Utrecht University Case Study 1

Spring 2015

In the first stage of the FaSMEd project, in Spring 2015, we worked with four fifth- and sixth-grade teachers of three schools to try out the Digital Assessment Environment (DAE) in order to figure out how the DAE can be used for formative assessment. The DAE includes four different mathematical domains: percentage, fractions, metric system, and graphs. In this UU Case Study 1 we describe how one fifth-grade teacher used the DAE to inform his teaching. For this case study two lessons were observed on the topic of graphs which is the topic that was agreed among the FaSMEd partners. The lessons were given after the teacher used the DAE for this topic. In the Netherlands the topic of graphs is not a core topic of the primary school mathematics curriculum. Only now and then the textbooks pay some attention to graphs. The lesson observations took place in two consecutive weeks in the last part of the academic year 2014/2015.

1. Tasks and resources used

1.1 Assessment and practice problems provided through the DAE

In UU Case Study 1 several problems were used:
- Seven problems included in the Graphs A Test of the DAE (see Appendix A)
- Seven problems included in the Graphs B Test of the DAE (see Appendix A)
- Seven problems for additional practicing in the DAE (see Appendix B).

To be able to compare the experiences gained from the experiments on formative assessment in various countries, it was decided to have at least one mathematics domain in common, that is, distance-time graphs. In the Netherlands, distance-time graphs are not a regular part of the primary school mathematics curriculum. Therefore, this type of graphs will be new to most students, although many students will have had previous experiences with reading data from other types of graphs and scales.

The DAE logged the answer of the students and provided the teacher with information about the students' accuracy in answering each problem as well as their given answer. In addition, the teacher could further analyse the students' steps in solving the problems by viewing the answers to sub-questions in the DAE. The teacher could deduct in which step the student had made a particular interpretation or calculation mistake by analysing the answers to these sub-questions. This information was supported by digital scrap paper. The students had the option to make notes on a digital scrap paper, and their notes remained visible for the teacher.

1.2 Materials and support for the teacher

The teacher used the manual written for FaSMEd teachers as a resource (for an English version, see: *FaSMEd: Digital Assessment Environment, version 28 June 2015*). This manual contains information about the theoretical background of formative assessment, the instructions for using the DAE, and didactical information about each of the subject domains assessed using the DAE, including graphs.

In addition, the teacher called in the assistance of the researchers. During a meeting between the teachers and the researchers, output of the first assessment lesson was discussed, and possible ways to use this information in a lesson were listed for the teacher to choose from. Interesting cases from the class were discussed more in-depth, with a particular focus on the students' current state of knowledge.

1.3 Information collected by using the DAE

The teacher used the DAE in three steps.

Step 1: The teacher administered the Graphs A Test

Step 2: The teacher gave Lesson 1 on graphs

Step 3 The DAE was used was in Lesson 2 for doing the practicing activity, and the teacher administered the Graphs B Test.

Lesson 1 and Lesson 2 were observed.

An overview of students' answers to each problem and associated accuracy can be found in Figure 1 and Figure 2, for the Graphs A Test and Graphs B Test, respectively. The overview in Figure 1 shows that the students were capable of solving, on average, a little less than half of the problems correctly ($M = 3.4$).

1	1.1		2	2.1		3	3.1		4		5		6		7	
	Kll			Kll			Kll						antw.6			
B	Ja		B			D			11						C	
B	Ja		A			A	Ja		11							
B			D			D			11				400		C	
B	Ja		A			B			11				400		C	
B			B			D			11				200		C	
C	Ja		B			A							400		A	
E			B			D			11				320		D	
E	Ja		B			D			11				320		D	
B			B			D			11						C	
B			D			B	Ja						333		C	
E			A			C	Ja		11				400		C	
B			A			B			11				320		C	
B	Ja		A													
B			B			D			11				200		C	
B	Ja		C			D			1				400		C	
E	Ja		B			B			11				400		A	

Figure 1: Information from the Graphs A Test in the DAE

Note. Columns in green and red display answers given by individual students, displayed on separate rows. Cells marked blue indicate the student has opened the digital scrap paper auxiliary tool.

The results of the Graphs B Test were slightly better. The students were capable of solving, on average, a little over half of the problems correctly ($M = 3.9$). Sixteen students were present during both lessons, and their number of correctly solved problems during the first lesson (*M* = 3.6; *SD* = 1.9) and the third lesson (*M* = 4.1; *SD* = 1.4) was not statistically significant, *t*(15) = 1.06, *p* = .15.

1	1.1		2	2.1		3	3.1		4		5		6		7	
	KII			KII			KII						antw.6			
D			B			E			11							
D			B			E			11				60		B	
B	Ja		A			D			11				30		B	
D			B			D			11				16		B	
B			B			D			11				28		B	
D			C			D			11				r320		B	
D			A			E			11						B	
D	Ja		D			E			11				16		B	
D			A			D			11				20		C	
C			A			E									D	
D			A			E			11						B	
D			B	Ja		D	Ja		11						C	
A			D			E			11				58		C	
D			A			B			11						B	
D			A			D			11				20		B	
D			A			D			11						B	
D			D			E			11						B	
C			A			E			11				30		B	

Figure 2: Information from Graphs B Test in the DAE
Note. Columns in green and red display answers given by individual students, displayed on separate rows. Cells marked blue indicate the student has opened the digital scrap paper auxiliary tool.

1.4 Results from the Cito Mathematics Test

To measure students' general attainment in mathematics, scores on the Cito Mathematics Test were collected. This is a national test completed by primary school students twice during each academic year, consisting of primarily context problems that cover a variety of mathematics domains, such as numbers and operations, measurement, and rational numbers. Test scores are converted into ability scores that typically increase throughout primary school, making a comparison of results throughout the academic career possible (Janssen, Scheltens, & Kraemer, 2005).

Prior to the start of the case study, the average ability score on the Cito Mathematics Test M7 was 93.7 (*SD* = 11.7). At the end of the case study, the average score on the Cito Mathematics Test E7 was 101.1 (*SD* = 12.7). Test scores at the end of the case study were significantly higher than at the start of the study, *t*(18) = 4.93, *p* < .001).

National averages of performance on these tests are 100 for the M7 test, and 105 for the E7 test (Flik, 2014). Progress in the case study classroom did not significantly differ from progress in the national population, *t*(18) = 1.56, *p* = .14.

2. Work with teachers

The case study was part of the try-out of the Digital Assessment Environment (DAE) that took place in April, May, and June 2015. Schools for this try-out were recruited in late 2014 and early 2015.

To get acquainted with the materials offered within the DAE, the principles of formative assessment, and the ways in which teachers could interpret and use student data, three professional development meetings were organised. Because the schools of the teachers were located close to each other, each meeting was organised at one of the schools with a rotation schedule for location. Each session lasted about 90 minutes and was led by two of the participating researchers. Table 1 shows the content of each professional development meeting in whicht the teacher of the UU Case Study 1 participated.

Table 1

Professional Development Meetings in which the teacher of the UU Case Study 1 participated

Meeting	Topics	Resources
1	• Theoretical background of formative assessment • Didactical background of percentages • Didactical background of fractions • Using the DAE • Planning of the study	• Teacher Manual: FaSMEd Digitale Toets Omgeving • Handouts of presentation for teacher
2	• Discussion of percentages output • Discussion of fractions output • Didactical background of the metric system • Didactical background of graphs • Further planning of the study	• Teacher Manual: FaSMEd Digitale Toets Omgeving • Student work (of participating classes) on percentages • Student work (of participating classes) on fractions
3	• Discussion of metric system output • Discussion of graphs output • Evaluation of the study • Further reading and resources • Planning of observation lessons	• Teacher Manual: FaSMEd Digitale Toets Omgeving • Student work (of participating classes) on the metric system • Student work (of participating classes) on graphs

For each meeting, the researchers prepared a powerpoint presentation which was presented on the smartboard in the classrooms. The information given to the teachers was supported by these slides (with printed handouts), as well as printed copies of the Teacher Manual. In Meeting 1, group discussions about the purpose of assessment were initiated and facilitated by the researchers by asking questions about the teachers' perception of assessment. Discussion in the Meeting 2 and Meeting 3 centred around student work on the previously completed tests. To facilitate the discussions in meetings 2 and 3, the researchers selected some interesting examples of student work as input for the discussion. All present teachers participated in all of the discussions as a group.

After each meeting, teachers were asked for their opinions on the study, the assessment tools, and, in the case of the second and third meeting, their students' work. The teachers reported that they were enthusiastic about the materials offered to them and that they could see the merit of formative assessment in the current form. However, they also reported that they had very little time to interpret the student work and that they preferred to analyse the output during the professional development meetings, with the assistance of the researchers. The researchers agreed to offer immediate assistance to the teachers and thereby limit the time they needed for the analysis of student work. The professional development meetings were evaluated by the teachers as clear and well-structured.

3. Classroom teaching

3.1 Educational background of the teacher involved in UU Case Study 1

The teacher in UU Case Study 1 has studied at the Pabo (Pedagogische academie voor het basisonderwijs; Pedagogical academy for primary education), which is the Dutch institution (University of applied sciences) for educational staff in the Netherlands. By the time of the study, he had been teaching for 15 years, all at the same school. Three years before the start of the study, a vacancy for vice principal had opened up at the school, after the former vice principal became principal at the same school. The teacher in UU Case Study 1 applied for vice principal and got the job. He continued teaching alongside his role as vice principal.

The teacher in UU Case Study 1 had attended several professional development meetings about spelling, reading, performance-driven teaching, and behavioural regulation. However, this teacher had no previous (formal) experience with formative assessment. He did, however, have experience with using technology for teaching and assessment in mathematics – the textbook has a software package with practice problems, assessment tools, and applications to use with the digital blackboard (digiboard). The teacher liked to extend these digital materials with input found using search-engines, such as YouTube videos.

Because the teacher had no previous experience with formative assessment, his knowledge of the topic was entirely based on the meetings organised by the researchers and the supportive materials handed out during the meetings. He started using this knowledge with the four tests provided in the DAE, but began to generalise his knowledge application before the end of the study by asking his students to attach their scrap paper to the test sheets of the Cito Mathematics Test and analysing their work. He saw an advantage in using student work to gain insight into students' calculation processes and using these insights for planning further instruction.

Prior to the start of the study as well as during and after the study, the teacher followed the manual provided with the textbook used in the classroom. Dutch teacher manuals for textbooks typically give extensive instruction on teaching materials, the pace of teaching, and the way to differentiate between student with a quick, intermediate, and slow learning pace. Student performance is elaborately indexed using test scores on each of the tests to be administered at the end of a series of lessons. In addition, this teacher used the answers of his students on practice problems to determine whether each individual student would need extended instruction about a topic. Participation in the FaSMEd study gave him the idea to use this self-taught formative assessment in a more structured way with the specific aim to inform his next lesson. He also expanded his teaching tools with the auxiliary tools provided in the DAE. The teacher reported that primarily the bar was a useful tool to graphically represent the proportions that are important for, amongst others, percentage problems.

An important feature of the teacher's teaching was helping students achieve to the best of their potential. If a specific student would experience problems, he would sit down with the student and ask to explain how they obtained answers to the problems they did not solve correctly. This would help the student and the teacher figure out what went wrong during mathematical problem solving, and thereby remedy difficulties at an early stage. The teacher found this to be an effective way to help students who experienced difficulties. Many of the difficulties with mathematics problem solving, according to the teacher, originated from poor reading and language skills of the students, which lead to difficulties in understanding the aim of often-used context problems.

3.2 Educational policy and resources

Learning aims of the students primarily centred around the nationally determined reference levels 1F and 1S (Noteboom, Van Os, & Spek, 2011). At the end of primary school, students need to have acquired a certain amount of knowledge and skills. The desired level is level 1S (strive). Students who cannot keep up with the desired pace need to minimally perform at level 1F (fundamental) at the end of their primary education. An elaborate manual describes which aspects of subject material within various domains of mathematics should be covered to achieve each of these levels. Textbooks for mathematics are written so that all students at a high and intermediate level should be able to achieve level 1S at the end of primary school, and so that students at a low level should be able to achieve level 1F. Heterogeneity within a classroom is dealt with by constructing basic exercises for students of all levels, and more specific learning materials for students in each level group (high, intermediate, or low).

4. The observed lessons

4.1 Procedure

To carry out the agreed case studies the four participating teachers in the first stage of the Dutch FaSMEd project were asked whether they willing to teach two lessons on graphs for observation purposes. Initially two teachers volunteered, but later one teacher withdrew, which meant that we could do only one case study in this first stage of the project and we planned to do a second case study later.

Prior to the lessons which would be observed, the students did the Graphs A Test in the DAE. This test was performed on the electronic tablets available for the students. The tablets were connected to the internet so that the students could log into the DAE. The teacher downloaded student results and discussed the output with the researchers before he gave the two lessons on graphs. The teacher used this discussion of the results to list ideas on how to use the information from the test in the lessons. The two lessons were observed by one of the researchers who made field notes. In addition the lessons were audio recorded.

Lesson 1 took approximately 30 minutes and all of the students in class participated (*n* = 19). The teacher used printed resources from the DAE. The students did not use electronic resources during this lesson. Unfortunately, due to equipment failure, most of the audio recording was lost.

During Lesson 2, students first practiced problems on graphs using a set of practice problems, during which they could work together and ask the teacher for feedback. Then, they were challenged to apply their newly gained knowledge in completing the Graphs B Test. They started to work in pairs, but after a few minutes, a number of students decided to work alone. Students completed the Graphs B Test individually. The teacher walked around in the classroom, answered questions, and the students also took the liberty to ask the researcher questions about the DAE when the teacher was occupied by helping another student. The entire lesson was audio recorded, with bits of conversations between students, or between students and teacher or researcher audible in the recording.

4.2 Observation of Lesson 1

Date : 23 June 2015
Grade : 5 (10-11 years old)

Before Lesson 1, students had completed the Graphs A Test from the DAE. The teacher, with the assistance of the researchers, had analysed the response by the students, and decided to teach a lesson about the same problems from the Graphs A Test. To this end, he printed the set of problems for each students and planned the lesson with the problems providing a structure for the lesson.

The teacher started the lesson by asking all the students to sit down at their own desk and pass around the worksheets with the problems. Each student was to fetch a pencil to write down the answers and make notes, if desired. As an introduction, he explained how on each page the students would find one of the problems from the activity of the previous weeks. He then asked the students whether they remembered the test on graphs and recognised the first item, and how the students had experienced the test. A few students responded, and said that they had found it difficult or engaging.

The teacher introduced Problem 1 to the students by reading the problem to them. He mentioned that many students had answered the problem correctly. He then dissected the text of the problem by explaining the relation between the presented time slots and the distance travelled within each time slot, and pointing out at which hour the train had been at which point on the presented track. He then repeated the question the students had to answer, and asked who of the students knew the answer to the problem. Many students raised their hand, and one was chosen to give the answer. The answer was correct, and the teacher asked how the student had figured out the answer. He then repeated the students' reasoning (*because it covered the most distance during that hour, so it had to be the fastest pace*) back to the students slowly and clearly.

Each of the problems was then addressed in a similar way. The teacher first read the problem to the students, then dissected the problem into smaller pieces. For the problems 2-6, he divided the problems into sub-problems by having the students compute, for example, the time taken to cover each of the sections of the track (problem 2). Students could raise their hand to give the answer to a (sub-)question, and in some cases, the teacher asked a particular student to give the answer without them raising their hands. One student remained silent after being asked a question. The teacher did not push for an answer and asked a different student for the answer instead. He also asked questions about the reasoning of his students (e.g.: *how did you know that*), and about the meaning of certain pieces of information (e.g.: *what does it mean if the line becomes steeper*). After each correctly answered question, the teacher praised the students, and repeated any reasoning out loud to the class.

The lesson ended after all the problems had been covered. The teacher ended the lesson by asking the students what they had learned. He then helped the students put their thoughts into words by rephrasing their examples of learned material into more general learning goals, non-specific to the problems presented.

During this lesson, the teacher matched his instruction to the needs of the children by analysing their work on the same problems and starting instruction at a the level of the majority of children. Extra information about the students' level of understanding was collected during the lesson by asking questions and letting the students answer. The teacher took individual differences into account by asking questions of varying degrees of difficulty, and, most of the time, by allowing the students to decide when they felt confident enough to answer a question. He repeated explanations of high-performing children to benefit the understanding of other children when faced with difficult questions. The teacher alternated between computational questions (e.g.: *how long did it take for the train to get from point A to point B*) and interpretational questions (e.g.: *what does it mean when the line becomes steeper*), making the lesson diverse and challenging for students of all levels.

4.3 Observation of lesson 2

Date	:	30 June 2015
Grade	:	5 (10-11 years old)

During observation lesson 2, students worked on a practice activity in the DAE made specifically for this purpose. The teacher first explained the students what they were going to do, and that the students were going to be working on their tablets in order to be able to use the DAE. He also told the students that they were allowed to work in pairs, and wrote down the web address on the smartboard to give the students easy access to the DAE. Each student or pair of students could then retrieve a tablet from the cupboard and log into the DAE. If any problems occurred with the log in procedure, both the teacher and the observer helped solving the problems, after which the students started working on the problems.

Most of the students decided to work in pairs at the beginning of the lesson, but after five to ten minutes, some of the students working in pairs had split up and decided to work individually. This was no problem, because there was a tablet available for each student.

The students worked on the problems on their tablets, and asked the teacher or each other questions about how to solve the problems that they found difficult. Communication was not only within pairs, but also between pairs, or between students working individually. Students asked each other questions, and sometimes compared their answers or commented on each other's work. Occasionally, they directed questions at the experimenter, who was at the same time audio-recording the lesson and making notes on the proceedings of the lesson. Questions to the experimenter were mostly about the functionality of the DAE; if a marker did not snap to the grid correctly, they would voice their complaints about that to the experimenter. Because the tablets were connected to the Internet, the students had the option to use the Internet as a resource when they were unable to solve a problem. However, none of the students opted to do so.

The teacher walked through the classroom and helped students with their work when they asked for help. Once students asked for help, he responded by asking questions (e.g.: *what does the problem say*; *so how many kilometres had been covered after the first half hour*) and pointing out information based on the students' questions, answers to questions, and work on the screen (e.g.: *it does not drive 120km in half an hour*, *but in a full hour*). He sometimes also gave students the answer to a partial question, and then asked the student to work out the final answer themselves. Occasionally, he gave instructions on how to use the digital environment (e.g.: *scroll up to see what the problem says*). Only if the student could not work out the answer to a problem based on the questions he asked and the pieces of information he repeated to the students, he gave more explanation about the problem. He only proceeded to the next student asking a question when a student he was working with was confident that they could take the next step on their own. When none of the students were asking questions, he observed individual students or student pairs working and checked the students' progress by looking at their screens.

The teacher motivated the students in several ways. When students could not answer a problem all at once, he divided the problem into smaller pieces, making the information more manageable to the students and the problem easier to answer. Then, when a student gave a correct answer to a sub-question, he verbally rewarded the student (e.g.: *that's right, good job*). A few students lost their motivation during the lesson. He encouraged them to keep trying by telling them that they would be able to solve the problems if they tried. Students, in turn, sometimes motivated themselves by concluding out loud that they had solved a problem correctly. Only one student lost her motivation at the beginning of the lesson, and the teacher did not interfere. After the lesson, he reported that the student often would refuse to work on assignments for short periods of time, but would continue her work if left alone for a few minutes. Indeed, this student had completed all the assigned problems at the end of the lesson without further prompting. She had, however, taken the initiative to ask another few questions to the teacher and the girl next to her.

The teacher mostly communicated with individual students or small groups of students, but managed the atmosphere in the entire class by making one general remark about the noise level. He also gave some general instructions to the entire class, such as instructions to proceed with the next activity upon finishing the practice problems.

A little more than ten minutes before the end of the lesson, the first students had completed their work. They proceeded with the Graphs B Test from the DAE. For this, they were instructed to work individually and under their own accounts. One by one, students started on the test. During this phase of the lesson, fewer questions were asked and the students did not ask for each other's feedback as often. When they did, however, the teacher did not object, but rather observed and let the students work with some interaction.

The lesson ended abruptly when the bell rang as a sign for lunch break. The teacher then instructed the students to put the tablets away. Those who had not yet finished the problems could continue their work after lunch.

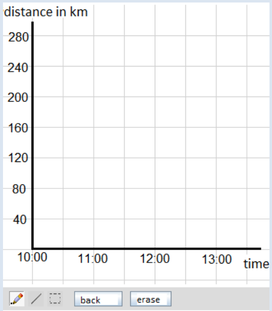
4.4 Reflections by teacher

The teacher reflected on the FaSMEd activities on two occasions: before the first observation lesson, during the discussion about the test Graphs A Test, and after the second observation lesson.

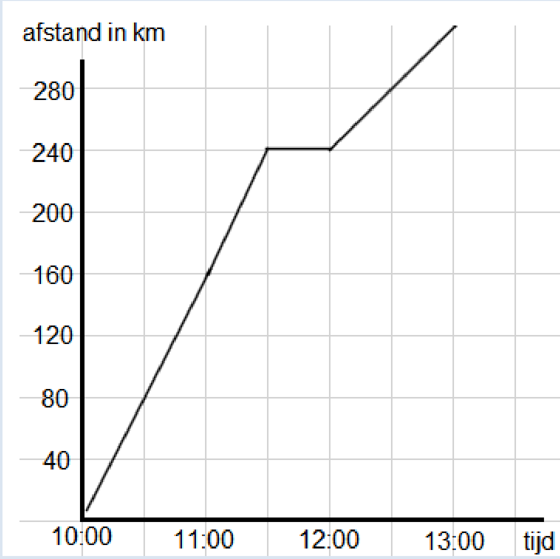
Before the first observation lesson, the teacher looked at the output of the students on the Graphs A Test. This concerned the class overview found in Figure 1, but also the output from individual students. Examples of this output can be found in Figure 3. These examples show how three individual students solved the presented problem. The teacher noted that each student had at least understood some of the problem, with Student 1 understanding how to draw this graph, but only missing the information about how the train first only drove 160 km/h for half an hour, instead of a full hour. He also noted that Student 2 had connected the relevant information on the x-axis with the corresponding information on the y-axis, but did not yet know how to connect these pieces of information. Finally, he noted how Student 3 drew lines from the time slot presented on the x-axis to the speed the train was driving at on the y-axis, but that the student had not seen that the information on the y-axis presented the distance covered, or understood that the total within one time slot would be added to the total from the previous time slot. The teacher noted that these examples of student work were interesting, and that they showed what the students did already understand, rather than what they did not yet understand. He pointed out that explanations of the problems could build upon this understanding.

Problem 6

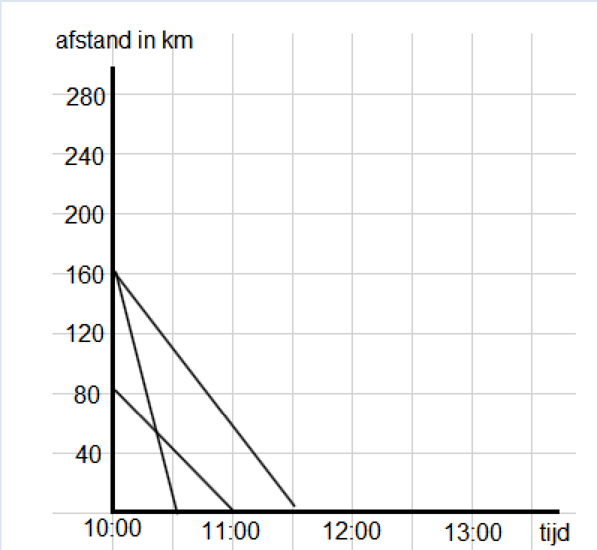
Draw the graph of the following train ride:
The train leaves at 10:00
Then the train drives for half an hour at 160 km per hour
Then the train drives for half an hour at 80 km per hour
Then the train stands still for half an hour
Then the train drives for half an hour at 160 km per hour



Example Student 1



Example Student 2



Example Student 3

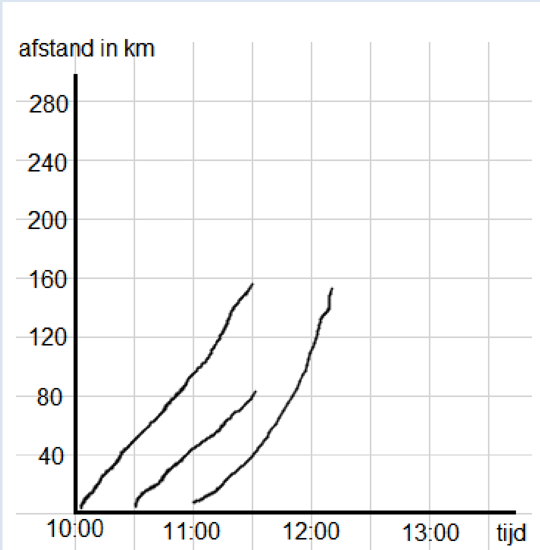


Figure 3. Examples of output from individual students on the DAE Graphs A Test.

The teacher also noted that he usually gained insight into students' understanding by asking them to demonstrate how they solved a problem and finding their mistake, which is how he found out what a student already understood and where his explanations could add to the knowledge of the children. He pointed out that he did this with individual students, and that this was the first time for him analysing work from the entire class to build upon.

After observation lesson 2, the teacher reflected on the questions the students had asked him. He remarked that many students failed to read the problems correctly, and that this caused them a lot of difficulties with answering the problems. To resolve this issue, he had directed the attention of the students to the written text a lot. For any other difficulties, he had asked questions about the problem and what the students already knew, which helped most students on their way to a sufficient extent.

The teacher also mentioned the student who had lost her motivation during the lesson. He mentioned that the student had shown similar behaviour before, and that he had learned when to talk to her and when to leave her alone by trial and error. He also noted that this particular student had difficulties concentrating on school work, but was often highly motivated to participate in stimulating class activities.

5. Student perceptions

5.1 Student background

Four students were selected for a group-discussion to map student perceptions by the teacher. The teacher selected students based on their differences with regard to mathematics ability (two students with average grades and two students with high grades), gender division (two boys and two girls), and perceived ability to voice their opinions. All students were from the same 5th grade class. An overview of these students can be found in Table 2. The q-sorting session was audio-recorded.

Table 2
Overview of Students Participating in Q-Sorting Activity

Student	Performance level	Gender	Learning difficulties
Student 1	Average grades	Female	Yes (concentration problems)
Student 2	Average grades	Female	No
Student 3	High grades	Male	No
Student 4	High grades	Male	No

During the q-sorting session, the students were taken to a small room next to the classroom, where students usually worked on computers. They each brought a chair, and the printed q-sorting statements were spread face-down on a stool in the middle of the circle of students. They were instructed to take the cards, read them, sort them, and talk about their thoughts on the statements written on the cards.

For the purpose of this case study, the q-sorting cards were translated to Dutch. The students only got access to the Dutch translation, not to the original English expressions. The translations of the q-sorting expressions can be found in Appendix B. The cards presented to the students only contained the translation, and no numbering.

5.2 Within-case analysis – Sorting profile

Although the students were eager to discuss their opinions about the statements, they did not know how to sort the cards. Instead, they decided to read the cards one by one and compare their opinions on the statements. Therefore, no analysis of the sorting can be made, but the way the students spoke about the statements and how they compared their opinions can be analysed. The students took turns reading cards and voicing their opinions on the statements. Each student voiced their opinion on each statement. The experimenter only interrupted on a few occasions, each time to redirect the attention of the students back to the cards when their discussion took a turn towards other subjects, or to encourage students to elaborate on their opinions. At the end of the session, less than half of the statements had been covered.

The students showed different styles in participating in the discussion during the activity. *Student 1* was vocal and confident, often taking the first turn to voice her opinion on a subject. She took up leadership by encouraging the other students to speak when they had not yet voiced their opinion on a particular subject. Occasionally, she interrupted another student to respond to what was being said.

Student 2 both voiced her opinion, by her own initiative or when asked, and listened to other students intently at equal rates. She often nodded when *Student 1* was speaking, and added her own interpretation of the expression when the other student was finished, agreeing with the stated opinions, but taking a slightly different perspective in describing her thoughts.

Student 3 was reserved, in the sense that he did not often take the initiative to speak. However, when asked, he spoke without hesitation and in a clear tone of voice. He occasionally took a moment to consider his thoughts, and then confidently voiced his opinion.

Student 4 was quiet. He often had to be encouraged to speak and spoke softly when he did. However, when prompted he brought up reflective thoughts. On more than one occasion, he asked further questions about the intended meaning behind the statements and only started answering a question when the group had determined the intended scope of a statement.

5.3 Within-case analysis

5.3.1 Mathematics perceptions

All students in the q-sorting session quickly agreed that they liked mathematics as a subject. *Student* 1 mentioned that she did not think mathematics was difficult, but that she did need the teacher to explain things to her. The other students agreed with that. Student *1* also reported, later during the session, that she did not think mathematics was frustrating. *Student 4*, however, mentioned that it could be frustrating when the material was too difficult, to which *Student 1* agreed. *Student 2* explained that she did not often show her frustration when she did not understand something, but that she felt it inside. She would then either ask the teacher for help or search for the solution to a problem a bit longer. *Student 4* suggested asking other students for help, but *Student 2* objected that this was often not allowed during class hours.

Mathematics did not make the students feel nervous. However, *Student 1* and *Student 2* both felt nervous when they had completed a mathematics test and were about to receive the results from their teacher. *Student 1* said that she often felt disappointed after getting her test results. She added that she thought that mathematics performance in general was deteriorating, because her brother had performed below expectations on a national mathematics test and because the news had reported on drops in performances. She attributed this to a hypothesised drop in teacher quality, and thought that testing mathematics abilities of teachers would solve this problem. She also thought that the quality of student teachers was lower than that of licensed teachers. *Student 2* did not agree with this, but said that the students learned less because they were distracted by the change in teachers. *Student 3* disagreed with the statement that teachers were underperforming, and pointed out that a change in teacher did not always mean a change in available teaching materials such as textbooks.

The students agreed that in order to learn mathematics, they needed to do a lot of similar exercises. However, through a short discussion of the similarities and differences between exercises, they collaboratively came to the conclusion that each exercise was slightly different from the other. For example, *Student 2* pointed out that the arithmetic operations were relevant in all grades, but that the problems that were presented in the textbooks became more difficult and involved higher numbers each year. At the end of the discussion, *Student 1* and *Student 2* saw more differences between the exercises, while *Student 3* and *Student 4* saw more similarities. The students agreed that a certain degree of repetition made it easier for them to solve mathematics problems.

The students all reported that tests would help them to work harder. *Student 2* said that this was because she wanted to get a good grade. *Student 1* emphasised that the teacher would also assign extra practice materials before a test.

None of the students thought that mathematics was a topic that was only relevant for school. When prompted, *Student 3* and *Student 2* brought up that they might solve mathematics problems when bored, but *Student 4* then proposed that they would also need mathematics for daily life, such as shopping and calculating a percentage of discount. All other students agreed to that statement. Later on during the discussion, they brought up other examples, such as dividing pocket money over causes (*Student 1*) or interpreting graphs from the newspaper (*Student 4*).

5.3.2 Learning perceptions

All participating students agreed that mathematics was not only for gifted people, but that everyone could learn mathematics. *Student 2* used her parents as examples, and said that her father was very intelligent but not very good at mathematics, while her mother was smart but not as much as her father, and still better at mathematics. *Student 1* added a description of a girl from the same class as an example, who, according to her, was intelligent enough but had problems with mathematics. She compared her classmate to *Student 4*, who, she said, understood each problem perfectly after a single explanation. *Student 4* modestly agreed with this statement, saying that he understood the explanations most of the time. *Student 3* agreed that he also usually understood mathematics lessons easily.

Student 4 reported that he thought that the source of individual differences in mathematics performance was the ability to focus one’s attention on a lesson. If a person was not able pay attention to an explanation, they would not understand the material. *Student 1* added that she also thought the quality of the teacher had an effect on student performance. As an example, she described how a student teacher from her school would sometimes interrupt students explaining the material to one another, thereby interfering with students’ understanding. She preferred to be allowed to work in interaction with other students. *Student 4* agreed that immediate intervention was not necessary, but that he did like the classroom to be a quiet place when he was working.

The students disagreed on what proportion of their understanding of mathematics would depend on the teacher. *Student 1* quickly stated that 50% of understanding was due to the teacher’s input, and 50% due to own effort and capacities. However, *Student 4* estimated the proportion of influence of a student’s own effort and capacities to be closer to 75%. They did agree that an experienced teacher could explain mathematics better than an inexperienced teacher.

Working with friends was only beneficial, according to *Student 1*, if that friend could explain the problems and was able to concentrate on the problems instead of talking about other topics during shared assignments. *Student 2* added that she liked to work quietly and in a concentrated way, and then concluded that she actually preferred to work alone on mathematics tasks. *Student 3* distinguished between learning phases. He pointed out that when a topic was new to the students, working in small groups was more beneficial, but once everybody understood a type of problem, it was more efficient to practice quietly.

5.3.3 Perceptions of the use of technology

Student 1 mentioned that she thought technology in the classroom, such as digital blackboards, had a positive effect on her level of understanding, because the teacher could explain things more easily, and the entire class could be involved in the instruction. Other students agreed that they liked the use of technology for instructional purposes.

Student 4 cautiously added that he was uncertain whether the use of technology as mentioned in the q-sorting expression meant that he could no longer use a notebook, implying that he would not like to lose access to notebooks. *Student 1* and *Student 2* agreed that the use of a computer for solving mathematics problems was less convenient than using notebooks and scrap paper. *Student 2* explained that she liked to write her calculations down, and *Student 1* added that writing with a mouse, if possible within a given digital tool, was not as easy as writing with a pen or pencil. Writing on the digital blackboard, however, did not cause her any problems, although she thought that fetching a piece of paper was quicker and easier than starting the digital blackboard if a single problem was involved. *Student 3*, by contrast, said that he preferred typing over writing, because he expected to need computer skills for a future occupation. He did, however, agree that solving mathematics problems with a computer caused him more problems, because of the difficulties with making digital notes.

The students reported that they had to complete weekly tasks (Dutch: weektaken) for mathematics on the computer. However, *Student 1* explained that she did not like these tasks, because they only involved repetition of material that had already been learned without the use of technology other than the digital blackboard, and that made the tasks too easy and boring. In response to another question, she mentioned that she found mathematics tasks on a computer frustrating. In practice, students used scrap paper for the more difficult problems. *Student 1* speculated that she would no longer need to use scrap paper once the class got full-time access to tablets after they would enter 6^{th} grade.

Student 1 also mentioned that she found the setting in which they used computers for learning somewhat distracting, because students were often working on different things in the same room, or were occupied with other things than school work. Looking down at a book was less distracting for her. *Student 2* added that it was easier for her to focus on a single solution strategy when she used a book, because the book would hold on to a particular approach, and websites for mathematics have various approaches that do not always match.

5.4 Cross-case analysis

A comparison between Utrecht University Case Study 1 and Case Study 2 shows a number of interesting differences. A first relevant difference is of course the age of the students: Case Study 1 concerns students in fifth grade, while the students in Case Study 2 were from sixth grade. Still, the students from Case Study 1 were in comparison more reflective than their peers in Case Study 2. They were aware of the fact that the activities were related to the

FaSMEd study, and adopted a very mature role during the q-sorting activity. Although their reflections generally stayed on a practical level, they made an obvious effort to think critically about the statements and distinguish between situations in which the statements did or did not apply. They also worked well together in comparison to the students from Case Study 2. Although one student had difficulties listening to other students instead of voicing her own opinion and interrupting someone else, she made obvious efforts to listen for longer periods of time. The other three students did not show any difficulties listening to other students and often nodded in agreement or reflected on someone's thoughts.

Although the students decided not to sort the cards, they may have underestimated their ability to do so. On one occasion, a student remarked that they had already read a similar card and concluded that they must be alike. This did not result in categories.

6. Context

6.1 Contextual information of school

Table 3

Information About the School Context

School Context

School Roll (number of pupils)	222 (Oct. 2010)
Staff Roll (number of teaching staff)	22
Geographical location (urban/rural, etc.)	Urban (smaller municipality in large urban area)
Relationship to other schools (e.g. cluster/Feeder/Part of a group of schools)	Part of a school foundation containing 6 schools to share knowledge and policies, but strategically independent.
Age range	4-12
Single or mixed gender	Mixed gender
Ethnicity	n/a
Mixed ability or selected (could include Special Educational Needs)	Mixed ability
Socio-economic intake (with local contextual indicators, e.g. UK Free School Meals)	n/a
How the school is judged to be performing in local context	Inspection reports classify schools as satisfactory, poor, or very poor. This school classifies as satisfactory.
Past experience of using formative assessment	No formal experience
Past experience of using technologies/tools	Software that comes with textbooks Digital blackboards Student and staff computers available Recent experiment with tablets for students
Previous experience of working within other research projects	Yes

6.2 Teacher demographic information
Table 4
Information About the Demographic Background of the Teacher

Teacher demographic

Subject area (science or mathematics)	All (primary) – current study is about mathematics
Role (e.g. Head of Department/Teacher, etc.)	Teacher; vice principal
Gender	M
Age range (under 20; 21-30; 31-40; 41-50; 51-60; over 60)	31-40
How long has he/she been teaching	15 years
How long has/she been working at this school	15 years
Past experience of using formative assessment within lessons	No formal experience
Past experience of using technologies/tools within lessons	Software that comes with textbook Digital blackboard with Internet resources
Past experience of working in a research project	Yes

6.3 Student demographic information
Table 5
Information About the Demographic Information of the Students

Class demographic

Age range	10-11 years (5th grade)
Number of students in the class	19
Gender split within class (male/female)	10 male; 9 female
Ethnicity	Various
Mixed ability or ability set	Mixed ability
Any relevant contextual information (do the class work well together or are there any particular difficulties/are they taught in this class for other subjects or only for this subject/do students have any additional needs (special educational need or are they being taught in an additional language/is there high mobility of students etc)	The students are taught by the same teacher for all subjects, except physical education. One student has special educational needs, but she takes part in the regular class curriculum. Remedial teaching is available within the school when needed, but used mostly by children in grades 1-3. The language of instruction is Dutch, but many students speak another language in the home environment.

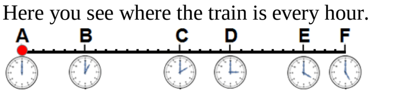
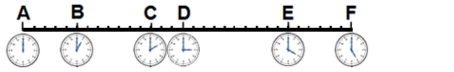
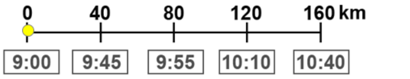
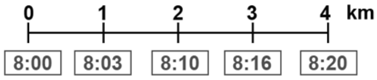
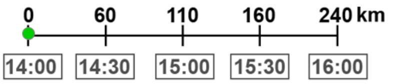
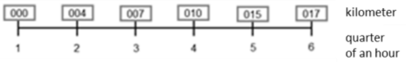
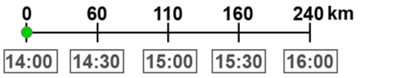
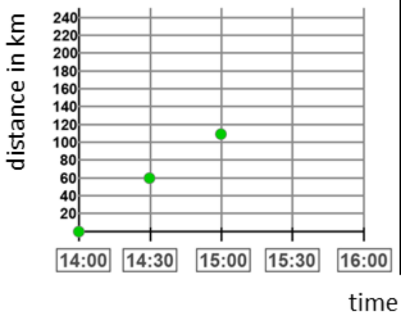
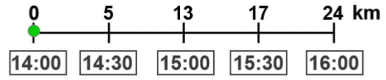
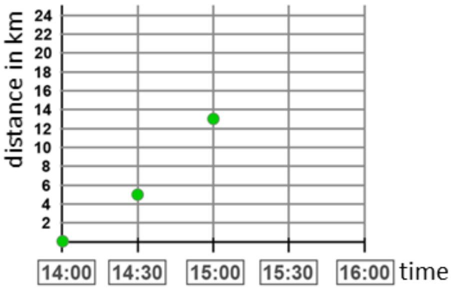
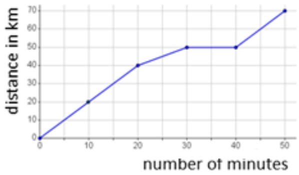
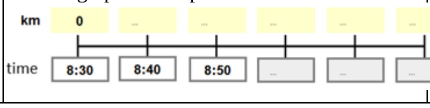
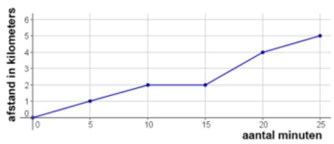
References

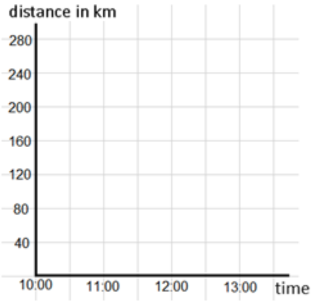
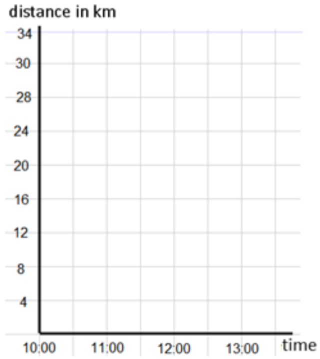
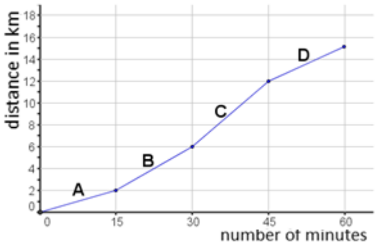
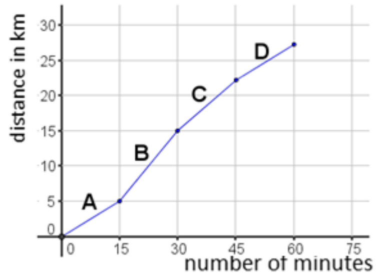
Janssen, J., Scheltens, F., & Kraemer, J. M. (2005). *Leerling- en onderwijsvolgsysteem rekenen-wiskunde* [Student monitoring system mathematics]. Arnhem, Netherlands: Cito.

Flik, A. (2014). *Tabellen tussenopbrengsten Cito LOVS* [Tables intermediate results Cito LOVS]. Retrieved from http://www.hco.nl/images/paginas/werkenaanopbrengsten/OGW_en_data-analyse/2015%20Tabellen%20tussenopbrengsten%20groepsniveau%20CITO%20LOVS.pdf

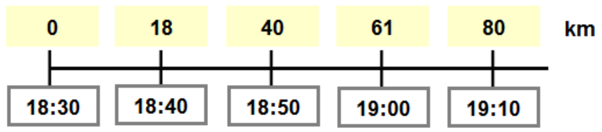
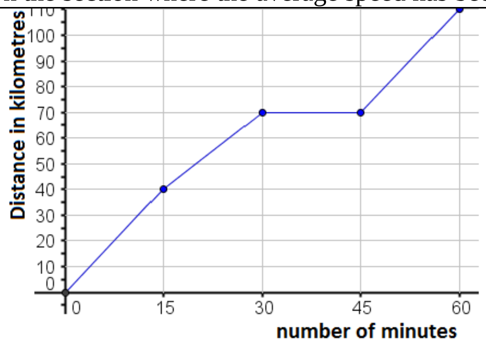
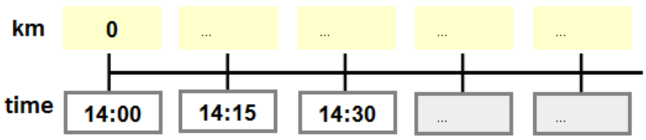
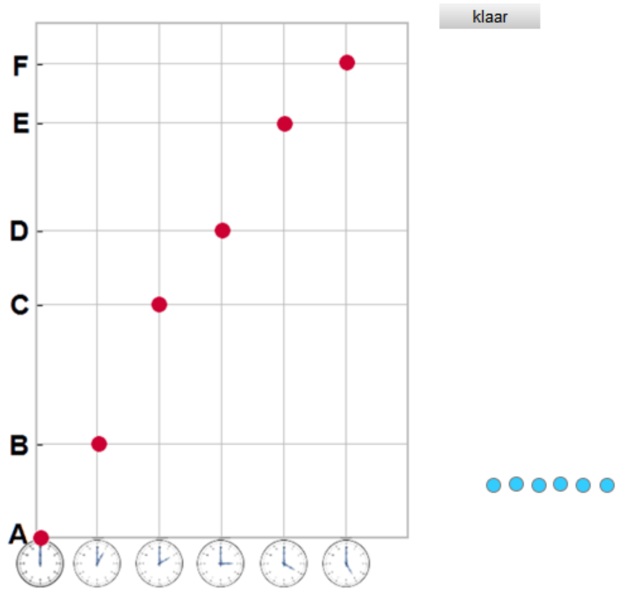
Noteboom, A., Van Os, S., & Spek, W. (2011). *Concretisering referentieniveaus rekenen 1F/1S* [Realisation reference levels mathematics]. Enschede, The Netherlands: SLO.

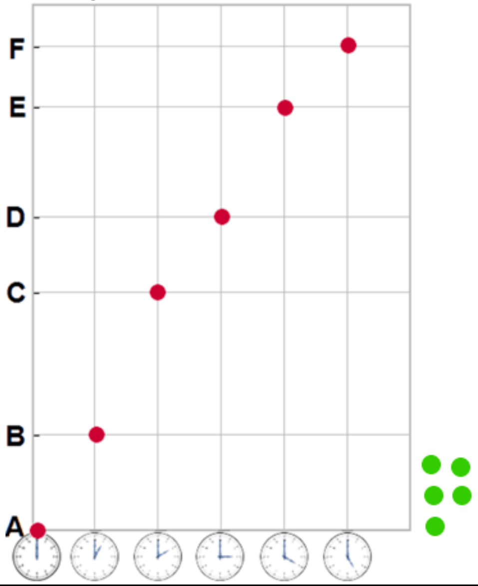
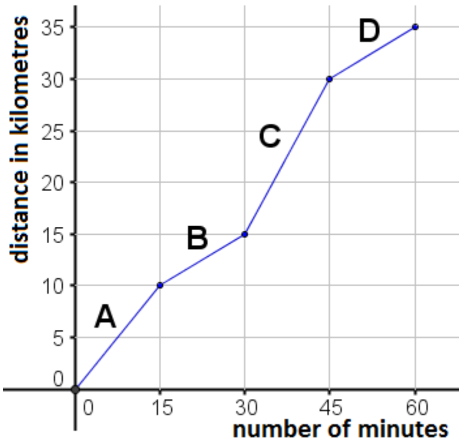
Appendix A: Problems Presented to the Students in the Graphs A and Graphs B Tests

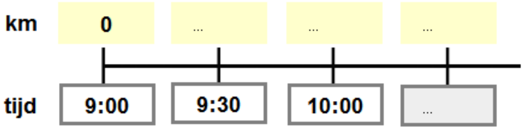
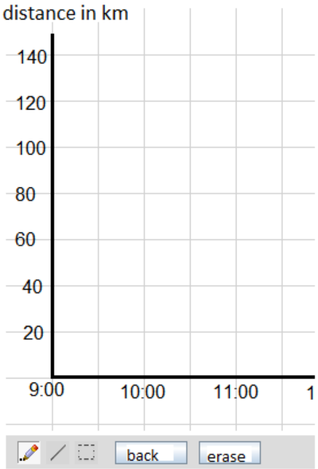
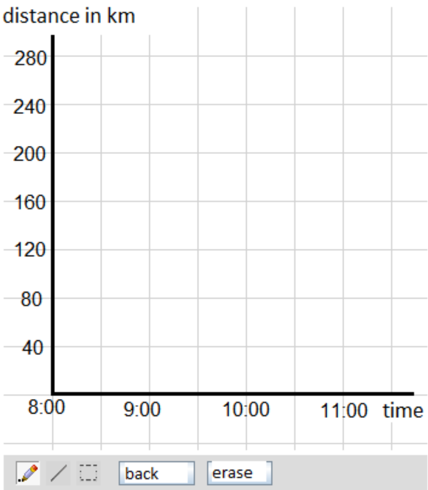
Graphs		
Core competency	Test A	Test B
Pictorially represented data: Drawing conclusions about speed for various distances that have been covered in the same amount of time	Problem 1 At twelve o'clock, the red train departs from A. One hour later it passes B. Here you see where the train is every hour.  Click on that part of the track where the average speed was the highest.	Problem 1 Jasmine makes a long ride by bicycle with her father. They leave A at 12 o'clock. An hour later, they pass B. Here you see where they are, each time an hour later.  Click on the part where the speed was, on average, the highest.
Schematically presented time-distance schedule: Drawing conclusions about speed for fixed equal distances that have been covered in varying amounts of time	Problem 2 The yellow train leaves at 09:00. After each 40 kilometers, the driver looks at his watch what time it is.  Click on that part of the track where the average speed was the highest.	Problem 2 Julius goes by bike to school. After each kilometer his bike computer gives a signal. Then he checks what time it is.  Click on which part his speed was, on average, the highest.
Schematically presented time-distance schedule: Drawing conclusions about the speed for varying distances that have been covered in fixed time slots	Problem 3 The green train leaves at 14:00. After each 30 minutes, the driver looks at the total distance so far.  Click on that part of the track where the average speed was the highest.	Problem 3 Karim goes by bike to his grandfather. Each quarter of an hour, he checks his bike computer, to see how far she is from home.  Click on which part his speed was, on average, the highest.
Completing a time-distance graph based on a schematically presented time-distance schedule in which the covered distances and needed time intervals are given	Problem 4 This is the schedule of the green train.  Use the green dots to complete the graph of this schedule. 	Problem 4 This is the schedule of Sandra and her Mum's bike ride.  Use the green dots to complete the graph of this bike ride. 
Reading data from a time-distance graph and making the corresponding schematic time-distance schedule	Problem 5  Use the graph to complete the schedule. 	Problem 5  Use the graph to complete the schedule of this bike ride 

Using the verbal description of travel times and covered distances for making the corresponding time-distance graph	Problem 6 Draw the graph of the following train ride: The train leaves at 10:00 Then the train drives for half an hour at 160 km per hour Then the train drives for half an hour at 80 km per hour Then the train stands still for half an hour Then the train drives for half an hour at 160 km per hour  How many kilometers was the total train ride?	Problem 6 Draw the graph of the following bike ride: Hans leaves with his race bike at 10.00h Then he rides 16 km per hour for half an hour Then he rides 24 km per hour for half an hour Then he walks 4 km per hour for half an hour Then the bike needs a repair (half an hour) Then he rides 16 km per hour for half an hour and arrives home.  How many kilometers was the entire bike ride?
Drawing conclusions about speed based on a time-distance graph	Problem 7 Click on the part where the average speed was the highest.  	Problem 7 Click on which part of the ride the speed was, on average, the highest. 

Appendix B: Problems Presented to the Students in the Practice Session

Problem 1	The train leaves at 18.30h. After each 10 minutes, the driver checks the total distance the train has covered.  Click on the section where the average speed has been highest.
Problem 2	 Use the graph to finish the itinerary of this train. 
Problem 3	Below you see where the red train is at each hour. The bleu train makes the same journey, but leaves A an hour later. Drag the blue dots for the blue train to the correct locations. 

Problem 4	A green train leaves C at 1 o'clock, passes D at 2 o'clock, arrives at E at half past three, stands still there for half an hour. Then, the train takes 1 ½ hours to get to F. Put the green dots for this train in the correct locations. 
Problem 5	Click on the section of the journey where the average speed has been highest. 

Problem 6	The train starts driving at 9.00h. Then the train drives 120 km per hour for half an hour. The the train stands still for half an hour. Then the train drives 180 km per hour for half an hour. 6a. Fill in the itinerary below.  6b. Draw the graph of the train's journey.  6c. How many kilometres was the train's entire journey?
Problem 7	Draw the graph of the following train journey: The train starts driving at 8.00h. Then the train drives 160 km per hour for half an hour. Then the train drives 80 km per hour for half an hour. Then the train stands still for half an hour. Then the train drives 160 km per hour for half an hour.  How many kilometres was the train's entire journey?

Appendix C: Selection and translation of Q-sorting cards

English	**Dutch**
1. Mathematics/science is difficult. + Using technology in maths/science is difficult.	Rekenen is moeilijk. + Een computer gebruiken bij rekenen is moeilijk.
2. Mathematics/science is fun. + Using technology in maths/science is fun.	Rekenen is leuk. + Een computer gebruiken bij rekenen is leuk.
3. Mathematics/science is important.	Rekenen is belangrijk.
4. Mathematics/science is exciting. +Using technology in maths/science is exciting.	Rekenen is spannend. + Een computer gebruiken bij rekenen is spannend.
5. Mathematics/science is something everybody can learn.	Iedereen kan rekenen leren.
6. Mathematics/science is used in everyday live.	Bij heel veel dingen in het dagelijks leven gebruik je rekenen.
7. One is born with mathematical/scientific understanding.	Goed kunnen rekenen is iets waarmee je geboren wordt.
8. Mathematics/science is a tool for doing something else.	Rekenen is een hulpmiddel om iets anders te kunnen doen.
9. I like mathematics/science. + I like using technology in maths/science.	Ik reken graag. + Ik gebruik graag een computer bij het rekenen.
10. Mathematics/science is frustrating. + Using technology in maths/science is frustrating.	Rekenen is frustrerend. + Een computer gebruiken bij rekenen is frustrerend.
11. Mathematics/science is either right or wrong.	Bij rekenen kan iets alleen goed of fout zijn.
12. I do not like mathematics/science. + I do not like using technology in maths/science.	Ik reken niet graag. + Ik gebruik niet graag een computer bij het rekenen.
13. Mathematics/science is not relevant for my future (life).	Rekenen is niet belangrijk voor mijn toekomst.
14. Mathematics/science means exploring and experimenting.	Rekenen betekent dat je iets moet uitzoeken en uitproberen.
15. To do mathematics/science means to solve many of the same tasks/exercises.	Rekenen betekent dat je veel van dezelfde oefeningen moet doen.
16. I learn things quickly in mathematics/science.	Ik leer dingen snel bij rekenen.
17. Mathematics/science helps us to think systematically and logically.	Rekenen helpt ons om logisch te denken.
18. Mathematics/science means seeing connections.	Rekenen betekent zien dat iets bij elkaar hoort.
19. Mathematics/science helps us to see/understand our surroundings.	Rekenen helpt ons om de wereld om ons heen te begrijpen.
20. I can do without mathematics/science.	Ik kan ook wel leven zonder rekenen..
21. I learn/understand mathematics/science best when I work on my own.	Ik leer het best rekenen als ik in mijn eentje mag werken.
22. I need the textbook to learn mathematics/science (or mathematics/science is best learnt with the help of a textbook).	Ik heb mijn rekenboek nodig om te leren rekenen.
23. Mathematics/science is best learnt by doing practical activities.	Je leert het beste rekenen door werkstukken te maken.
24. Mathematics/science requires a lot of repetition.	Rekenen betekent veel herhaling.
25. Mathematics/science makes sense in the real world.	Rekenen krijgt betekenis in het dagelijks leven.

26. Mathematics/science is only for the mathematics/science classroom, not for real life outside.	Rekenen is alleen voor in de klas, niet voor buiten school.
27. In mathematics/science (lessons) there is no time for reflection.	In rekenlessen is geen tijd om door te denken over dingen.
28. Only gifted people understand mathematics/science.	Alleen slimme mensen begrijpen rekenen.
29. If I do not understand something, I work with it until I get it right.	Als ik iets niet begrijp, dan werk ik net zo lang tot het lukt.
30. I am nervous in mathematics/science lessons. + I am nervous when using technology in maths/science lessons.	Ik word zenuwachtig tijdens rekenlessen. + Ik word zenuwachtig wanneer ik een computer moet gebruiken in rekenlessen.
31. I feel that I can do/understand mathematics/science.	Ik vind dat ik goed kan rekenen.
32. To learn/understand mathematics/science depends on the teacher.	Of je rekenen kunt begrijpen hangt af van de meester of juf.
33. In mathematics/science (lessons) there is no room for expressing one's own ideas.	In rekenlessen is het niet goed mogelijk om met eigen ideeën aan te komen.
34. Mathematics/science is best learnt (in collaboration) with others.	Rekenen leer je het best in samenwerking met anderen.
35. I understand better if I work with friends in mathematics/science.	Ik begrijp het beter als ik met rekenen met mijn vriendinnen/vrienden samenwerk.
36. Exams are boring.	Toetsen zijn saai.
37. I like exams because I can see how I am doing.	Ik maak graag toetsen omdat ik dan kan zien hoe het gaat.
38. Exams help me to work more.	Toetsen helpen mij harder te werken.
39. Working with technologies in mathematics/science is useful.	Werken met een computer in rekenen is nuttig.
40. We use a lot of tools in our mathematics/science lessons.	We gebruiken veel hulpmiddelen (blokjes, linialen, enzovoort) tijdens de rekenles.
41. Our teacher in mathematics/science always uses some kind of technology for the lessons.	Onze leraar gebruikt altijd wel een vorm van technologie (computer, digibord, enzovoort) in de rekenles.
42. I can better understand when I use the technology tools in our mathematics/science lessons.	Ik begrijp het beter wanneer ik technologie (computer, digibord, enzovoort) gebruik in de rekenles.
43. When we use technology during the mathematics/science lesson, I quickly understand if and why I am wrong.	Wanneer we technologie (computer, digibord, enzovoort) gebruiken in de rekenles zie ik snel of ik foutjes maak en waarom.
44. When we use technology during the mathematics/science lesson, I better understand what I have to do to improve my understanding.	Wanneer we technologie (computer, digibord, enzovoort) gebruiken in de rekenles snap ik eerder wat ik moet doen om het beter te begrijpen.
45. The use of technologies during the mathematics/science lesson enable me to better understand the objectives of the activities.	Door technologie (computer, digibord, enzovoort) te gebruiken in de rekenles begriip ik het doel van de oefeningen beter.
46. It takes me twice as long, if I have to work with the technology tool, and cannot ask the teacher directly.	Als ik met technologie (computer, digibord, enzovoort) moet werken en het niet aan de meester of juf kan vragen, doe ik er twee keer zo lang over.
47. I prefer to talk to the teacher, rather than find out myself with the technology.	Ik praat liever met de meester of juf dan dat ik dingen uitzoek met de computer.
48. For me, the technology does not work, or help.	Voor mij helpt het niet om een computer te gebruiken.

49. I feel that the teacher knows much better where we are, when s/he uses the technology tools.	Volgens mij weet de meester of juf veel beter of we goed leren als hij/zij werkt met een computer..
50. When we work together, it makes sense to use the technology.	Als we samenwerken is het nuttig om de computer te gebruiken.
51. Our teacher uses the technology to find out where we are in our learning/with our exercises/ …	Onze meester/juf gebruikt de computer om te weten te komen hoe ver we zijn met het rekenen.
52. With the tools/technology I can find out myself whether I can do the tasks in mathematics/science.	Met de computer kan ik er zelf achter komen of ik de rekenopdrachten beheers.
53. I never know what to do with the computer/technology.	Ik weet nooit wat ik met de computer moet doen.