaching setting and the artefacts involved in it. In the musical metaphor of orchestration, setting up the didactical configuration can be compared with choosing musical instruments to be included in the band, and arranging them in space so that the different sounds result in a polyphone music, which in the mathematics classroom might come down to a sound and converging mathematical discourse.

An *exploitation mode* is the way the teacher decides to exploit a didactical configuration for the benefit of his or her didactical intentions. This includes decisions on the way a task is introduced and worked through, on the possible roles of the artefacts to be played, and on the schemes and techniques to be developed and established by the students. In terms of the metaphor of orchestration, setting up the exploitation mode can be compared with determining the partition for each of the musical instruments involved, bearing in mind the anticipated harmonies to emerge.

A *didactical performance* involves the ad hoc decisions taken while teaching on how to actually perform in the chosen didactic configuration and exploitation mode: what question to pose now, how to do justice to (or to set aside) any particular student input, how to deal with an unexpected aspect of the mathematical task or the technological tool, or other emerging goals. In the metaphor of orchestration, the didactical performance can be compared to a musical performance, in which the actual interplay between conductor and musicians reveals the feasibility of the intentions and the success of their realisation.

Didactical configurations and exploitation modes were introduced by Trouche (2004). As an instrumental orchestration is partially prepared beforehand and partially created ‘on the spot’ while teaching, we felt the need to add the actual didactical performance as a third component (Drijvers et al., 2010). Establishing the didactical configuration has a strong preparatory aspect: often, didactical configurations need to be thought of before the lesson and cannot easily be changed during it. Exploitation modes may be more flexible, while didactical performances have a strong ad hoc aspect.

Even if the metaphor of instrumental orchestration is appealing, it has its limitations like every metaphor. If we think of a teacher as a conductor of a symphony orchestra consisting of highly skilled musicians, who enters the concert hall with a clear idea on how to make the musicians play Beethoven the way he himself reads the century-old partition, we may feel uneasy with the metaphor. However, if we think of the class as a jazz band (Trouche and Drijvers, 2010) consisting of both novice and more advanced musicians, and the teacher being the band leader who prepared a global partition but is open for improvisation and interpretation by the students, and for doing justice to input at different levels, the metaphor becomes more appealing. It is in the latter way that we suggest to understand it.

Earlier research focused on the identification of orchestrations within whole-class technology-rich teaching. Drijvers et al. (2010) identified six types of such orchestrations, termed Technical-demo, Explain-the-screen, Link-screen-board, Discuss-the-screen, Spot-and-show, and Sherpa-at-work, with the following global descriptions.

1. The *Technical-demo* orchestration concerns the demonstration of tool techniques by the teacher. It is recognized as an important aspect of technology-rich teaching (Monaghan, 2001, 2004). A didactical configuration for this orchestration includes access to the technology, facilities for projecting the computer screen, and a classroom arrangement that allows the students to follow the demonstration. As exploitation modes, teachers can demonstrate a technique in a new situation or task, or use student work to show new techniques in anticipation of what will follow.

2. The *Explain-the-screen* orchestration concerns whole-class explanation by the teacher, guided by what happens on the computer screen. The explanation goes beyond techniques, and involves mathematical content. Didactical configurations can be similar to the Technical-demo ones.

As exploitation modes, teachers may take student work as a point of departure for the explanation, or start with their own solution to a task.

3. In the *Link-screen-board* orchestration, the teacher stresses the relationship between what happens in the technological environment and how this is represented in conventional mathematics of paper, book and blackboard. In addition to access to the technology and projection facilities, a didactical configuration includes a blackboard and a classroom setting such that both screen and board are visible. Similarly to the previously mentioned orchestration types, teachers' exploitation modes may take student work as a point of departure or start with a task or problem situation they set themselves.

4. The *Discuss-the-screen* orchestration concerns a whole-class discussion about what happens on the computer screen. The goal is to enhance collective instrumental genesis. A didactical configuration once more includes access to the technology and projecting facilities, preferably access to student work, and a classroom setting favourable for discussion. As exploitation modes, student work, a task, or a problem or approach set by the teacher can serve as the point of departure for student reactions.

5. In the *Spot-and-show* orchestration, student reasoning is brought to the fore through the identification of interesting student work during preparation of the lesson, and its deliberate use in a classroom discussion. Besides previously mentioned features, a didactical configuration includes access to the students' work in the technological environment during lesson preparation. As exploitation modes, teachers may have the students whose work is shown explain their reasoning, and ask other students for reactions, or may provide feedback on the student work.

6. In the *Sherpa-at-work* orchestration, a so-called Sherpa-student (Trouche, 2004) uses the technology to present his or her work, or to carry out actions the teacher requests. Didactical configurations are similar to the Discuss-the-screen orchestration type. The classroom setting should be such that the Sherpa-student can be in control of using the technology, with all students able to follow the actions of both Sherpa-student and teacher easily. As exploitation modes, teachers may have work presented or explained by the Sherpa-student, or may pose questions to the Sherpa-student and ask him/her to carry out specific actions in the technological environment.

The above categorization, with three more teacher-centered and three more student-centered orchestrations, resulted from a study on the use of applets for the exploration of the function concept in grade 8, and emerged from observation of three teachers in a relatively guided situation (Drijvers et al., 2010). Of course, from these limited data from a specific context, we cannot claim completeness. Rather, we wonder how specific this categorization is with respect to the type of technology, the mathematical topic, the whole class teaching format, the level and age of the students, and the amount of guidance teachers were provided with. Therefore, the goal of the study presented in this chapter is to investigate in another teaching context

- in which types of orchestrations teachers transform the available technological resources; and
- how these results relate to the above categorization.

Also, we are interested in the professional development that takes place while teachers include technological resources into their teaching. This professional development is a process of change, which involves both the teachers' own instrumental genesis (Drijvers and Trouche, 2008) as well as documentational genesis (Gueudet and Trouche, 2009, Chapter 2). Therefore, we want the present study to shed light on the change processes that occur when teachers engage in an experimental setting.

14.3 Research Setting

The research was carried out in the context of a pilot initiated by the publisher of the main Dutch textbook series for secondary mathematics education. The publisher, seeking for ways to improve their product and to integrate technology, decided to offer to their customers' schools an online, interactive version of a chapter on algebraic skills for grade 12, the final year of pre-university secondary education. For this online module, the Freudenthal Institute's Digital Mathematics Environment (DME) was used. DME is a web-based environment which integrates a content management system, an authoring tool and a student registration system, and which already contains content in the form of an impressive amount of applets and modules (Bokhove and Drijvers, 2010). The new module for this pilot was designed by the authors of the textbook series, with support of the Freudenthal Institute DME experts. The module includes tasks as well as video clips with elaborated examples. The tasks provide feedback to students' answers, with decreasing feedback levels as the module advances. A pdf file of the original textbook chapter was also made available online, with embedded links to the new online activities[1]. Figure 1 shows a part of the book file on the left, and one student's work in the digital environment on the right. The book text includes a reference to the online module and the task to solve two equations. In the right screen, the student makes a mistake in the last line, and gets feedback saying "This step contains both correct and incorrect parts. Remove or replace the incorrect parts".

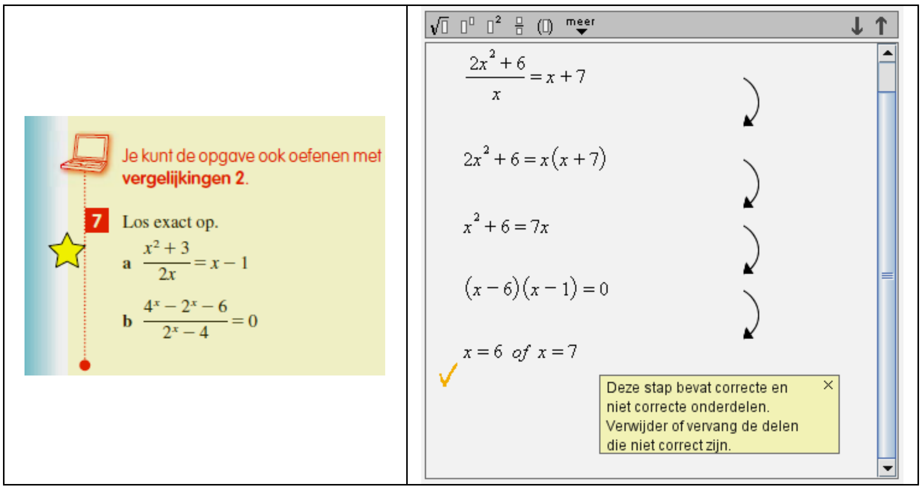

Figure 1: Screen shots from book (left) and digital environment (right)

Nearly 70 schools reacted to a message from the publisher and volunteered to join this pilot teaching sequence. The teachers of these schools were provided with some online guidelines for the use of the module and with support to generate login accounts for their students and the pilot begun.

For the students, the set of resources in this pilot includes the regular textbook, the online book chapter, digital modules including feedback and video clips, and the traditional resources such as paper and pencil and calculator. As the work is stored on a central server, students can access, revise and continue their work at any time and from any place with internet access.

For the teacher, the set of resources is similar, but provides the additional option of access to student work. Overviews of whole class results as well as individual student work can be monitored by the teacher through the internet.

14.4 Methods

The research methods include a case study focusing on one teacher, a survey among all 69 participating teachers, and interviews with five teachers. The *case study* was carried out in two

[1] The module (in Dutch) is available through http://www.fi.uu.nl/dwo/gr-pilot/ .
The information for teachers and the pdf of the original textbook chapter can be found at http://www.epn.nl/wps/portal/epn/getalenruimte/ictpilot#vwo .

classes of one of the pilot schools, a school in a small, prosperous town in the Netherlands with mainly 'white' student intake. Both classes, with 30 and 14 students, respectively, were taught by the same, experienced teacher, who was close to his retirement. The teacher initially volunteered for the pilot, but later intended to step back, because on the one hand computer facilities in school were insufficient and on the other hand his students objected to the idea of practicing algebraic skills with the computer, whereas they would need to master them with paper and pencil in the national central examination. Concerning the first issue, we were able to offer him a loan set of 30 netbook computers for the period of the teaching sequence. On the students' concerns, we convinced the teacher that practicing skills with computer tools was expected to directly transfer into better by-hand skills. He spoke again with his students, and they accepted to participate in the pilot. During the period of the pilot, this teacher had a heavy teaching load, with 26 50-minutes lessons a week to teach, and an additional remedial teaching practice at home. A technical assistant was available in school to set up the classes with the netbook computers, and to make other practical arrangements such as charging the batteries, et cetera.

Most of the lessons (23 out of 36 during an 8-week period) were observed and videotaped. The video registration was done by a mobile camera person, who followed the teacher very closely during individual teacher-student interactions, so as to capture all speech and screens. Video data were completed with field notes from observations. A final interview with the teacher took place after the teaching sequence. Data analysis took place with software for qualitative data analysis[2] and focused on the identification of orchestrational aspects of the teaching.

The case study was set up to enable us to address the research question in a qualitative and in-depth manner. To complement the very specific data from the case study with a more general view on all the participating teachers, a *survey among all participating teachers* was set up. It consisted of two online questionnaires, one before and one after the teaching sequence. The response was 49 out of 69 for the pre-questionnaire, and 41 out of those 49 for the post-questionnaire. Non-response was caused by the fact that not all teachers who originally volunteered for the pilot really started their participation, and that some of the teachers who filled in the pre-questionnaire did not start either, or stopped the pilot before bringing it to an end. Some of them sent messages by email, indicating reasons such as time constraints, lesson cancellation because of illness, or other unforeseen circumstances.

[2] We used Atlas ti, www.atlasti.com

To somewhat bridge the gap between the detailed case study data and the global survey data, interviews were held after the teaching sequence with five teachers, including the one engaged in the case study. These interviews had a semi-structured character, the post-questionnaire providing the backbone of the interview. We will only use interview results here as illustration of the findings.

14.5 Results

14.5.1 Results from the Case Study

The results of the case study show that one particular orchestration type was highly dominant. We call it *Work-and-walk-by*. The didactical configuration and the corresponding resources basically consisted of the students sitting in front of their netbook computers, with wireless access to the online module and their previous work as well as to the textbook chapter in pdf format. In addition to this, a blackboard or whiteboard allowed the teacher to write down additional explanations. A data projector showing the online environment was available in most lessons, but was hardly used. As exploitation mode, the students individually worked through the online module on their netbook computers, and the teacher walked by and sat down with students to answer questions and eventually monitor the students' proceedings (see figure 2). As a reaction to student questions, the teacher in some cases went to the blackboard to write down an algebraic explanation or technique, but still speaking to the individual student who had raised the issue. Concerning the didactical performance, the initiative for teacher-student interaction was taken by the student in almost all cases. If an interaction with a student led to a new insight for the teacher, such as an understanding of a technical issue, he sometimes went back to students whom he had previously spoken to on a similar issue, as to disseminate the news.

An interesting aspect of this Work-and-walk-by orchestration concerns the *determination* of students' difficulties. If a student has a question while the teacher walks by, the latter is faced with the issue of where the heart of the problem lies: is it a lack of the student's algebraic understanding or skill? Is it a technical problem caused by the student, for example a mistake in entering an expression? Or is it a limitation of the online module, which in some cases gave inappropriate feedback, or was very strict in expecting a specific answer, such as 3½ instead of 7/2? As the teacher's resource knowledge was limited, he was not aware of the peculiarities of the online module. Therefore, determination in some cases was difficult and took time. Mismatches between student problems and teacher reactions could be observed, but became less frequent as the pilot advanced.

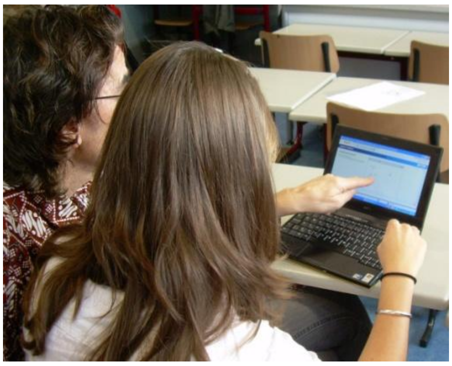

Figure 2: The teacher (left) helping a student (right) individually

As an example of such a mismatch, one of the students was stuck when she had rewritten an equation to ${}^{e}\log(x) = -5$. The teacher understood this as a mathematical issue and walked to the whiteboard. He wrote down ${}^{2}\log 8$.

Teacher: ${}^{2}\log 8$, what is that?

Student: 3.

Teacher: Why?

Student: Because 2 to the power 3 is 8.

Then the teacher continued with ${}^{e}\log(x) = 5$, which was solved by the student as well. Walking back to her, it turned out that her problem was not a mathematical one, but rather how to enter e, the base of the natural logarithm, into the digital environment. The teacher at the end solved this, after consulting another student. Instead of focusing on the meaning of ${}^{e}\log(x)$, he might have considered the technical issue at once, which shows that determination difficulties can lead to interactions that are longer and less efficient than needed.

The previous episode shows that determination in some cases was hindered by the *technical issues* the teacher encountered. Some technical problems, such as students who forgot their login code or the web address of the online module, or netbooks which lack battery power or fail to connect to the wireless internet, were dealt with by the technical assistant, who attended the classes most of the times, and always in the first part of the teaching sequence. Technical problems within the online module, however, often appeared in the individual student-teacher interactions during the Work-and-walk-by orchestration. As the teacher himself was not familiar with the module, he often was unable to solve students' problems, which led to uncertainty about whether it was a mathematical mistake or a technical problem that caused the technology to report an error. Compared to the Technical-demo orchestration described earlier, there was little technical guidance or attention to students' instrumental genesis, even if he used to 'spread the news' in individual interactions, as soon as one of the students solved a technical issue or found a convenient technique. The analysis also shows that such technical complications interfering with the mathematical content of the student-teacher interactions became less frequent as the teaching sequence advanced.

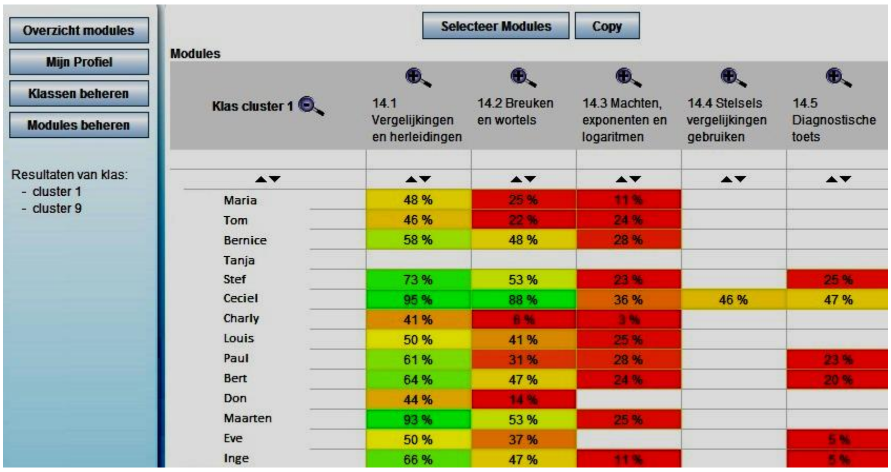

Figure 3: Overview of student results generated by the DME

This Work-and-walk-by orchestration took at least 90% of the lesson time in the lessons we observed, and remained dominant throughout the pilot teaching sequence as a whole without much variation; still, some *changes over time* in its didactical performance, and in the type of teacher-student interactions in particular, could be noticed. First, later in the teaching sequence, when he had time to find out how it worked, the teacher used the data projector to show the overall advancements of the students, so that each individual student could monitor if he or she was more or less on schedule (see Figure 3). Second, as both teacher and students during the teaching sequence got more familiar with the online module, its technical demands and its feedback, the student questions and the student-teacher interactions gradually focused more on algebra and less on technical issues. As a consequence, the character of these interactions changed from technical discussions into 'Explain-the-screen' or 'Discuss-the-screen' interactions. Also, the teacher went to the board less frequently, but instead used the online module more often as an environment to check algebraic claims or techniques. He encouraged students to type something in to see if it is correct, and used this as a way to explain the algebra.

As an example of this, one of the students walked to the teacher carrying his notebook computer. The task on the screen was to simplify a radical expression, and the student ended up with $43\sqrt{\frac{1}{6}a}$.

Student: And it [the learning environment] says it is good, but it wants it to be easier.

Teacher: Yes that's right, because there is a fraction [points at the 1/6 at the screen] in the, .. eh, under the nominator [points at the square root sign, and that is actually what he means]. It is that, that he does not want, I think.

[...]

Teacher: The 1/6, you can also see that as 6/36...

Then the teacher explained what to do with the 6/36 as to further simplify the expressions under the square root sign and asked the student to type this in.

Teacher: You have to remove as much as possible under the square root sign, and no fraction.

In this interaction, the teacher focused on the mathematical issues, and used the online module as an environment to have things found out by the student. The teacher ended with some more general guidelines.

If we relate the findings presented in this section to the six whole-class teaching orchestrations types identified above, we already noticed some Explain-the-screen and Discuss-the-screen elements within the didactical performance of the Work-and-walk-by orchestration. The same holds, to a lesser extent, for the Technical-demo orchestration: technical issues regularly emerged in the individual student-teacher interactions, even if the teacher was in many cases not able to solve them. Elements of the Link-screen-board orchestration could also be observed, as the teacher regularly walked to the whiteboard to explain the algebra, or used paper and pencil to do so. The Spot-and-Show opportunities that the didactical configuration offers were not exploited. The same holds for the Sherpa-at-work, even if the teacher by the end of the teaching sequence invited students to carry out a specific technique in the digital environment, which can be seen as an individual ‘Sherpa-at-work light’.

All together, the case study reveals a teaching practice which heavily relies on one single orchestration type, the Work-and-walk-by orchestration. Little variation was found, and the available resources were exploited to a limited extent. To understand these observations, we reflected on this teaching practice in the interview with the teacher after the pilot, and we observed two regular lessons taught by this teacher in different classes. In the *final interview*, the teacher admitted that he had not had the time to prepare his lessons or to familiarize himself with the online module and its technical peculiarities: “Well, I don’t know much about it [the technology, PD] myself. I did not invest time in preparation”. In addition to this, he explained his attitude of leaving much initiative to the students and of giving limited attention to whole-class teaching: “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.” He admitted that he had to explain some things several times to different students, as he was moving to the students one by one. Through the use of the board for individual explanations, he hoped to make these explanations also accessible to other students.

To compare the case study teacher’s pilot lessons with his regular teaching, *two ‘normal’ lessons* in different classes are observed. Even if his teaching in this pilot is similar to his regular teaching, there are some differences. The analysis of these lessons does suggest that the teacher is more central in his orchestrations in the regular lessons. For example, some whole-class explanations could be observed, and the teacher seemed more confident, also in guiding the use of technology, in this the graphing calculators.

As a final remark on the case study, it is worth while noticing that the students’ original objection against using computers to practice by-hand algebraic skills gradually disappeared. More and more, they used the netbooks, and textbooks and notebooks were hardly seen by the end of the teaching sequence.

14.5.2 Findings from the Questionnaires

Even if the word ‘orchestration’ was not mentioned in the questionnaires, some of the questions and their responses provide insight in the orchestrational choices made by the participating teachers. We now present some results on these choices.

One question on both the pre- and the post-questionnaire was: which ICT-means were used? In the pre-questionnaire this concerned the use of technology in the teacher’s lessons preceding the pilot; in the post-pilot questionnaire, this concerned tool use during the pilot. Participants could click on more than one answer. Table 1 summarizes the findings. Data shows that the technological devices which are most frequently used during the pilot are the computer lab and students' computers at home, which contrasts to the more teacher-driven 'regular' use of ICT before the pilot. Teachers seem to have changed the didactical configurations for the case of the pilot.

Table 1: ICT means used during the pilot

ICT-means used (more answers possible)	**Pre-pilot (*N*=47) Frequency (%)**	**Post-pilot (*N*=41) Frequency (%)**
Data projector	57	46
Teacher's computer	57	32
Interactive whiteboard	55	37
Computer lab	0	83
Student computers in classroom	0	29
Students' home computers	0	83

Table 2: Expected and effectuated working formats used during the pilot

	Expected (Pre-pilot, % of *N*=47)			**Effectuated (Post-pilot, % of *N*=40)**		
Working formats	**Not**	**Sometimes**	**Often**	**Not**	**Sometimes**	**Often**
Whole-class explanation	0	36	64	32	48	20
Whole-class demonstration	19	62	19	38	47	15
Whole-class homework discussion	4	47	49	40	47	13
Whole-class presentation	57	38	2	100	0	0
Individual work	6	26	66	2	2	96
Work in pairs	9	30	60	28	25	47
Group work	53	38	4	93	5	2
Homework	23	28	47	7	53	40

One question on the pre-pilot questionnaire concerned the working formats the teachers were expecting to use during the pilot, and a similar one on the post-pilot questionnaire asking which working formats they used indeed. Table 2 summarizes the findings. It shows that individual work, work in pairs and homework are the most frequently used working formats, whereas whole-class explanations and whole-class homework discussion occurred less than expected beforehand, in spite of the opportunities the didactical configuration offers for it.

Table 3: ICT used in working formats

	Post-pilot (% of *N*=41)		
ICT in working formats	**Not**	**Sometimes**	**Often**
Whole-class explanation	58	32	10
Whole-class demonstration	41	24	20
Whole-class homework discussion	61	34	5
Whole-class presentation	98	2	0
Individual work	15	5	80
Work in pairs	51	17	32
Group work	93	5	2
Homework	24	32	44

A follow-up question in the post-pilot questionnaire was whether technology was used in the mentioned working formats. The results shown in table 3 confirm the previous impression, namely that technology during the pilot was mainly used for individual work, work in pairs and homework, and not so much in whole-class orchestrations.

In this light it is somewhat surprising that the option to show students' home work by means of a data projector or interactive whiteboard, and to use it as a catalyst for whole-class discussion, was hardly used, whereas the teachers usually used such technology in whole-class teaching settings according to the pre-pilot questionnaire results. Even if the teachers beforehand expected some more individual work or work in pairs, this seems to have happened to a larger extent, and opportunities for using ICT in the way they were most familiar with, remained unexploited.

To summarize the findings from the questionnaires, we conclude that before the pilot, teachers indicated that they used technology mainly in whole-class teaching settings, probably with the teacher operating the technology. In spite of this preference and experience, during the pilot they privileged individual work and work in pairs, which turn out to be the dominant orchestrations, and thereby neglected options for whole-class teaching offered by the technology. Even if the variety among all teachers seems to be greater than was observed in the case study, the results point into the same direction. They suggest that many teachers in the pilot changed their orchestrations from whole-class teaching using tools such as a data projector or an interactive whiteboard to student-centered orchestrations, for example in computer lab and home settings. Compared to the teachers' experiences with technology in their teaching, this is a shift from the teachers using technologies such as interactive whiteboards and data projectors, towards students using mainly computer labs and home computers.

It is not clear if the six identified whole-class orchestration types also appear in the context of this pilot. The questionnaires do not offer enough information. The focus on individual work and work in pairs is clear, but we do not know what happened besides that. Spot-and-show orchestrations and Sherpa-at-work orchestrations, however, do seem to be very rare, even if some teachers in the interviews reported incidentally using these orchestration types.

While interpreting these findings we should notice that most of the teachers engaged in this pilot were not experienced, at least not in using the specific technology, and were left over to themselves with little support. Of course, teachers' expertise matters. As an illustration of this, we observed an expert teacher, who was the main designer of the online module, in one of his lessons. As a result of his own instrumental genesis, he was aware that entering formulas in the digital environment can be laborious, and that shortcut keystrokes and copy-paste options can help a lot. As an experienced teacher, he knew that students initially complain saying that writing down formulas with paper and pencil is much faster than entering them in a digital environment. Combining the results of his own instrumental genesis with his pedagogical experience, he set up a Technical-demo orchestration in which he demonstrated the main editing techniques and highlighted their importance. He also included this as a suggestion in the teacher guide that came with the instructional material, but probably many teachers did not read it, which can be interpreted as a limitation of the preparatory documentational work.

14.6 Conclusion and Discussion

14.6.1 Conclusion

What answers to our initial questions do our findings suggest? A first question was to investigate in which types of orchestrations teachers transform the available technological resources. The findings from both the case study and the questionnaires – albeit the first to a greater extent than the second – suggest that individual, student-centered orchestrations are dominant when teachers use the resources that were developed in the frame of this pilot. Teachers tended to privilege students working individually or in pairs on the online module tasks, and devoted little time to whole-class explanation or homework discussion, whereas their expectation before the pilot were different. The case study resulted in the identification of a Work-and-walk-by orchestration, which in itself is not very surprising one. However, we were surprised by its dominance and by the fact that other orchestrational opportunities of the available technology were not exploited, whereas more variation could be observed in this teacher’s regular lessons.

Several factors may explain this phenomenon. First, the subject, practicing algebraic skills, probably is more suitable for individual work or work in pairs than for whole-class teaching. Second, the computer labs, in which many lessons apparently took place, may be less suitable for whole-class teaching. Third, individual orchestration types are probably the easiest thing to do for a teacher, who is not feeling confident about his or her own technical skills. Fourth and final, it may be the technology itself that invites student work rather than whole-class teaching. Our impression from interviews with teachers is that all these factors play a role. Data is insufficient to decide on the impact of each of them.

A second point of interest is how these results relate to the categorization of orchestration types described in section 2. Of course, the latter typology emerged from whole-class teaching episodes, whereas in this pilot mainly individual orchestrations were found. Still, from the case study observations we conclude that the six whole-class teaching orchestration types identified earlier have their counterparts, or at least similar aspects, in the context of the present study. Even if many teachers seem to prefer individual interactions to whole-class teaching in this case, at the level of the didactical performance we see elements that are more explicitly part of the didactical configurations of the typology found earlier. The overall conclusion, therefore, is that the six whole-class orchestration types of course are not exhaustive, but do contain elements that can be observed in other orchestrations as well. As a new orchestration type, the Work-and-walk-by orchestration was identified. We expect the list of possible orchestrations to be extended in future, not as to strive for a complete list, but as to provide teachers with a diverse repertoire of possible orchestrations as source of inspiration to their professional activity.

A third and final point of interest concerns the change processes that occur when teachers engage in an experimental setting. The conclusion here is twofold. First, the case study provides insight in the change process during the pilot teaching sequence. The findings suggest a stable and not so dynamic orchestration, in which there is not much change, at least not at the superficial level. Meanwhile, at the level of didactical performance a process of professional development was observed, showing for example an increased focus on the algebra and on what we might call 'Explain-the-screen', at the cost of attention to technological issues. Second, the findings of the questionnaires shed light on the change that takes place when teachers engage in such a pilot, compared to their regular teaching practices before the pilot. The data suggest that many teachers, who were used to integrating technology in a teacher-centered way – the teacher using a computer connected to a projector, or using an interactive whiteboard – in the frame of this pilot switched to student-centered orchestrations. It seems that most of them during the pilot sequence did not extend their teaching technique repertoire with, for example, a Spot-and-show orchestration type, even if the technology supports the monitoring of student work by the teacher anytime and anyplace.

14.6.2 Discussion

The study that we report on here has some important limitations. First, the danger of presenting one single case study is that the results are too much influenced by the particular situation and at the particular teacher involved. Second, the additional data has the weakness of providing just global information on teachers' use of resources and the resulting orchestrations and teaching practices. Even if the latter issue is partially solved by additional interviews, we should be careful with interpretations from these results. And finally, comparing whole-class orchestrations from Drijvers et al. (2010) with the more individual orchestration types found here is not a straightforward thing to do. In fact, we had not expected such a big shift in orchestration types for this pilot; to observe this happening is one of the most interesting aspects of this study.

These limitations being noticed, the findings further evidence the difficulties that teacher may encounter when integrating technological resources into their teaching practices. In terms of semiotic mediation (Bartolini-Bussi and Mariotti, 2008; Mariotti and Maracci, Chapter 3) is not easy for a teacher to exploit the semiotic potential of resources. Resources invite the professional development of a repertoire of appropriate orchestrations. The genesis of such a repertoire seems to be related to the teachers' own processes of instrumental genesis and documentational genesis (Gueudet and Trouche, Chapter 2). To engage in such a process, a sense of ownership for the teaching is needed: if teachers are used to just following the text book, and don't have the time or don't see an interest in designing their teaching, creating multiple repositories of resources can not be expected to influence teaching practice very much. Furthermore, support for teachers is a precondition. Such support might be organized in professional developments activities, in which co-design and networks for collaboration might be expected to be productive.

My closing remark concerns the framework of instrumental orchestration. Ruthven and colleagues offer a different framework for studying classroom practice, which distinguishes five key structuring features: working environment, resource system, activity format, curriculum script, and time economy (Ruthven, Chapter 5; Ruthven and Hennessy, 2002). This model to me seems less specific for the integration of technological resources than is the orchestration framework; still, there do seem to be links between the two, which deserve further exploration.

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