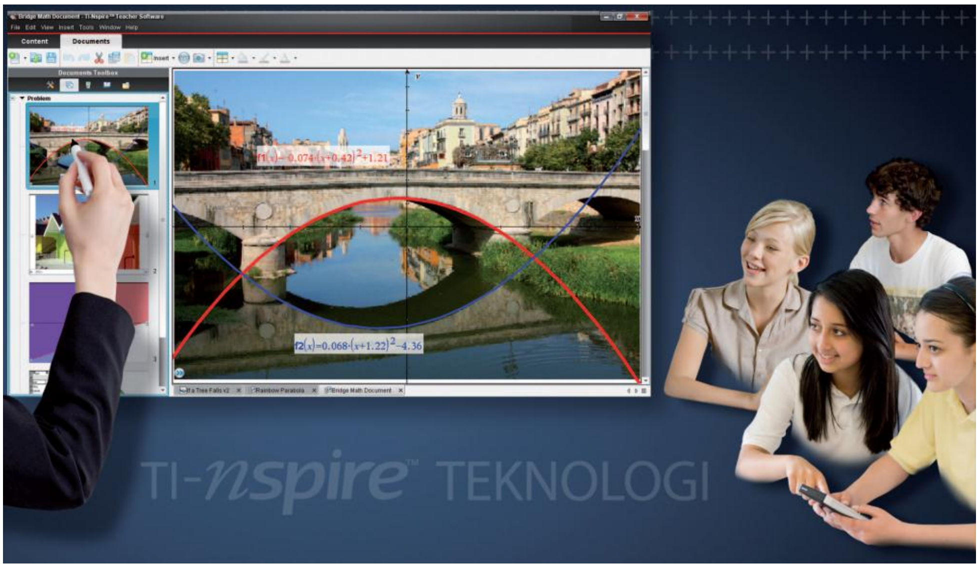
MALMÖ UNIVERSITY

Report from the research project

Teaching and learning mathematics at secondary level with TI-Nspire technology



Per-Eskil Persson

PhD Mathematics and Learning

Malmö University

per-eskil.persson@mah.se

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Abstract

Research of technology used in mathematics education has been mainly focused on the calculators. Therefore it has been of great value, as in this study, also to study how teachers and students can use laptops with TI-Nspire technology and software, with or without concomitant use of handheld devices. Of particular interest has also been examining possible changes in teachers' teaching experience, the students' problem-solving methods and the students' mathematical learning and deeper understanding of mathematics, and other outcomes of education in this technological learning environment.

Eight classes of students in theoretical programmes at upper secondary level in southern and central Sweden, as well as their teachers, were using TI-Nspire CAS in a regular course, Mathematics A or Mathematics B, during a whole semester. They used the software and/or handhelds continuously during the course and also, where appropriate, implemented the national test on laptops.

Experiences of students and teachers, concerning opportunities and the positive sides as well as obstacles and problems, agree well. Almost all showed significant progress during the study, both in terms of management of technology in the math work, and when it comes to integrating it into a high-quality learning environment. A majority of the students testified about the positive impact that the use of technology had on their view of mathematics and of what mathematical activities would include. This raised at a great extent their interest in the subject and gave them more confidence towards mathematics.

Perhaps the most important results of this study are how TI-Nspire software on laptops could be used in regular education in courses at upper secondary level. Its various possibilities, of technical, mathematical and conceptual nature, have had the opportunity to appear in this relatively long study. But also the various obstacles and risks of this type of technology were identified, and teachers' approaches to them have been reported. They agree that CAS represents a difficulty, especially for low-performing students, but also carries an incredibly powerful potential in mathematics. Experiences from the use in the national tests were positive, and the barriers that existed for the use of laptops could in practice be eliminated.

Special attention has been given in the study to the question if the combination of handheld unit and computer has added something extra to education. The results indicate that there are several reasons to consider this technical solution, such as the hand units being better in certain situations; for quick calculations, for tests and in other subjects; while computers presenting an advantage for working with graphs or to solve larger problems and finally to document them. This indicates that implementation of new technology must always be preceded by a careful analysis of how it is meant to be used in education in practice.

Keywords: CAS, computer, digital, high school, laptop, national test, technology, TI-Nspire, upper secondary.

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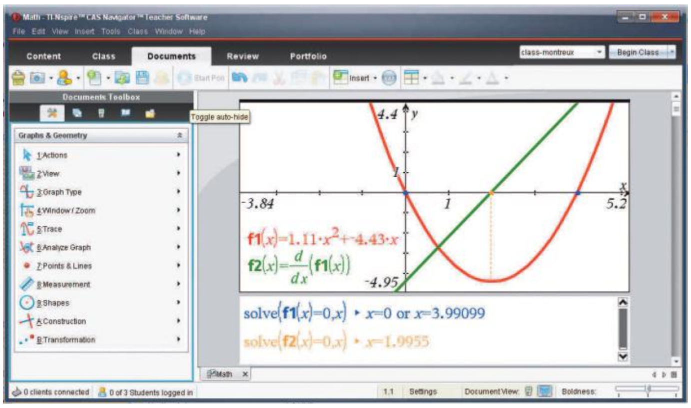
Introduction

Calculators and computer software have been used for a rather long period in mathematics classrooms. A development of the calculators (handheld units) has taken place through the years, from basic calculators to graphing ones, and now advanced calculators working with computer algebra systems (CAS) and with dynamic graphs and geometry. At the same time, computers have changed from being large and rather rare in mathematics education into smaller, mobile units (laptops) that can more easily be used in instruction with continuity. The software has simultaneously changed from more particular mathematics programs to more general ones. One observation is that calculators and computer software show a converging development, even if there are differences in the practical use of them. They can be combined through a system of software and hand units that gives the user the opportunity to choose when and where he/she wants to use the one or the other. The TI-Nspire system, with or without CAS, can be used either as handheld units or as computer software, or as a combination of the two.



A curriculum material, *'Nspirerande matematik'*, was constructed mainly for an on-line use in the two first mathematics courses at upper secondary level in Sweden, and is especially intended for a dynamic use together with TI-Nspire technology (Texas Instruments, 2011). The preliminary material was tested in three classes during spring semester 2010, and was evaluated in the pilot project *'Nspirerande matematik – A pilot evaluation and research project with TI-Nspire technology'*, which was reported in June, 2010. Some of the results and conclusions of this study was used to improve the curriculum material, which in its final form is published on the net (Persson, 2010).

However, the use of technology in this pilot study was mainly limited to handheld units, except for the teachers' demonstrations, in the teaching practice. And much of published research of technology used in mathematics instruction is also limited to handheld calculators. Thus, it is of great value to also study how teachers and students are able to use laptops with TI-Nspire technology as software, with or without the simultaneous use of handheld units, and with the constructed curriculum material as an optional aid. Of special interest is furthermore to investigate possible changes in teaching practice, of students' problem-solving methods and of students' mathematical learning and deeper understanding of mathematics, as well as other outcomes of this technological environment for teaching.

Theoretical framework

The theoretical background for this evaluation rests on the classical *didactic triangle* with its three main elements *student-teacher-mathematics*, discussed for example by Steinbring (2005). This model has, however, been presented in various ways, depending on the overarching theory of learning and on the special context. The focus here lies on processes of mathematical interaction between individuals in the classroom (e.g. Cobb & Bauersfeld, 1998), a mainly social constructivist view. Learning takes place through experiences that are mediated by tools (Vygotsky, 1978), that can be mental (like spoken language), symbolic (like mathematical signs) or physical (like compasses), and with assistance drawn from other, competent individuals. Calculators and computer software hold a special position here, as they can be seen as tools within all three aspects.

The three pillars of the didactic triangle can be interpreted with a double meaning, both as the *learning processes*, where teacher and the learners interact around the subject matter, and as the *individuals* and the *subject matter* with the *learning outcomes* that are involved in the educational situation. This is shown in figure 1.

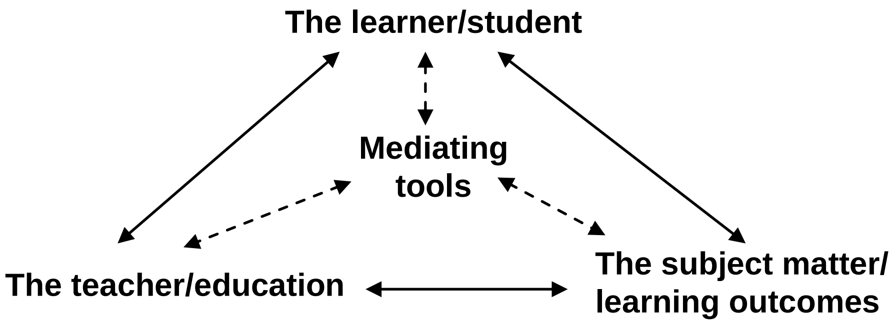


Figure 1. The didactic triangle with mediating tools as facilitators.

Another important ground for discussing the interactions is the *theory of didactical situations*, developed by Brousseau (1997), and which describes extensively the structure and the functioning of mathematical learning-teaching processes and its different phases. Of special interest here are the mechanisms of regulation of the didactical interactions between the teacher and the students (*the didactical contract*), which includes what actions that are expected and ‘allowed’ in the classroom work by the interactors involved (teacher and students).

Balling (2003) distinguishes between the use of software and calculators as *calculating tools, teaching tools* and *learning tools*. When they are used mainly for facilitating calculations (extensions of the calculators used before), they function as calculating tools. When the teacher takes advantage of their possibilities to illustrate and show important features of concepts and methods, they are used as teaching tools. Finally, when students use them for exploring mathematical objects, to discover concept features and to solve problems, they have the role of learning tools.

A tool can develop into a useful *instrument* in a learning process called *instrumental genesis* (Guin & Trouche, 1999, Laborde et al., 2005), which has two closely interconnected components; *instrumentalization*, directed toward the artefact, and *instrumentation*, directed toward the subject, the student (See fig.2). These processes require time and effort from the user. He/she must develop skills for recognizing the tasks in which the instrument can be used and must then perform these tasks with the tool. For this, the user must develop *instrumented action schemes* that consist of a *technical part* and a *mental part* (Guin & Trouche, 1999;

Drijvers, 2002, Drijvers & Gravemeijer, 2005). To learn instrumentation schemes does not in itself induce mathematical meaning and knowledge. Instead the teacher must actively guide the students in a controlled evolution of knowledge, achieved by means of social construction in a class community (Mariotti, 2002). Of special interest is the *instrumental orchestration*, which is defined as the intentional and systematic organisation and use of the artefacts available in a learning environment by the teacher, in order to guide students' instrumental genesis (Drijvers et al, 2010). In the present research project, TI-Nspire CAS calculators together with the emulating computer software are the physical parts of the instrumentation process.

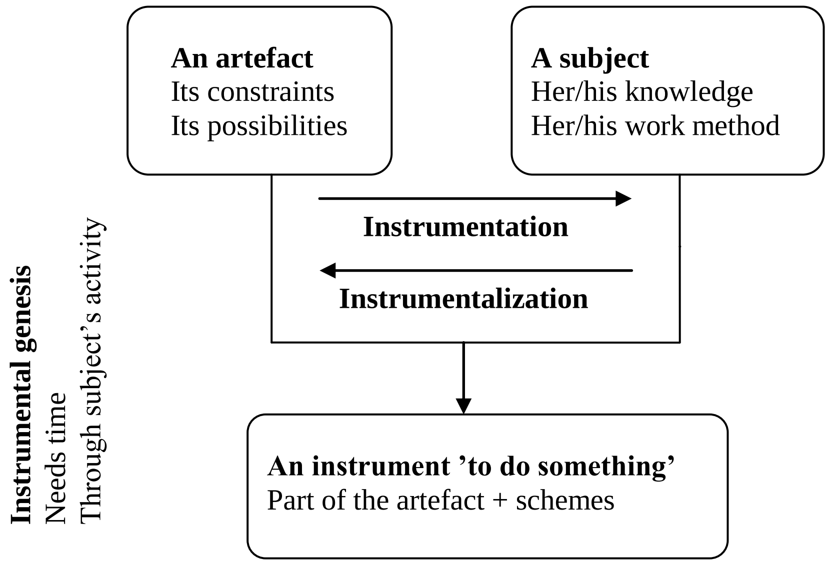


Figure 2. From artefact to instrument (Trouche, 2005)

In the present research project, TI-Nspire CAS calculators together with emulating computer software are the physical parts of the instrumentation process. But the setting for this is within the curriculum material, which is intended as the basic mediating tool for the learning process, replacing the ordinary textbook.

The term *resources* is used to emphasize the variety of artefacts we can consider: a textbook, a piece of software, a student's sheet, a discussion, etc. (Gueudet & Trouche, 2009). A resource is never isolated; it belongs to a *set of resources*. A process of genesis takes place, producing what is called a *document*. The teacher and the students build schemes of utilization of a set of resources for the same class of situations across a variety of contexts. This process is called a *documentational genesis* and also takes time and effort (Gueudet & Trouche, 2009). The participation and identity in the mathematical classroom builds on *integrated communication* and on *representational infrastructures* (Hegedus & Penuel, 2008). The way this is realised in teaching practice decides the effectiveness of information transfer and of cooperation, both student-student and teacher-student.

The TI-Nspire environment has been studied for example by Artigue and Bardini (2009). They give a list why this type of technology can be considered as novel and special:

- *Its nature: the calculator exists as a "nomad" unit of the TI-nspire CAS software which can be installed on any computer station;*

- *Its directory, file organiser activities and page structure, each file consisting of one or more activities containing one or more pages. Each page is linked to a workspace corresponding to an application: Calculator, Graphs & Geometry, Lists & Spreadsheet, Mathematics Editor, Data and Statistics;*
- *The selection and navigation system allowing a directory to be reorganised, pages to be copied and/or removed and to be transferred from one activity to another, moving between pages during the work on a given problem;*
- *Connection between the graphical and geometrical environments via the Graphs & Geometry application, the ability to animate points on geometrical objects and graphical representations, to move lines and parabolae and deform parabolae;*
- *The dynamic connection between the Graphs & Geometry and Lists & Spreadsheet applications through the creation of variables and data capture and the ability to use the variables created in any of the pages and applications of an activity.*
(Artigue & Bardini, 2009, p. 1172)

In their results they noted that:

> *…the introduction of this new tool was not without difficulty and required considerable initial work on the part of the teachers, both to allow rapid familiarisation on their part and those of the pupils but also to actualize the potentials offered by this new tool in mathematics activities* (p. 1179).

They also claim that:

> *These characteristics affect teachers and students differently, and individuals belonging to the same category differently, according to their personal characteristics and experience. They can have both positive and negative influences on teaching and learning processes and need to be better understood* (p. 1179).

Aldon (2010) has studied the use of TI-Nspire calculators, and assumes that the calculator is both a tool allowing calculation and representation of mathematical objects but also an element of students' and teachers' sets of resources (Gueudet & Trouche, 2009). As a digital resource, these handheld calculators possess the main functions required for documentary production. Also Weigand and Bichler (2009) have researched the use of calculators, and they formulate some interesting questions for research, like:

- *When working with new technologies, polarisation occurs in that some students benefit greatly from symbolic calculators use, whereas for other students, SC use inhibits performance or even decreases performance. Are there ways to get all students convinced of the benefits of the SC?*
- *The reasons for non-use of the calculator are on the one hand the uncertainty of students regarding technical handling of the unit and on the other hand a lack of knowledge regarding use of the unit in a way which is appropriate for the particular problem. Is there a correlation between these two aspects?*
- *The responses of the students confirm that familiarity with the new tool requires a very long process of getting used to it. It is surprising that it took almost a year to establish familiarity with this tool for students to use it in an adequate way. After one year of SC use, confidence in and familiarity with the SC grow. However there is still a large group of students who experience technical difficulties when operating the SC. Will there be ways to shorten this period of adjustment?* (pp. 1199-1200)

Affective factors play a most important role in the outcomes of mathematical education. Debellis and Goldin (1997) suggested four facets of affective states: emotional states, attitudes, beliefs and values/morals/ethics. This has been elaborated further by others (e.g. Hannula, 2002), and especially the *intentions* and *goals* for the mathematical education that students and the teacher have are vital. They are not always coinciding, and that is particularly the case when technological tools and mathematical texts are used in instruction. There are also other elements of *attitudes* and *beliefs* that teachers hold that can present obstacles and cause problems for the using of these, such as the perceived change in their classroom practice or how they believe such teaching will impact on students' learning (Brown et al, 2007; Pierce & Ball, 2009). Another important factor for teachers engagement in integrating technology into their instruction is whether it is included in the national respectively local curriculum or not, and if it therefore is allowed or even demanded in the national tests and examinations. This is especially true for CAS, which has the problem of becoming legitimized within the school culture (Kendal & Stacey, 2002).

Aims of the study

The intention was to make a study of the use of TI-Nspire CAS technology, as software for laptops and as software combined with handheld calculators, in some Natural Science classes where each student has continuous access to his/her own laptop and can use it for mathematics as well as for communication over the net (Intranet and Internet). Classes with only handheld units were to be used as control groups. The study should be based on the experiences of teachers and students, on observations of lessons, of a problem-solving situation constructed by the researcher, and on students' use at the Swedish national tests for the courses "Matematik A" and "Matematik B" at upper secondary level.

Of special interest for the study are possible changes in the students' classroom work and of teachers' instructional practice when they migrate from their current handheld (in most cases graphing calculators) to either version of TI-Nspire or the combination of the two. A special aim was to discern the advantages with using both handheld and laptops in the classroom work, and if important features and possibilities of the technology are missing when only laptops are used.

Teachers, as well as students, should have the opportunity to show and also express their opinions of the use of this material and this technology, especially compared to other learning tools like ordinary textbooks and graphing calculators or software, e.g. Geogebra. However, one of the main questions is the effects of this special learning environment on students' ability to solve problems and on their mathematical knowledge and conceptual understanding.

The aim was also to present results that can be transferable to educational situations in other countries than Sweden. What are the general benefits and special values for teachers as well as for students in using the TI-Nspire technology on their laptops, with or without handhelds, and what are the trade-off for teachers who must choose to change from their current handheld to either version of TI-Nspire?

Research questions

The research questions are structured according to the three corners of the ‘didactical triangle’:

A. Students/learners

1. What experiences do students express of the learning environment, which includes TI-Nspire software on laptops, combined and not combined with handheld units, and also with handheld units alone, especially in comparison with other types of learning environments?
2. a. Which changes in working styles and in the ways students interact and cooperate can be detected over the research period?
   b. In particular, what are the differences between the classes with only the laptop environment, and those who also use the handhelds?
3. What effects on classroom discourse can be detected when working within the different types of TI-Nspire environment?

B. Teachers/educators

1. a. Which benefits and special values do teachers express of the two types of learning environment with TI-Nspire, especially in comparison with other types of learning environments?
b. In particular, does the use of handhelds together with laptops add extra values to the teaching opportunities?

2. a. How has this technology supported new approaches to teaching for the teachers involved in the research project, leading to a change in their teaching practice?
b. What common obstacles to high-quality teaching have they detected?

3. Which examples can be found of how the teachers have used the possibilities of the technology intentionally to promote student reflection on mathematical methods and concepts?

C. Cognitive and affective learning outcomes

1. What skills in using the TI-Nspire technology in both versions for problem-solving and in exploring mathematical tasks do the students show after working with it for a longer period?

2. a. Which examples of how the instrumental and the documentational geneses have progressed during the project can be found?
b. In particular, are there differences between the environments with and without handhelds units?

3. How do the teachers as well as the students involved in the project estimate the effects of the environment on students’ development of deeper understanding of mathematical concepts and methods?

4. How does the use of the two types of technology and the curriculum material affect students’ motivation, interest and self-confidence when working with mathematical activities?

Methods and methodology

This study has the intention of giving a view of students' and teachers' experience, over a longer time period, of the learning environment with TI-Nspire technology in the laptop version, with and without the presence of handheld units, the handheld version, and of its learning outcomes. Thus, a research design consisting of different methodological elements is appropriate, mainly focussing on qualitative approaches, but also with some quantitative parts. This use of different methods is necessary in order to provide answers to all research questions, but also to strengthen the reliability of the results through method triangulation.

Eight teachers from seven different schools in middle and southern Sweden participated in the research project. The schools are spread over a rather large area and are situated in communities of varying size, from towns to middle-sized or larger cities. The eight classes were all taking their first year of the Natural Science programme (6 classes) or Social Science programme (2 classes) at upper secondary level, and they have during the project been studying the two first courses in mathematics, Matematik A and Matematik B, or in one case only Matematik A. One of the schools is of a special kind and the eight students from this all have physical disabilities that strongly influence for example their possibilities to write by hand. But it is possible for them to use computers and different types of software, e.g. TI-Nspire, even if this sometimes demands supporting software of different kinds.

The number of students involved has in total been 133. Five of the classes have used only the laptop version of TI-Nspire, one class has used laptops combined with the TI-Nspire handheld units, and two have only had handhelds. The six classes with access to laptops have by special permission by The Swedish National Agency for Education been allowed to use laptops in the national tests for research purposes. The use of the special curriculum material ('Nspirerande Matematik') was optional for the teachers. They have been able to continue using their ordinary textbooks and own material, at their own will.

The classes and the teachers had each been visited twice during the project. In comparing the data collected at the different occasions, it was possible to detect signs of progression in a variety of ways, such as teaching practice, the students' use of the material and the technology, dialog and collaborative learning in the classroom, conceptual understanding etc. The second visit also included a special problem-solving experiment aimed at detecting the students' skills and knowledge in using TI-technology for calculating, problem-solving and reflecting on answers and results that the technology presents for them.

The methods used involved the following main parts:

- *Teacher interviews.* A deep, semi-structured interview with the teachers was made in connection with the first visit at the schools. All interviews were recorded and later transcribed.
  Research questions: B1, B2, B3, C1, C2, C3, C4. (see appendix A)
- *Student interviews.* Two students were chosen from each class to be interviewed in semi-structured form directly after the observed lesson by the first visit. And directly after the teaching experiment a focus group of 5-6 students were interviewed about their experience of the task and of TI-Nspire in general. Both of these types of interviews were also recorded and transcribed.
  Research questions: A1, A2, A3, C2, C3, C4. (see appendix B and C)

- *Classroom observations.* At the first visit at each school a lesson was observed by the researcher, using a special observation form.
  Research questions: A1, A3, C1, C4. (see appendix D)

- *Teaching experiment.* In the later part of the course (Matematik A or B), all students participated in a problem-solving experiment, conducted by the researcher, and designed to detect the students' ability to use the TI-Nspire technology in a versatile way in longer, exploring task, and to record and communicate the result in a documental form (tns-file). A suitable problem-solving task was constructed within the area of linear functions and inequalities for Matematik A, and within the area of quadratic functions and equations for Matematik B, respectively.
  Research questions: A2, A3, C1, C2, C4. (see appendix E, F and G)

- *Teacher questionnaire.* At the end of the school year all teachers were given questions concerning their overall experience of using the material and the different combinations of technology in their teaching practice, as well as their estimations of the effects on students' deeper understanding of mathematical concepts and methods and the effects on students' motivation, interest and self-confidence in connection with mathematics. The questionnaire was in whole net-based.
  Research questions: A2, B1, B2, B3, C2, C3, C4. (see appendix H)

- *Student questionnaire.* All participating students had the opportunity to express their experience of the learning environment with the types of technology they have used, their estimations of the quality of the mathematical learning with it, and of how it has affected their motivation, interest and self-confidence. Also this questionnaire was net-based.
  Research questions: A1, A2, C1, C4. (see appendix I)

- *Collection of material.* The intention was that interesting teaching material, tasks, tests, etc. that the participating teachers had produced during the project would be collected. Of special interest are the results of the national tests, providing an opportunity to detect possible differences between the classes using both handhelds and laptops and those who only had access to laptops. Some samples of the students' produced tns-files and how they are organized in folders were also to be collected.
  Research questions: A2, B2, A3, C3.

Data collection

The research project was set during the school year of 2010-2011. Preliminary contacts were taken with teachers who were interested in participating and also with their headmasters. The reason for this was to secure the schools involved and that no obstacles for the project were raised within their organisations. One special concern was that the IT-staff at each school was able to give their support in case of possible technical problems with installation of the software in the local networks and at the laptops used. By the end of November a list with teachers and schools was ready, and a first net-meeting within the project took place on December 2.

The implementation of the software and/or the handheld units was initiated at the seven schools or had, in fact, already started at a couple of them. However, at the following net-meeting on January 13, it became clear that this implementation was going to be prolonged and delayed in some cases. This was caused by a number of technical as well as other problems, such as licenses that did not work etc. In fact, by the time of the first round of visits one of the classes had just started using TI-Nspire.

The first round of visits to the seven schools was made February 1-24. The planned interviews and the observation of one lesson with the technology used in the classrooms were completed. It became clear that the teachers and the classes at that point were on somewhat different stages in the process of implementation of the TI-Nspire-system into their mathematics work. Some had used handheld units already from September, and some had just had their first experiences of TI-Nspire. This was not entirely a negative effect for the study. On the contrary, it gave an interesting view of these different stages and of the opinions of students and teachers in the middle of the implementation process.

All interviews were made and recorded, and also later transcribed. The students participating in the interviews had been asked in advance and had given their personal consent to this. Before the interviews, the students also were told the purpose of it, and were given guarantees for anonymity. The impression was that they generally expressed their true and honest views of the material, the technology and their classroom work, without trying to answer in a way that they believed to be 'correct' in any way. Their answers contained both positive and negative statements, and had seemingly high credibility. The nine (for one class double) teachers interviewed presented in most cases extensive answers to the questions asked, and also gave a clear impression of honesty in them. It was possible to discuss both their progresses and their shortcomings with the material and the technology, and they reflected on much on what they had done, or not done, in class.

On March 11, a special project meeting was held with researchers and all participating teachers. The aim with this was to give information and to answer questions from the participating teachers, and also to give them an opportunity to present and to discuss experiences from the project so far. Of special interest were good examples of activities that have been used in their teaching, of which some was presented at the meeting. Some demonstrations of different activities that are suitable for mathematics education were also given, followed by a discussion of how it can be used in classroom work. In some respects, this project meeting was also intended as a part of the teachers' professional development within the project (see appendix J).

The second round of visits was made during May 10 to June 1. Central in these was the teaching experiment, conducted by the researcher, in which the students were given a longer task with three levels of difficulty (see appendices E and F). The students were allowed to cooperate during the solving of the task, and they could also ask the researcher or their teacher if they got stuck somewhere in the solving process. A general impression was that most students put great effort into working with the task, and that they had a genuine will to complete it, even if the part with the highest level was hard for them. Many students also worked rather fast with the task and finished it much before the end of the lesson. All students' solutions were saved and handed in as tns-files through the network that was normally used for file transfer. These files were collected as data from the experiment.

Directly after the experiment a focus group of 5-6 students from each class were interviewed about the task that was given, how well this fitted into the mathematics and the use of TI-Nspire they had experienced in their courses and of their experiences of the technology in general. Again, the students appeared to speak rather freely and they expressed important views, of positive as well as negative nature. The focus group in itself also created a discussion among the participating students that was fruitful for the quality of the opinions that were expressed.

The web-based questionnaires for the students and for the teachers were published for them on May 25, approximately two weeks before the end of the school year. By then, the experiences and opinions of the students were not expected to go through any major changes within the project. The responsibility to arrange for the students so that they could fill in the forms was given to the teachers, also for those who only used handhelds, and the hope was that there would not be any problems to find some time for this. Unfortunately, some problems with allocating time for the students must have appeared, and four of the classes gave poor or no response at all. In one case, the problem was of a technical nature within the questionnaire form, for which the researcher was responsible. But in other cases the reason given was lack of time. Another problem, also of technical nature, showed in the teacher questionnaire. The construction of one question was made in such a way that it became difficult for the teachers that had used handhelds to submit the form. All teachers but one however managed to overcome this problem.

All the material was classified according to the research question it belonged to. This was facilitated by the organization of interviews and questionnaires, which contain elaborations of the overall questions. Partial exceptions were that the interviews were semi-structured, the questions for the focus groups were even freer and that the questionnaires contained open-ended questions. An answer to one of the research questions could in some cases appear at the ‘wrong’ place. The on-line questionnaires were created in a platform in which the responses are automatically organized and partially analysed statistically. Only about half of the students responded to the survey, which gives less much weight to some of the quantitative results of this. One lucky thing, though, is that the ‘missing’ classes came from all three types of TI-Nspire configurations, so that the students that really answered the questionnaire in fact represent the profile of all students in the project. This fact reduces the lack of reliability of the results of the survey somewhat.

Results and analysis

In this section, the main results of the various methods in the study are reported. Some of the data that is shown is in the form of verbalisations from students and teachers, which have been translated into English by the researcher. Abbreviations that are used in these are: F = female student, M = male student, T = teacher, and I = interviewer. If for example more than one teacher appears in the same interview block, they will be labelled T1, T2 etc. In some cases, the same utterings appear more than once in the results presented. The reason for this is that these can shed light on more than one research question.

The informants

The eight teachers, three female and five male ones, have worked at upper secondary level between 2 and 24 years, with a median of 15 years. Two of them mainly teach within the Social Science programme and the others mainly within the Natural Science and Technology programmes. These last two programmes contain several mathematics courses, the five courses Matematik A-E and two more optional courses that are taken during the students' three years at upper secondary school. The teachers in the project usually follow their students through all the courses. They believe themselves to be experienced or quite experienced with the use of calculators (7/8 answer 'large' or 'very large'), which they have used in instruction for many years. They are also experienced or rather experienced with computer software in instruction (7/8 answer 'rather large' or higher). However, when it comes to CAS, only 3/8 claims that they have rather large experience or more, and 5/8 that they have little or not so large experience. All the teachers also claim that they had very little or no training at all in the use of technology in mathematics in their pre-service education, and that they had had no in-service training at all after that, except for shorter courses that have been arranged by Texas Instruments. They have been forced to learn how to use technology mainly by themselves.

The students are of rather equal gender. Of those who answered the questionnaire are 45 % female and 55 % male. That also fits well with the observations of all the eight classes at work. A majority of the students claim that mathematics is an important subject for their coming profession (74 %), that mathematics is interesting (55 %) and that mathematics is useful in other subjects and in their everyday life (77 %). A minority says that mathematics is difficult (22 %) or that mathematics is boring (6 %). The interviewed students have with no exceptions used only simple calculators at lower secondary level, and none has worked for example with a graphic calculator before starting at this level. Some of the classes had initially graphing calculators at the beginning of the autumn semester (August), and only later (sometimes as late as February) did they get access to TI-Nspire. But in some other classes the students instead started directly with TI-Nspire calculators, and did not use graphing calculators as a middle step.

Teachers' and students' experiences of a learning environment with TI-Nspire

The combined data from the interviews and the questionnaires give an interesting picture of the advantages as well as the difficulties with using TI-Nspire technology. Many of these are well-known opinions of teachers and students that have been presented in other research of the use of technology in general. But the difference here is that this research project concerns the use of laptops in regular teaching over a longer period. In tables 1 and 2, common answers from teachers and students have been compiled. Of special interest are answers that have been given by both categories. Some comments have been added in cases where the answer is frequent.

Advantages	**Teachers**	**Students**	**Comments**
A clear and distinct screen.	X	X	Frequent in interviews
Fast and flexible to work with.		X	Rather frequent
Easier to present new concepts and demonstrate in whole class.	X	X	5 teachers
Easy and useful for work with functions and graphs.	X	X	Frequent, 70 % in st.q. all teachers
New possibilities in the geometry and chance areas of mathematics.		X	
You can write all of the solutions to tasks in the program/on the handheld.		X	
You can easily check answers, also those you solve by hand.	X	X	
You can manage more difficult tasks, on a higher level.	X	X	Rather freq., 42 % in st.q. 6 teachers
New tools, like the solve-command, give you more power.		X	Rather frequent
You can learn more and understand mathematics better.	X	X	3 teachers
You can use several ways to solve a problem.	X	X	6 teachers
You can focus on understanding instead of making a lot of calculations.	X		
Easy to use after a while.	X	X	
Useful in other subject, e.g. physics and chemistry.		X	
Easier to communicate.	X		3 teachers
Mathematics is more interesting with TI-Nspire		X	24 % in st.q.
More fun to work with mathematics	X	X	34 % in st.q. 6 teachers
You cooperate more in problem-solving		X	21 % in st.q.
The use of TI-Nspire has changes my conceptions of how you work with mathematics.		X	26 % in st.q.

Table 1. Common advantages with using TI-Nspire technology. Remarks about how frequent the answer is and some results from the questionnaires are given in the comments column.

The interviews gave many interesting points of view from the students. Two male students in the first interview:

M1: It's very smooth, and it shows that you can figure out math a lot easier when you have computers. So instead of a notebook in which you must have an entire page for a task, you can write down everything on your computer and save it. Then you can look at how you solved it.

M2: Before, you had to fight a lot when you were solving tasks, but here you have it in a simpler way and you can handle the more difficult tasks.

Examples from two female students in the focus groups:

F1: We had geometry quite early, and then it became useful right away. It is quite different and not what you're used to. It helped a lot.

F2: But the graphs are much easier to do on the computer than on the calculator. And finding points of intersection is fast.

Two teachers:

T1: I am very positive to using that type of tool. I think you get a much better understanding, an eye-opener, and not as much tinkering by hand with miscalculations. You get a much better picture, and it binds better ties between math and physics as well.

T2: I welcome it, because I think it can increase understanding. You can check calculations, make your own calculations and test different ways of calculating. One can see how mathematics can be related. Then I think it might be a little more fun and interesting, hopefully. That you do not always work exactly the same with the book, but you can work in different ways. I hope the students may think it is fun to explore and learn, get some wow-experiences.

Generally, difficulties or genuine obstacles were much less mentioned by both teachers and students. One exception was technical problems of different kinds; network problems including Internet, installation and re-installation, battery problems etc. These are of less importance for this study, as they do not generally concern TI-Nspire in itself. But practical problems have an indirect impact on teachers and students beliefs of the usefulness of the technology, so the must yet be considered to some degree. In table 2, the common difficulties are collected, some of which are rather frequent in the questionnaires.

Also here, the interviews gave some interesting views of opinions from students and teachers. And sometimes the difficulties were mentioned together with some advantages:

M: It's a pretty steep learning curve, I think. It's been 1-2 months now and only now you have they really started to get acquainted with everything. In the beginning it was quite chaotic.

F: The calculator in itself was not so difficult. There was more to find the menus and documents.

T1: Being able to calculate is a part of the skills you should have in mathematics, so you have to train to calculate even with paper and pencil and the head. But this is only one part. The most important thing is to understand what to do and perform what you are supposed to do. There the computer does not cause any problems. There, I imagine that it can facilitate, because you can do things faster. You can concentrate more on the bits that I did today. So I cannot see any greater dangers.

T2: I fear that the students who has trouble keeping up with the others too easily use the calculator to see that it got right what he did, without really thinking through the task itself. I fear that they will enter 'solve' to see what happens. Then you do not get this struggling like you get when sitting with pencil and paper.

Difficulties and risks	**Teachers**	**Students**	**Comments**
Hard to start with TI-Nspire.	X	X	6 teachers
Students think it is hard to use in 'normal' school work.	X		6 teachers
Takes time to learn how to use TI-Nspire, e.g. find your way in menus.	X	X	Rather freq., 47 % in st.q. 3 teachers
Difficult to use different tools, e.g. for functions and graphs.		X	Rather freq., 39 % in st.q.
Sometimes difficult to know how to start solving a problem.		X	Rather freq., 42 % in st.q.
Sometimes you do not know what you are doing, especially using CAS.		X	
Sometimes hard to interpret the answers you get with CAS, e.g. with the solve-command.		X	26 % in st.q.
CAS difficult to handle. The step up from graphing calculators is high.	X		
It is essential that you also practice solving tasks with paper and pencil. You must do both.	X		Frequent in the interviews
When you work with paper and pencil you understand better.	X		
A risk for the less able students that they cannot manage this technology, especially CAS.	X		
A risk for the less able students that they learn less than without technology.	X		Rather freq. in interviews
Technology often brings problems of technical nature, e.g. empty batteries, starting up etc.	X	X	Frequent in interviews

Table 2. Common difficulties with using TI.Nspire technology. Remarks about how frequent the answer is and some results from the questionnaires are given in the comments column.

The teachers generally were quite concerned about the risks with using TI-Nspire 'too much', especially in connection with CAS. Most of them especially claimed that the students must use paper and pencil for writing down solutions to all tasks, and some also said that it was crucial for their understanding of mathematics. It is important with both technology and paper-and-pencil. They also saw risks for the less able or 'weaker' students. One such risk was that these students have too much problems with handling the technology, especially CAS, and another that they get too dependent of the technology in mathematics work (se interviews above). But the teachers could also see advantages with the technology compared to only using paper-and-pencil. These coincided well with what the students claimed (see table 3).

Advantages with TI.Nspire compared to paper-and-pencil work	**Teachers**	**Students**	**Comments**
You work faster, so you reach further in mathematics and you get better knowledge.	X	X	Frequent by students
Nicer and more accurate graphs	X	X	Freq. by both t. and st.
You can make more difficult algebraic calculations.		X	
You can easily try many alternatives, e.g. for a function.		X	
You have usually many alternatives to how to solve a problem.	X	X	
You work more in groups than with p-o-p.		X	
You can focus more on understanding e.g. a graph and less on plotting and drawing it.	X	X	
Better understanding of mathematics with TI-Nspire.	X		
Easier to check answers, which is rarely done with p-o-p.	X	X	Frequent by students

Table 3. Advantages with TI-Nspire compared to paper-and-pencil work. Remarks about how frequent the answer is and some results from the questionnaires are given in the comments column.

Excerpts from interviews with teachers and students:

M1: And if you then are to work with math, you will still have a calculator. You will not sit and calculate in your head a lot of difficult things. So I would still need a calculator. It seems unnecessary not to have calculators.

M2: One sees it in a completely different way when using it [TI-Nspire]. Where is the point of intersection, the slope of the line and so on.? It helps a lot. Which also makes it more fun.

F1: We had geometry quite early, and then it became useful right away. It will be quite different and not what you're used to. It helped a lot.
I: In what way is it easier?
M3: It is more accurate when you draw. You can get the angle without protractor and so on.
F1: The greatest is that you can twist and drag in the figures. You cannot do that on paper. It gives more of understanding.

T1: One advantage with technology is that it is faster. You can more quickly get to what is important in mathematics. If I have to draw something on the board, without technology, it *takes a very long time, and then of course the students are asleep when I do it. Then it's really good with this, one can immediately draw and then you have mathematics.*

T2: I am convinced that it helps students to understand. When I went to school myself, we had slide rules and tables. And it took time to draw graphs. I am confident that our students of today have a much better idea of what it is about, mathematics, derivatives, integrals, etc., because they've seen it so much more.

The classes involved in the project worked with three types of technological equipment: only laptops only handheld units, or the combination of the two. An interesting point here is which advantages that are mentioned by the informants for each of these types (see tables 4, 5 and 6).

Advantages with laptops compared to handheld units.	**Teachers**	**Students**	**Comments**
Larger screen with colour. You see more of what you are doing. User friendly.	X	X	Frequent in interviews.
Easier to work with a whole keyboard	X	X	
You can use the usual key commands for computers.		X	
Easier to edit expressions and text		X	
Easier to find your way in menus	X	X	
Better for handling tns-files	X	X	

Table 4. Advantages with laptops compared to handheld units. Remarks about how frequent the answer is and some results from the questionnaires are given in the comments column.

Excerpts from interviews with teachers and students:

T1: The small display on the handheld does not provide the same opportunities as on a laptop. It becomes too messy on the handheld.

T2: User-friendliness is very much better on the computer software than on the calculator, so it is easier to use. And it's bigger and better with color screen. And a little bit easier also with file management. Users can post files that students can download. It's easier than if you were to send out files with "connect-to-class", with this as an extra task on the calculators.

F: But the graphs are much easier to do on the computer than on the calculator. And finding points of intersection is fast.

Advantages with handheld units compared to laptops.	**Teachers**	**Students**	**Comments**
Faster with handheld when you are doing simpler calculations.		X	Rather freq. by students
Therefore more flexible in other subjects, e.g. physics.	X	X	
Easier with handhelds in test situations.	X	X	
Easier to carry than a laptop.		X	
Therefore less risk forgetting to bring.		X	
It takes more time to start the computers.	X		
More technical problems with computers.	X		
You are not dependent on a network.	X	X	

Table 5. Advantages with handheld units compared to laptops. Remarks about how frequent the answer is and some results from the questionnaires are given in the comments column.

Excerpts from interviews:

M1: It is much more comfortable to sit with a calculator in a test instead of a computer in front of you. And the handheld is very pleasant to work with when you want to get something fast. It is also easier to move around and carry a calculator than a computer.

M2: That's because it's easier to have the calculators [in physics and chemistry]. And there you do not need a large screen. One need only enter a few calculations.

Advantages with having handheld units combined with laptops.	**Teachers**	**Students**	**Comments**
You can choose yourself which is best in each situation if you are used to both.		X	
Handheld units are better to use at tests, but computers in the everyday work.	X		
Handheld units are better for quick calculations, computers for working with graph or solving larger problems	X	X	Rather freq. by students
Easier with transfer of files when you do it yourself.		X	
You are not so dependent on a network.	X	X	

Table 6. Advantages with having handheld units combined with laptops. Remarks about how frequent the answer is and some results from the questionnaires are given in the comments column.

Excerpts from interviews:

F1: When you work with the computer it is easier to find what you want. The hard part is when you are having a test. Then you have the hand unit instead.

M1: Because we have a math book in the computer, it is convenient to have the calculations on the computer. In physics and chemistry, we use the handhald as we have regular books and it is much easier to have the handheld than the computer then.

T: It gets much clearer on the computer with graphs. It has more space to explore in them. For students, despite having the computers, handhelds are many times better. So it's both. They use both continuously.

The students were also asked in the questionnaire if they wanted to keep that configuration of equipment that they had used in the project, or if they had wanted another if they could have chosen themselves. Of those who had been using only laptops, 72 % answered that they only wanted laptops and that handhelds were unnecessary. The rest all wanted a handheld unit to combine with the laptop. The reasons these students gave are essentially the same as those given in table 6. One example:

M: It's good, because a laptop has bigger screen and is in a whole easier to work with. However, it can be a hassle to carry around, especially when you often need a power source, given that our computers have pretty poor battery life.

Of those who only had handheld units, 80 % answered that this is enough and that laptops are unnecessary. Those who also wanted a laptop gave reasons that have also been presented above, like:

M: You can get a little 'locked in' and it is sometimes difficult with the calculator interface.

Those who had both laptop and computer answered unanimously (100 %) that this is what they really want. Reasons were given such as:

F: Nice when you are in class to sit with the computer and later during recess you may use the calculator.

M: What is bad about the calculator is that it is more difficult to handle, such as selecting menus, but the computer may be too large for the school tables. But that is precisely why it's good to be able to choose between computer and handheld, you can adjust the selection to the situation.

Picture 1. Students working with computers and with handheld units.

To make a summary of the opinions of the equipment the students had used: Most of them where satisfied with what they had, and did not want to change. But the combination of laptop and handheld unit protrudes somewhat, in that all the students who had that equipment believed and gave reasons for this being the best.

Using TI-Nspire at the National tests

A crucial point when using laptops in mathematics education is whether these can be used in tests of various types. If they are not allowed, and the students are forced to use calculators at the tests instead, the motivation for working with computer software is bound to be much weaker. Some of the teachers in the project had divided their own tests in two categories: tests with only paper and pencil, and tests with laptops. But the critical problem was that laptops normally are not allowed at the national tests, of which the students in the project had to do at least one. So special permission to use laptops for research purposes was applied for at the Swedish National Agency for Education. Permission was granted on two main conditions: First, any communication between students or through Internet was forbidden, and second, unwanted files that could be used for cheating should not be accessible. Only the software TI-Nspire was allowed for the students to use.

There were several ways that these conditions could have been met by the teachers. For example, it would have been possible to create special ‘test clients' for the students to log into that only contained the software. Or the wireless network could somehow been turned off during the test. Ordinary desktop computers without network could also have been used. Of the six teachers in the project that used laptops at the national tests, five of them solved the problems with the two conditions in the same way. They positioned themselves behind the students, so that they could watch all screens the whole time.

From the teacher questionnaire:

> *T1: Students sat in a large classroom all facing forward. I stood in the back of the classroom so that I could see all the computers. For questions they had to come to me, not I to them, because to the students should not know which way I looked. We can not turn off the wireless network. This interferes with other activities too much.*
>
> *T2: Few students (12), making it easy for me to check that nothing else than the calculator program was used.*

To the question whether any problems appeared, a couple of teachers answered:

> *T1: A student got up Facebook directly when she started the computer. But it was good that I told her. Others realized that I checked.*
>
> *T2: On two occasions I had to correct students. One got up Facebook and another school's website. It was totally unnecessary because they were not allowed to not be on the Internet at all.*
>
> One of the teachers instead applied the method of the closed down network:
>
> *T: We used the computers in both Ma A and Ma B. The school had shut down Internet*

access just for the computers that students used when they wrote the tests. We had no action against the bluetooth, but students did not use this, I am quite sure.
We had to place students with computer to computer and back to back with a larger wooden screen between the computers when they were sitting next to each other.
Students appreciated having them in the test, since CAS is much clearer on the computer than on the hand units.

Most of the teachers simply answered ‘No’ to the question about problems, so the overall result of this point in the study is that it is possible to manage national tests with laptops. And if this is implemented at a larger scale in the Swedish school system, solutions like turning off the Internet during the test or creating special ‘test clients’ for the laptops could be more possible to use.

For those students who had access to handheld units, there were no problems in using the TI-Nspire CAS calculators, since they have been allowed at the national tests since 2007. Of course, also for these, unwanted files that could be used for cheating should not be accessible. But this is easily managed with the special ‘test mode’ that is available, and which is controlled by the teacher.

Changes in working styles and in the ways students interact, cooperate and document their work.

In a ‘normal’ mathematics classroom in Sweden it is not unusual that students work rather alone with his/her tasks. The teacher has a shorter whole-class session in the beginning of the lesson, but after that very little discussion about mathematics is present. Sometimes two students sitting next to each other have some shorter conversation and maybe interaction, but mostly it is the teacher who circulates and gives support to the students in their personal work.

The main change in the way students interacted in this project was that they cooperated more working with TI-Nspire than they had done before. It was more discussions in pairs, in groups, and in whole-class. Many times, spontaneous grouping took place during mathematical activities. Interesting enough, many of these discussions started with practical questions about how TI-Nspire could be used for a particular task or problem and then gradually turned into more mathematical ones concerning methods and concepts. This change was mentioned in many interviews, both with teachers and with students. In the teacher questionnaire, however, only half of the teachers claimed that students’ ways of working with mathematics had changed in a decisive way, and the others that the changes were rather small.

M: I think you work more in groups. Because if I have found on the calculator how to do, it's always someone who asks: "How do you do?". On paper, everyone knows how to do, so then you work alone.

T: They always help each other. I think that is really important in all teaching that they are actually talking to each other and try to help each other, for in the debate student to student, they also learn much. But if they cannot solve it together, they raise their hands.

Another important change was that students’ classroom work tended to be less controlled by the teacher, which gave them more independency. One reason for this was that the teachers were not experts on the technology, so that some of the students after a while knew as much as or more than the teacher of how TI-Nspire functions. Another reason was that the teachers gave more problems and tasks of an exploring nature that often demanded some discussion to fully solve.

I: Is it difficult if the teacher is not an expert on the program?
M: But it is human in some way. Sometimes some student comes and helps her. It feels like we hang out more, we understand her better and she understands us better. Instead of that she is acting as a strict teacher who says "So we do!", and then it's over.

T: Usually it is the students who are having the knowledge of the more practical management. There is always someone in the class who knows, and then knowledge is transmitted through students more often than through me. If anything pops up during the lesson, they most often help out each other.

A third main change was that lessons contained more communication student-student and teacher-student through networks and in other electronic ways. This gave the students additional abilities in the important communication part of 'ICT', which is especially mentioned in the curriculum. And the students used the laptops more directly in the classroom:

T: But I have noticed that there are some that use the TI-Nspire continually in their schoolwork. When I am having a demonstration they take notes like this. And that I did not believe. I thought they still write down on paper. And it is both girls and boys.

For the students of the special school for physically disabled the change was considerable. Without using computers and TI-Nspire, they can read text and tasks in a textbook but usually cannot write by hand, due to problems with their fine motor skills or even to hold a pen. Instead, each student must have a personal assistant that write down what the students tell them, draw graphs etc. For them TI-Nspire opens up fantastic new possibilities where they can calculate, make diagrams and write text, and then save it and/or print it out. These students handed, in fact, in all their solutions to the National tests as tns-files.

Picture 2. Students from the school for physically disabled working with their computers.

One important question is if any particular differences in working styles or in cooperation could be detected between classroom work with laptops and with handheld units. Teachers and students gave rather few examples of differences, but one that mentioned by a few students was that those with handhelds tended to cooperate less than with laptops. Another difference, which could be discerned through the interviews, was that it was harder to transfer files with handhelds, which caused that the classes worked less with ready-made tns-files (constructed by the teacher or available in the 'Inspirerande matematik' material). A third difference mentioned was that it was harder to write text in the handhelds, so the students tended to document their work only on paper.

Changes in teaching practice and obstacles to high-quality teaching

TI-Nspire CAS opens possibilities to make substantial changes in teaching practice. Crucial is the way teachers approach mathematical concepts, use the different representational forms and the methods connected with mathematical activities. But it is also in the ways teachers organise the classroom work and how they handle the technology in general.

In the beginning of the project, most of the teachers were rather unfamiliar with the TI-Nspire software and the handheld units. They were, as mentioned above, also rather new to using CAS in mathematics teaching. In the teacher interview they were asked about in what ways they used the laptops or the handhelds. The alternatives were: for demonstration during reviews, for general discussion in class, for helping students or groups of students. The answers in the teacher interviews varied quite a lot, mainly depending on what skills the individual teacher had, or thought he/she had. Here are some examples:

> *T1: Firstly, during demonstrations, and I give them tips on how to use TI-Nspire. E.g. last fall, I showed how to find points of intersection between the graphs, and it was many steps that must be taken. And now, I showed how to do this here, and so easy it was! They became very delighted over this.*

> *T2: My reviews, of course, and then students can work simultaneously. And it is clear that when you move around in the class and help, you obviously take advantage of the software and show them and try to make them understand how to use it. Group discussions can of course also be very good sometimes, when they are sitting working and are forced to try to explain to each other.*

> *T3: Help to individual students: The advantage of TI-Nspire is that you can easily go back and see exactly what they have done. And it rewrites the expression, making it easier to identify their own errors. Sometimes I bring my own calculator, and sometimes I show on theirs.*

The use of technology for demonstration and review was quite frequent among the answers, as well as help to individuals and groups. The responses to the questionnaire at the end of the project showed that most of the teachers thought that their ways of teaching had changed to some extent (6 out of 8 teachers), while one of them did not think so and one did not know. The general changes they stated was that they used computer and projector more, that they worked more with problem-solving and that they used group work more in their teaching.

The teachers were also asked in the interviews about how they *intended* the students to work with the technology. The alternatives here were: as a calculating aid, as a problem-solving tool, to discover and understand mathematical concepts and methods etc. (*calculating tools*, *teaching tools* and *learning tools*, Balling, 2003). Again, the answers in the interview varied:

T1: Since I am a beginner, then it is the first option, of course. The second one, I am going with, but the third one... I have not got that far myself. But it's something I can imagine doing.

T2: They use it for greater understanding. E.g. now they see the graphs and the different solutions and they see it very fast. They see the different possibilities that exist with it.

T3: It's probably all those things.

But what happens when students have difficulties in handling the technology or the mathematics they encounter there? Do they ask another student, ask the teacher, try to figure it out for themselves etc.? The students generally answer that they ask the teachers, but many also try to get help from other students. But it varies from case to case, depending on the nature of the difficulty.

M1: You check much yourself, and if you can find it then you can ask Mats. Or else there is someone else in the class who have found it.

M2: It takes time when you raise your hand. There are many who need help. Otherwise, just ask your neighbour, because what you yourself have difficulties with your neighbour may not have. You can help each other.

In the teacher interviews, the teachers also explained what happens when many students had similar difficulties:

T: Often you move around the classroom and help students who have difficulties. But if you notice that a task reappears, you take it on the board.

But most of the teachers also told that they wanted the students to help each other, and that it was very positive if they did so. The reasons for this are that it is good for the students to think and try for themselves before they get a sometimes too quick help, and that is important that students talk and discuss mathematics with each other. And some of the students often have acquired good skills in handling the technology.

T1: They always help each other. I think that is really important in all teaching that they are actually talking to each other and try to help each other, because in the debate student to student they learn much. But they cannot solve it together, they raise their hands.

T2: Usually it is the students who have the knowledge of the more practical management. There is always someone in the class who knows, and then knowledge is transmitted through students more often than through me. If anything pops up during the lesson they most often help out each other.

T3: It feels better when they are trying themselves for a while before they ask me, of course. If they ask me directly and I help them, not much has been solved for them actually. They have just been served a solution without having worked the problem. So I prefer that they do not call me directly. And I always encourage cooperation. To discuss the problems together and help each other I see as a great resource in the classroom.

A crucial question in this study was whether the teachers had used the technology intentionally in some ways to make students reflect on mathematics. In the first interviews, some of the teachers explained that the simply had not reached so far yet. They had too little experience of the technology. But some explained that cooperation between students, as mentioned above, is of great importance also for their reflection. And reflection is important for the understanding of mathematics. The teachers were also asked if they had used tns-files that they had constructed themselves in their teaching. Some gave a negative answer, such as:

T: No, this far I have not come yet. But this is the hope for the future. But it's also about time. You must have enough time for everything, prepare, etc. And it takes time to create your own tasks.

The teachers that actually had started making tns-files were asked about their thoughts and intentions with these. A couple of answers:

T1: Yes, I have made some. It's much fun to work with. And it will probably be more and more that you will find things you can do. Then to create a whole problem that can give something can be a bit difficult. It is supposed to be something that increases understanding, because that's always what you're after and what I also believe this is so good at.

T2: Yes. It may be like today that they supposed to focus on problem solving and not burn their energy or get lost in the calculations. You should get a feeling for how things fit together.

These answers show that the teachers who had made their own files already had started to think about how to use TI-Nspire for more than just as a calculating tool, and that they make connections between problem-solving and mathematical understanding.

Progression of instrumental and documentational geneses

Several students explained in the first interview how difficult and complicated TI-Nspire seemed the first time they started it. It contained so many 'things' that they hardly knew where to begin. This was reinforced by the technical problems that aroused in connection with the software installation. One student called it chaotic, and this was the expression one of the teachers used as well. But most of the students also answered that after a short while, when they had got familiar with the software or the handhelds, it did not seem so complicated at all.

M1: It looked very complicated and I thought: This will never work. But then once you got to know it and were clear about what to do, it was not that difficult.

M2: It's a pretty steep learning curve, I think. It's been 1-2 months now and only now you have they really started to get acquainted with everything. In the beginning it was quite chaotic.

M3: There are a lot of functions, and once you have learned them, it becomes quite easy to use. So it's good.

The experiences of the teachers are similar, even if one teacher says that there were no real problems in the beginning.

T1: A circus! Really hard! It took a few lessons before we got it to work for everyone.

T2: I find this software very easy to get started with. There is of course much that is difficult, but there is no high threshold. And for young people who are familiar with computer programs, this is nothing strange at all. They are up and running quickly.

The teachers had different strategies to minimise the problems, such as taking small steps, showing procedures step-by-step, making, making 'cheat sheets' etc.

T1: Then you have to start with tasks with not too many technical steps, for them to get started. But then they learn more themselves, and they know such things that I don't much faster. We took 10 minutes each lesson and had some thing like this that you could show.

T2: I showed on my computer and then everyone had to do likewise. It took quite some time. I have since self-made crib sheets for the functions they need to use much. What they are supposed to do step by step.

During the project, the students' versatility in the use of TI-Nspire has progressed substantially. Many of the difficulties they saw in the beginning have disappeared, even if there still are a few students who have rather great problems with the use of the software or the handhelds. In the teachers questionnaire 6 out of 8 teachers answer that some students have remaining difficulties with the use of TI-Nspire, but also that most students have made progress in their way to work with it. Five teachers also answer that some students like to explore TI-Nspire in order to find new functions, and that these often share what they find out with other students and sometimes also with the teacher.

T: But then there are some students who understand a little quicker and can show the others. So suddenly you have a whole staff that helps. And it's lucky that you have that.

The ways that students documented their work with tasks and problems showed very little progress during the project. To some degree this was due to the fact the teachers rarely used the possibilities to work with files with many pages or pictures, and that the students did not use the notes in TI-Nspire to document, with the exception of one class where it was rather common. This was also the notation from the observation of a lesson with that particular class.

I: Are you familiar with problems where you have multiple pages you switch between?
F / M: Yes.
I: And also where you respond by sending in the tns files?
F / M: Yes.

The students were, however, generally saved their work as tns-files. They used these mostly to go back and see how they had solved a task or a problem when a similar one came. But some exceptions existed:

M: When I saved, I got one document, not all the tabs.

Were there then any differences between environments with and without handheld units? One such difference was that it was much more difficult to work with text using the handhelds. The display is also rather small and so is the keyboard. This makes it difficult to acquire any higher speed in the work with more complicated problems.

T: It is sometimes a little bit small in the display and the keypad is a bit difficult to work with. But there will of course come new calculators soon. But it feels a little frustrating that it should be the stumbling block when one wants to investigate something. There, the computer version is much, much better.

Many of the students still used their calculators in physics and chemistry, while they used laptops in mathematics. And individual students had sometimes special way of checking solutions:

I: I watched an interesting thing today when students worked with the task you gave. One student did the task on the computer, but then when he wanted to check it, he picked up the calculator and made it there.
N: That I did not see.
I: Can it be due to inexperience with the TI-Nspire?
N: Exactly. The calculator, they know.

Skills in using TI-Nspire technology for problem-solving and in exploring tasks

As mentioned earlier in the report, problems-solving tasks and especially exploring tasks were not among the types that many of the teachers started with. CAS was also a bit of an obstacle for those who had little or no experience in using it in instruction. One teacher explained:

T: Now I will introduce the CAS, so now I'm more worried about how they will receive this. Those who use this are usually the 'wrong' students. I fear that those who have not thought through the math will also be those who go along with just testing: This is right and this is wrong. But those who really have embraced the mathematics, they may not even bother to try, because they know it will be right. So it is the 'wrong' students that are using this technology.

But other teachers were already confident that the students would manage:

T1: They already invent their own methods to check things out. They have found the true-false function to check if expressions are equal. I have not taught them this. We see that they are a bit faster at detecting patterns, too.

T2: The more they learn the technology and the freer they become. And there's always a bunch which are doing the other way, with trial and error, and it does not work so well in the long run. But you must work really hard on it so that they get it as their tool.

With the problem-solving experiment near the end of the project, students' general skills in using the software or the handheld units were put to a test. The problems that the students were presented to were constructed with three levels: First involving ordinary calculations and/or readings of graphs, then some more complicated calculations with comparing different answers and making decisions, and last an exploring task where the students had to write answers in plain text.

The problem suited for Matematik A (see appendix F) was solved by two of the classes. It was called "Holiday cabin" and described three holiday companies with different fee policies. The students were first to calculate the fee for some given time-length, then they were asked to represent the fee policies with functions and graphs, and last they should sort out which company had the least fee for all possible time-lengths of staying in the cabin.

The problem for Matematik B (see appendix G) was solved by six classes. It was called "Intersection points" and was based on two functions, one quadratic and one linear that intersected each other ($f_1(x) = x^2 + 1$ and $f_2(x) = 2x + 4$). First the students were asked to read and note the points of intersection, also in the case when the linear function was moved so that there was no intersection. Then they had to find out with which constant term in the linear function (instead of 4) you get two, one or no intersections. After that they were asked to solve a non-linear system of equations that in reality exactly reflected the graphs in the first part (the students were supposed to discover this). Then a parameter *m* was introduced in the linear function for the constant term, and they were asked to solve the system again and explained why this general solution created two, one or no solutions for the system: $\begin{cases} x^2 - y = -1 \\ 2x - y = -m \end{cases}$, with the solutions $\begin{cases} x = -\sqrt{m} + 1 \\ y = m - 2\sqrt{m} + 2 \end{cases}$ or $\begin{cases} x = \sqrt{m} + 1 \\ y = m + 2\sqrt{m} + 2 \end{cases}$

The students then were asked to reflect on the two solutions and explain why they created the different types of solutions for varying values of *m*.

The observation of the classes showed that they handled TI-Nspire in a mainly satisfying way. Their problem-solving skills with TI-Nspire were good, with only a few exceptions. Many also managed to give good answers to the more difficult parts of the problems. The methods they used in the solving process varied. Some worked more with algebraic methods, others more with graphic solutions. For example, some students demonstrated that they can manipulate graphs by dragging them up and down. Others instead worked with the equations for the functions and made changes in them, either in the entry line or in the formula inside the diagram.

The students were given the problem directly through tns-files and were asked to write all their solutions in the file and return it afterwards. These files were then collected by the teacher and later given to the researcher. These files can be analysed mathematically in detail, but that will not be done within this report. Writing text within TI-Nspire seemed however to cause some problem for many students. They were generally not used to writing text in the system, and especially was it the case for students who used handheld units. When asked about this, they explained that it was hard for them to write, because the keyboard was small, it did not contain Swedish letters like å, ä and ö (they had not discovered that they easily could reach these letters quite like the way they do at their cell phones). There was, as has been mentioned before, one exception. In one of the classes, this method of distributing tasks and for the students to hand in their solutions writing text was common in the daily classroom work. For this class, which used laptops, text represented no obstacle.

The problem for Matematik A did not demand much use of CAS, but the one for Matematik B really did so. For most students, solving equation systems with CAS presented no problem, even if they used different ways to enter the system (probably due to the ways the teachers had instructed). But some students had certain difficulties, and had to ask for some help. They also thought that the solution they got to the equation system with the parameter was ‘weird’ and therefore probably wrong. Some point of views that were given in the focus group:

Matematik A:

M1: It was things that we've done before.
M2: Things that we knew, nothing particularly new.
I: Was the software good for working with such a task?
M2: I think CAS is great for this kind of tasks.

F: The first two questions were not so difficult, but the third one was pretty tricky. But we have had similar questions.
I: It felt as if you were a little inexperienced at reading the intersections.
F / M: Mm.

Matematik B:

F1: It was pretty similar to what we usually get in math books.
F2: And sometimes we get ... and we will work in pairs. And you probably get one of those sent to the calculator.

F: We have not used this ‘solve’ in systems of equations before, but we have made it algebraically by hand.

F: The exercise was not so difficult in itself, but we do not usually do such exercises.
I: Mention something specific that was an obstacle for you!
F: Exercise 6, the penultimate. That kind of task we have not had. Like having an m besides x and y.

Effects on students’ development of deeper understanding

An important question, and at the same time difficult to answer, is whether the students developed a deeper understanding of concepts and methods in mathematics. The teachers were specifically asked this in the questionnaire by the end of the project. All 8 of them (100%) answered that the students more easily use TI-Nspire to illustrate mathematical objects and to examine them thoroughly. Six teachers say that it gives more opportunities within problem-solving and that the students can manage more difficult tasks. But only 3 teachers definitely claim that the students seem to build a deeper understanding for mathematics with TI-Nspire. One reason for this point of view, which more than one teacher gave, is that deeper understanding always involves the use of paper and pencil. You can calculate and explore with the technology, but you need to transfer the results outside of it to really understand. All students do not document the solutions they make with TI-Nspire on paper, so the technology could even make harm to their understanding. And the teacher must check that all students really get the knowledge they are supposed to, and that is impossible if they do not record their work on paper. One teacher also says that students should not do *everything* with the calculators.

In the interviews, the teachers were generally positive, but also cautioned for some risks that they saw. Some point of views:

T1: We have worked a lot also with the students to take on the mathematical language, and there I find that the calculators support. I do not see the risks, but you have to work consistently with algebra also so that you get the craft.

T2: I fear that students who has trouble keeping up with the others too easily use the calculator to get it right what he did, without really thinking through the task itself. I fear that they will enter 'solve' and so see what happens. Then you do not get this struggling as you get when sitting with pencil and paper.

T2: There is a risk that students do not write down what they did and that their learning therefore suffers.

I: But do you see any risks?
T3: Yes, if the teacher relies too much on it and lets it go on. That you do not have an eye on that the students really learn.

Some students claimed in the questionnaire that TI-Nspire has had a positive effect on their understanding:

M1: A very useful tool that has given me a better understanding of how e.g. quadratic graphs look and work.

M2: You have learned to understand a little more in mathematics, and you begin to understand how certain things are made up!

In the focus groups, the opinions of TI-Nspire also were generally positive, including the ways the teacher handles it:

F/M: He sees on us if we do not understand. He is particular about that we understand everything.

F: It's faster. You see the big picture very quickly, and you have time to learn much more.
M: It feels as if we solve a lot more difficult tasks.

F: Indirectly it impacts understanding that we've have time to do more.

M: The 'solve' function is wonderful. We understand the calculations, but with this function it unnecessary to do all parts.

But there were also thoughts about possible negative effects:

M: But sometimes it feels as if you lose the problem solving. You only work on the calculator and you do not think about how you could have solved it in a different way.

F: Though one can get a little lazy. If you only use the TI-Nspire you might forget how to do it by hand. And this may well be very negative.

Students' motivation, interest and self-confidence

The positive effects of using technology in mathematics education have been reported in many studies (cf. Persson, 2010). Teachers and students were asked about these effects, both in the interviews and in the questionnaires. Especially the attitudes to TI-Nspire were interesting in this project. One crucial point was the introduction and implementation of the software or handheld units. Some teachers' voices:

T1: In the beginning, many became negative or semi-negative, because it takes time and that they had trouble getting it to work. And then there are of course skeptical people.

T2: It has been more positive than negative. They expect, when they start on the NV, that they shall get good mathematical tools. But this has worked more smoothly than a calculator would have done. And much prettier. Experiences of insight have occurred, such when we worked with data statistics. This they also think has been very 'tasty', aesthetically pleasing.

T3: Some positive and some negative. They are e.g. one student asked how long this project should last, because she had not yet come into the software properly.

T4: It has not been a problem. This is indeed a very fun class. They are most talkative about the subject itself, about what they should.

In the teacher questionnaire, 6 of the 8 teachers answer that the students seem to think that mathematics is more fun when they can use TI-Nspire. But some also say that students' opinions of the software vary highly from person to person. In the questionnaire, 34 % of the students answer specifically that mathematics is fun when you can solve more difficult problems, e.g. with the solve-command. An example of how they explain this:

M: TI-Nspire has been very good and has helped a lot in mathematics. This has made it more fun, and you feel good.

In the discussions in the focus groups, students gave several interesting views, such as:

M1: Not interesting, but smoother. The math does not change. Two times two is not fun when doing it on your computer.

M2: A huge boost. It became more fun with math and we learned more and got more out of it.

M3: One sees it in a completely different way when using it. It helps a lot. Which also makes it more fun.

M4: I think it's an incredible help to look at the graphs and do calculations with functions. I would like to continue to work with TI-Nspire later.

F: Yes, you can do much more.
I: Does this also make it more interesting?
M1: One can do more advanced tasks.
M2: You feel more sure, too.

M3: What I noticed when we switched to the Texas book and calculator was that we help each other a lot more in class. Before you sat with the book and worked for yourself.

As expected, most students think that it is more fun with mathematics with TI-Nspire, because mathematics appears in a new way, it gives you more power and it is appealing to work with. This affects their beliefs about mathematics and mathematical activities, and the also believe that TI-Nspire has a positive effect on their mathematical knowledge and ability. The usefulness of technology in the future was also commented by both teachers and students:

T: Once the students have finished school and have started to work, then they will have their resources, and why not teach them to use them from the beginning? Then the national tests sholud be constructed from this point of view. One should have a national test which actually benefit from the new technology with CAS, and can use it in a good way.

M: And if you later is to work with math, then you still will have a calculator. We will not sit and calculate in the head a lot of difficult things. So I would still need a calculator. It seems unnecessary not to have calculators.

Summary and conclusion

This study is based on a number of research questions concerning the participating teachers' and students' experience of and development in using TI-Nspire technology. TI-Nspire was used in three different configurations by the students: only on laptops, only on handheld units and on a combination of the two. Of special interest was if there were any significant differences between these three settings and in particular which advantages that could be discerned with the "double solution", that is students using the combination of laptops and handhelds.

This summary has been given principally the same designations as the research questions:

A. Students/learners

1. **a.** Students expressed a number of common advantages with the TI-Nspire technology in general. Among these were more physical ones, like a good screen and fast and flexible to work with. But more important are the mathematical ones, e.g. easier to work with functions and other areas of mathematics, new ways to work with problem-solving, managing more difficult tasks etc., and the conceptual ones, like learning more mathematics, understanding it better and possibilities to focus on understanding.

b. Among the risks and difficulties with TI-Nspire were that it is difficult to start with and that it takes some time to learn how to use. However, after that first 'break-in' period, most students thought it was fairly easy to use. Special difficulties were mentioned in connection with CAS, i.e. that it is hard to handle and to understand the answers, and that you sometimes do not know what you are doing.

c. Some advantages with TI.Nspire compared to paper-and-pencil work were also mentioned. You work faster, so you reach further in mathematics and you get better knowledge. It is easier to work with graphs, to do more difficult algebraic calculations and to try many alternatives. Checking answers to tasks is also more frequent, and the understanding of mathematics is promoted when you do not have to focus on simple calculations or plotting graphs.

d. Advantages with laptops compared to handheld units that were mentioned were: a larger screen with colour so you see more of what you are doing, easier to work with ha whole keyboard, more user friendly, easier to edit and finding your way in menus, easier to handle files etc.

e. Advantages with handheld units compared to laptops were e.g. faster with handheld when you are doing simpler calculations and therefore more flexible in other subjects as physics, easier to handle in test situations, easier to carry than a laptop and therefore less risk forgetting, and that you are not dependent of a network.

f. Advantages with having handheld units combined with laptops were that you can choose yourself which one is the best in each situation if you are used to both. Handheld units are better for quick calculations, computers for working with graph or solving larger problems. It is also easier to transfer files when you have access to the whole system, and you are not so dependent on a network that might not function so well.

2. **a.** The main change in the way students interacted in this project was that they cooperated much more working with TI-Nspire than they had done before. Another important change was that students' classroom work tended to be less controlled by the teacher, which gave them more independency. A third main change was that lessons contained more communication student-student and teacher-student through networks and in other electronic ways. For the students of the special school for physiologically disabled the change was considerable, in that they could work with mathematics much more independent of special help than before.

b. Among differences in working styles or in cooperation between classroom work with laptops and with handheld units are that those with handhelds tended to cooperate less than with laptops, that it was harder to transfer files with handhelds, and that it was harder to write text in the handhelds, so the students documented their work only on paper.

3. The effects on classroom discourse when working within the three types of environment was not easy to detect in this project setting. But both students and teachers told that they talked more mathematics in the classroom, and that this to some degree was provoked by discussions about how to handle the technology, both with ordinary tasks and in problem-solving.

B. Teachers/educators

4. **a.** There was a high correlation between the benefits and special values of the three types of TI-Nspire environments that the teachers and the students mentioned. This is important for the decisions to start using this technology in mathematics at schools and in classrooms. The students' opinions are important if such implementation is to be successful. One main difference, though, is that students generally mentioned more advantages than the teachers, and likewise, the teachers mentioned more risks. Among such risks were that you understand less with technology than you do when you work with paper-and-pencil, and that the less able students learn less than without technology, because they cannot manage this technology, especially CAS.

b. Advantages with handheld units compared to laptops, which teachers mentioned in addition to the ones the students gave, were e.g. that it takes more time to start the computers and that there are more technical problems in connection with these. Handheld units are also better to use at tests, compared to computers in the everyday work. Most of the teachers believed that a combination of handheld units and laptops is the ideal situation in the total classroom work.

c. At the national tests laptops were used without any larger problems. The method used by all the teachers was to position them during the test so that it was possible for them to watch all the students' laptop screens. This particular experiment was successful, but also showed that more technical solutions are not chosen at first hand.

5. **a.** Most of the teachers stated that their ways of teaching had changed to some extent. The general changes they stated were that they used computer and projector more, that they worked more with problem-solving and that they used group work more in their teaching. The ways they intended the students to work with the technology, as a calculating aid, as a problem-solving tool, to discover and understand mathematical concepts and methods etc., varied to some extent but their explicit goal was all of these alternatives.

b. Among common obstacles to high-quality teaching were that students could have difficulties in handling the technology or the mathematics they encounter there. Most of the teachers told that they wanted the students to help each other, because it is good for the students to think and try for themselves before they get a sometimes too quick help, and that it is important that students talk and discuss mathematics with each other.

6. Not so many examples of how the teachers had used the possibilities of the technology intentionally to promote student reflection on mathematical methods and concepts could be seen in the project. For example, most of the teachers did not construct their own tns-files for such a purpose. However, some explained that the cooperation between students is of great importance also for reflection, and reflection is important for the understanding of mathematics.

C. Cognitive and affective learning outcomes

5. With the problem-solving experiment near the end of the project, students' general skills in using the software or the handheld units were put to a test. The observation of the classes showed that they handled TI-Nspire in a satisfying way. Their problem-solving skills with TI-Nspire were good, with only a few exceptions. Many also managed to give qualitatively good answers to the more difficult parts of the problems. But the students were generally not used to writing text in the system, and especially was it the case for those who used handheld units.
6. **a**. Several students explained in the first interview how difficult and complicated TI.Nspire seemed the first time they started it. But most of the students also answered that after a short while, when they had got familiar with the software or the handhelds, it did not seem so complicated at all, and this was also the observation by the teachers. The students' versatility in the use of TI-Nspire progressed substantially during the project, and by the end of it many of the difficulties they saw in the beginning had disappeared, even if a few students still had some problems with the use of the software or the handhelds.

   b. The ways in which students documented their work with tasks and problems showed very little progress during the project. Most of them used paper and pencil to document, which also was what the majority of the teachers wanted them to do. But two of the classes, using laptops, were exceptions, in that they were used to the teacher giving them tasks as tns-files which they were to return with their solutions written in. A clear example of differences between environments with and without handheld units in documenting is that it is more difficult to work with text using the handhelds. The display is rather small and so is the keyboard. This makes it difficult to acquire any higher speed in the work with more complicated problems.
7. All of the teachers answered that the students more easily use TI-Nspire to illustrate mathematical objects and to examine them thoroughly. Six teachers said that it gives more opportunities within problem-solving and that the students can manage more difficult tasks. But only three teachers definitely claim that the students seem to build a deeper understanding for mathematics with TI-Nspire. A reason for this, that teachers indicated, is that deeper understanding always involves the use of paper and pencil. They believed that you can calculate and explore with the technology, but you need to transfer the results outside of it to really understand.
8. A majority of the teachers answers that the students seem to believe that mathematics is more fun when they can use TI-Nspire. But some also claim that students' opinions of the software vary highly from person to person. However, most of the students claim that it is more fun with mathematics with TI-Nspire, because mathematics appears in a new way, it gives you more power and it is appealing to work with. This affects their beliefs about mathematics and mathematical activities, and they also see TI-Nspire as having a positive effect on their mathematical knowledge and ability. The usefulness of technology in the future was also commented by both teachers and students.

This research project, with all the different methods used, has created a lot of data. Some parts of the data point in somewhat different directions, but this is to be expected when you make research involving people. Humans are individuals, with different beliefs, interests and goals.

These can create obstacles when new technology is introduced, especially in a special subject like mathematics, where the beliefs about what counts as proper activities and methods are deep. And that goes for both teachers and students, as well as parents, headmasters and others in society, whose opinions do not show in this study.

Some interesting and important conclusions have been possible to draw, particularly of the benefits and difficulties of using laptops, with or without handheld units. These conclusions involve sometimes rather superficial things like appearance and size of the screen or similarity with computers, but in the classroom situation, in modern society, such things could also be essential for students' attitudes and how they understand the benefits technology can offer. Efforts to create an overall technical solution in the classroom, in which various technological applications can be used, points in the long run towards laptops being introduced in such a way that each student has a separate unit that he she disposes all the time. The question that arises is whether the hand units are needed at all? But students and teachers in the study also stated for mathematics education crucial things like the importance of problem solving and exploration and development of deeper understanding of mathematical concepts and methods. Perhaps the hand units have an important place here?

In this study, the three different technological combinations have appeared as the platform for the, as mentioned above, versatile TI-Nspire technology. Students and teachers have used this in regular education for a whole semester, and during this long time period have been able to utilize almost all aspects of it that Artigues and Bardini (2009) mention. The results from this study largely confirm their observations on the difficulties and the great efforts that meet students and teachers when they start using the technology. They also mention the substantial individual differences in how the instrumental genesis progresses. Some individuals benefit quickly from the technology, others will take a very long time. This is also described by Weigand and Bichler (2009), and the results of this study show good compliance with their observations. They formulate some important research questions (see above) which they would like answers to. Unfortunately, it was not possible in this study to answer them all, even if some light has been shed on some of them. For example, the findings suggest that there is a correlation between the uncertainty of dealing with the technical part of the unit and lack of knowledge about how to use it for the present problem. However, it seems that such deficiencies can be quickly removed for many students, if opportunities for collaboration in the classroom are given and if the teacher encourages students to support each other around the use of technology.

Teachers and students in the study showed significant progress in the instrumental genesis and also to some extent the documental one. But here a much more complicated process is required, and the results suggest that this may take a long time, maybe several years. It is difficult to insert technology as an organic part of the resources of a "document" (Guedet & Trouche, 2009) which represent whole work sessions or lessons in mathematics. However, even here a certain development was observed, and there were signs of a continuation of the process involving the TI-Nspire for both teachers and students, now at a higher level.

In the interviews and in the observation sessions it was apparent what a great role the affective factors played. A large majority of the students testified about the positive impact of the use of technology on their view of mathematics and of what mathematical activities would include. This raised to a great extent their interest in the subject and gave them greater self-confidence towards mathematics. But there was also a small minority who were negative from the start, and some maintained this attitude throughout the project. The interpretation of their reasons for this is that they carry with them a strong conception of mathematics learning which is difficult to shake, and that adds a barrier for both their instrumental genesis and their willingness to embrace technology in general. One of the questions Weigand and Bichler (2009) asked was whether there are ways to get all students convinced about the benefits of technology, and the answer to that question is that there probably exist no such ways, at least not in the relatively short term. Some students may only be persuaded to getting used to the technology, not to immediately like it. The study also confirms the teachers' major role in the process. Their beliefs and attitudes are reflected in the students' to a large extent, and this can be both an advantage and a hindrance in terms of students' attitudes toward technology (cf. Brown et al, 2007; Pierce & Ball, 2009).

Perhaps the most important results of this study are how TI-Nspire on laptop computers, laptops, has been used in regular education in upper secondary courses. The various obstacles and risks of this type of technology have been identified, and teachers' approaches to them have been reported. But above all, the various possibilities (see Artigues & Bardini, 2009), of technical, mathematical and conceptual nature, had the opportunity to appear in this relatively long study. It is interesting how the students' and teachers' experiences and opinions are consistent in this respect (see summary above). It is much about speed and accuracy as well as the wideness of forms of representation that technology offers. It is also agreed that CAS represents a difficulty, especially for low-performing students, and simultaneously has an incredibly powerful potential in mathematics teaching. This potential only a few students are able to take full advantage of, even though most of them can use CAS in a basically satisfactory way. Experiences from the use in the national tests were also positive. The barriers that existed for the use of laptops could be effectively eliminated, and this shows that it is possible to perform one of the sections of each national test with laptops as aids.

Special attention has been given in the study to whether the combination of hand unit and computer has something extra to add to education. According to the results, there are several reasons for considering this technical solution. The hand units are better in certain situations, for quick calculations, for tests and in other subjects. They are also easier to bring and are not as technically vulnerable. The computers are better for working with graphs or to solve larger problems, and to document them. On them you can also combine the TI-Nspire with for example word-processing programs or other applications. In whole, it is also easier to upload or transfer files when you have access to the entire system, and you are not so dependent on a network that might not function so well. These characteristics of the different technological environments have, to the author's knowledge, not been investigated previously in a realistic situation such as in this study. On the whole there are relatively few reported results of research on technological platforms as laptops in mathematics teaching, and this study can make an important contribution to the understanding of the terms of such use.

The teachers were finally in the questionnaire asked if they thought that participation in this research project had been developing for them in their teaching. Five of them answered that it was to some parts, and three that it was in many ways. Some of their comments were:

> *T1: New teaching roads have been opened and I am interested to continue working with the software.*

> *T2: It has developed me a lot, especially within data and statistics.*

> *T3: Has been fun to see what is possible to do with the new technology. When my own*

knowledge and practice is better, I will benefit greatly from having seen all the possibilities.

Afterword

In this study the first main purpose has been evaluating and researching the use of technology that has been produced by Texas Instruments, and for this purpose it has been financed by this company in cooperation with Malmö University. Texas Instruments has, for obvious reasons, had some requests regarding the research questions posed. But the right to formulate them, the methods used and implementation of these has been the researcher's. It is obviously of fundamental importance in assessing the value of the study that this could be implemented with full scientific freedom, both during the research process and later in the different forms of reporting made from the results. In this study, Texas Instruments Guidelines for Research (Guidelines for research - policies for independence and integrity of research, 2010), based on the ethical foundations of the American Educational Research Association, have been observed in all respects.

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Appendix A: Lärarintervju 1

Lärare:____ Datum:____________

Bakgrund

1. Hur länge ha du undervisat i matematik på gymnasiet, och inom vilka program har du huvudsakligen arbetat?

2. Vilka erfarenheter har du av att använda räknare och/eller datorprogramvara i matematikundervisningen? Vilka räknare/vilken programvara har du använt?

3. Vilken utbildning har du fått i att använda räknare och datorer i undervisningen (lärarutbildning och olika typer av fortbildning)?

Uppfattningar

4. Hur ser du generellt på användning av olika former av teknologi i matematikundervisningen? Är det några skillnader på räknare och datorer?

5. Vilka för- och nackdelar kan du se med att fortlöpande använda räknare/datorer jämfört med att huvudsakligen arbeta med papper och penna?

6. Ser du speciellt några risker med att använda teknologiska hjälpmedel, när det gäller elevers förståelse för matematik och för deras räknefärdigheter utan dessa hjälpmedel?

Användning i undervisningen

7. På vilka sätt utnyttjar du själv räknarna/datorerna när du undervisar i matematik?
(för demonstration vid genomgång, för allmän diskussion i klassen vid problemlösning, när du hjälper enskilda elever eller grupper, etc.)

8. Hur avser du att eleverna ska använda teknologin i matematikarbetet?
(som räknehjälpmedel, som problemlösningsverktyg, för att upptäcka och förstå matematiska begrepp och metoder, etc.)

9. Använder eleverna i allmänhet teknologin på de sätt som du önskar att de ska? Om inte, kan du se några orsaker till detta?

10. Använder du egenkonstruerade uppgifter och problem? Vilka tankar har du i så fall kring räknarnas/datorernas roll vid problemlösandet när du konstruerat dem?

Introduktion och implementering

11. Beskriv hur du gick tillväga när du introducerade räknarna/programvaran för eleverna.

12. Vilka specifika problem stötte du på i samband med introduktionen och implementeringen? Hur löste du i så fall dem?

13. Har du sedan stött på flera problem, och hur har dessa i så fall lösts?

14. Beskriv hur elevernas reaktioner varit vid introduktionen och även senare i undervisningen.

15. Hur får eleverna hjälp när de inte riktigt vet hur de ska hantera räknaren/programmet? (frågar grannen, får din enskilda hjälp, du tar upp problemet med hela klassen, eleven får själv klara ut problemet, etc.)

Appendix B: Elevintervju

Lärare:_________________________________ Datum:____________

Grupp/klass:__________________ M/K: ____________

Bakgrund och uppfattningar

1. Vad tycker du om matte?
   (roligt/tråkigt, svårt/lätt, onödigt/användbart)

2. Hur van är du vid att använda räknare/datorer i matten? Tycker du att det är svårt att hantera dem?

3. Vad är bra och vad är dåligt med att använda räknare/datorer i matematiken? Försök säga något av båda delarna.

Introduktion och implementering

4. Vad tycker du nu om TI-Nspire-räknarna/TI-Nspire-programmet?
   (bra/dåligt, svårt/lätt, intressant/ointressant, användbart/mindre använvändbart)

5. Var det svårt att börja använda räknaren/programmet? Beskriv någon svårighet du stött på.

6. Hur får du hjälp när du inte riktigt vet hur du ska använda teknologin?
   (försöker själv till det går, frågar kompis, frågar läraren, läser i instruktionsbok, etc.)

Användning i undervisningen

7. Hur är det att använda räknaren/programmet i matematiken, jämfört med tidigare? Försök beskriva skillnader så noga du kan.
   (Är det roligare, lättare, blir du mer intresserad, klarar du svårare uppgifter?)

8. Finns det speciella skillnader mellan att använda räknare och att använda dator? Beskriv så noga du kan. Är det bra att ha båda tillgängliga, och att välja vilken du vill använda i olika situationer?

9. Blir det några skillnader i hur du samarbetar med kompisar när ni arbetar med matematik? Beskriv hur.

Appendix C: Fokusgrupp

Lärare:___________________________________ Datum:_____________

Grupp/klass:___________________ Antal M/K: _____________

1. Jag vill först fråga er om övningen som jag lät er göra.
   - Var den svår tycker ni? Och var den långt från vad ni är vana vid i matematiken?
   - Nämn något särskilt som ni kanske hängde upp er på.
   - Tyckte ni att ni lärde er något av den? Vad i så fall?
   - Andra kommentarer ni vill göra?

2. Sedan vill jag fråga er om räknarna/datorprogrammet.
   - De ligger ju långt från vad ni kunnat använda i matematiken tidigare. Har det varit svårt att lära sig att använda dem?
   - Nämn några konkreta problem ni haft med dem.
   - Hur har ni kunnat kommunicera mellan er själva och med läraren? Hur överför ni tns-filer? Och brukar ni lämna in lösningar till uppgifter via tns-filer till läraren?
   - Övrigt om räknarna/mjukvaran?

3. Till sist vill jag gärna veta hur ni tycker att användningen av TI-Nspire har påverkat era mattekunskaper och er inställning till matte.
   - Tycker ni matematik som ämne blivit roligare och intressantare när ni kan arbeta med TI-Nspire?
   - Beskriv på vilket sätt det i så fall blivit roligare/intressantare. Berätta gärna om någon händelse ni minns.
   - Har användningen av TI-Nspire hjälpt er att förstå matematik på ett bättre sätt? Hur?
   - Är det någon skillnad när läraren ska gå igenom något nytt? På vad sätt då?
   - Har era mattekunskaper blivit bättre än de skulle varit utan TI-Nspire? Förklara varför/varför inte ni tror så.

4. Nu har ni chansen att lämna ytterligare kommentarer om TI-Nspire och matteundervisningen. Var så goda!

Appendix D: Observation av lektion

Lärare:____ Datum:______________

Lektionens disposition:

Användningssätt av teknologin:

Kommunikation i klassrummet:

Svårigheter med materialet eller teknologin:

Motivation, intresse etc.

Uppnående av lektionsmålen:

Övrigt:

Appendix E: Observation av experiment

Lärare: ________________________________ Datum:____________

Grupp/klass:_________ Antal elever : _________ Uppgift: ____________________

Plattform: ____

Igångsättning:

Samarbete:

Ihärdighet:

Lösningar:

Affektion:

Övrigt:

Appendix F: SEMESTERSTUGAN

I denna övning ska du skriva in alla svar på anteckningssidan 1.2.
Du kan använda grafsidan (1.3) för att rita grafer för de olika alternativen, och du kan utnyttja räknarssidan (1.4) för att göra de beräkningnar du behöver.
När du är klar med övningen ska du spara den och sedan överföra den till din lärare.

Tre semesteralternativ:
Familjen Sommarhage har tänkt sig att hyra en semesterstuga för några dagar. De har inte riktigt bestämt sig för hur många, utan funderar på olika tidslängder mellan en enda dag och två veckor. För att priset de måste betala ska passa med semesterkassan tar de reda på vilka prissättningar tre stycken stugbyar har.
- ”Stugbyar AB” tar ut en grundavgift på 1250 kr och ytterligare 100 kr per dygn.
- ”Semestersol” tar ingen grundavgift, men har en lite högre dygnskostad på 250 kr.
- ”Strandängen” tar betalt per hel vecka, oavsett hur många dagar man stannar under veckan.
Priset för första veckan är 1500 kr, men man kan bo kvar ytterligare en hel vecka mot ett tillägg på 950 kr och därefter 950 kr per påbörjad vecka.

1. För att jämföra priset för olika hyrtider, vill familjen beräkna kostnaden för att bo på de olika ställena under tre olika tidslängder:
- en ”långhelg” på 3 dagar
- en hel vecka
- under 10 dagar
Hjälp familjen Sommarhage med att göra dessa beräkningar! Om de vill ha det billigaste alternativet, vilket ska de då välja för var och en av de tre tidslängderna?
SVAR:

2. Ett sätt att beskriva hyreskostnaden för de tre alternativen är att ange en formel för sambandet mellan hyreskostnaden, y kr, och antalet dygn x man hyr stugan.
Ställ upp sådana formler för alternativen ”Stugbyar AB” och ”Semestersol”! Varför är det svårare att hitta ett sådant samband för ”Strandängen”?
SVAR:

3. För att jämföra hyreskostnaden för de olika stugorna kan man rita grafer för de olika alternativen. Gör detta! Eftersom familjen Sommarhage inte vet hur lång semester de tänker ha, ska man kunna avläsa hyreskostnaden för alla tidslängder från 1 dygn upp till 20 dygn i ditt diagram.
Använd diagrammet för att hjälpa familjen Sommarhage att besvara följande frågor:
a. Efter hur många dygn blir det billigare att hyra en stuga hor ”Stugbyar AB” än hos ”Semestersol”?
SVAR:
b. Hur många dygn måste man hyra för att alternativet ”Strandängen” ska vara billigast?
SVAR:
c. När är alternativet ”Semestersol” billigast? Ange antal dygn.
SVAR:

Appendix G: Skärningspunkter

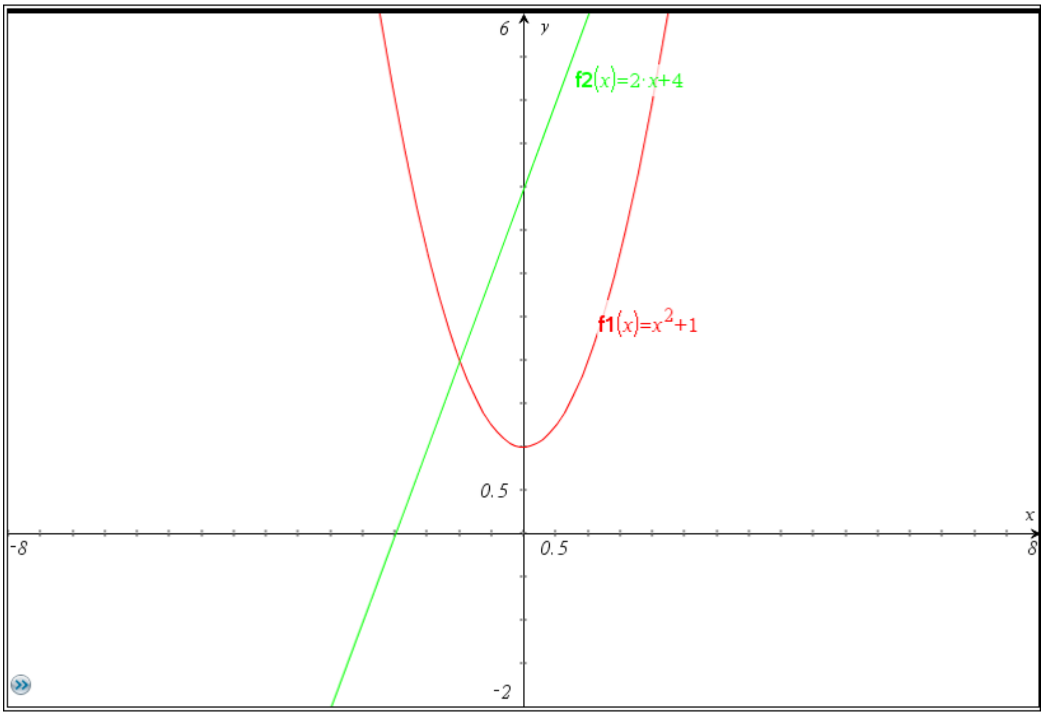
1.1 SKÄRNINGSPUNKTER OCH EKVATIONSSYSTEM
I denna övning ska du lämna alla svar på de två anteckningssidorna 1.2 och 1.4.
Undersökningar av grafer och beräkningar gör du på grafsidan 1.3 och räknarsidan 1.5.
Spara din fil med ditt namn som tillägg och överför den till din lärare när övningen är klar.

1.2 Skärningspunkter mellan grafer.
1. På nästa sida (1.3) visas graferna för de två funktionerna y=x^(2)+1 och y=2x+4
De kallas här f1(x) respektive f2(x).
Bestäm koordinaterna för alla skärningspunkter mellan de två graferna. Skriv svaret här:

2. Ändra f2(x) så att den istället visar funktionen y=2x-1.
Bestäm igen koordinaterna för alla skärningspunkter:

3. Låt nu f2(x) stå för funktionerna
y=2x+m , där m kan vara vilket tal som helst, postivt, negativt eller noll. För vilka värden på talet m får man två skärningspunkter, ingen skärningspunkt alls, eller exakt en skärningspunkt med grafen till y=x^(2)+1?
Svar:

1.3



1.4 Ekvationssystem
4. Lös på räknarsidan (1.5) ekvationssystemet:
system(x^(2)- y = -1,2x - y = -4)
Jämför med svaret du fick på uppgift 1.
Vad är din slutsats av jämförelsen?
Svar:

5. Lös på samma sätt ekvationssytemet:
system(x^(2)- y = -1,2x - y = 1)
Kommentar till resultatet?
Svar:

6. Lös systemet med ett m som kan vara vilket tal som helst:
system(x^(2)- y= −1,2x - y= −m)
Vilken allmän lösning har systemet?
Svar:

7. För vilka värden på m har systemet i uppgift 6 två lösningar, ingen lösning alls och precis en lösning? Och vilken blir lösningen när den bara är en enda?
Svar:

Appendix H: TI-Nspireprojektet: Enkät till medverkande lärare, maj 2011

1.
Hur många år har du varit matematiklärare på gymnasienivå?

2.
Hur stor vana anser du dig ha att använda räknare i undervisningen?
- Mycket stor
- Stor
- Ganska stor
- Inte så stor
- Liten
- Ingen alls

3.
Hur stor vana anser du dig ha att använda datorprogram i undervisningen?
- Mycket stor
- Stor
- Ganska stor
- Inte så stor
- Liten
- Ingen alls

4.
Hur stor vana anser du dig ha att använda datoralgebra (CAS)?
- Mycket stor
- Stor
- Ganska stor
- Inte så stor
- Liten
- Ingen alls

5.
Har du ändrat ditt sätt att undervisa och de arbetssätt du använder i klassrummet när du började använda TI-Nspire?
- Ja, en hel del
- Ja, något
- Inte alls

6.
Om du svarade ja på fråga 5, på vilka sätt har din undervisning förändrats? Beskriv så noga du kan.

7.
Är elevernas sätt att arbeta med matematiska uppgifter och problem annorlunda när de använder TI-Nspire?
- Ja, väsentligt annorlunda
- Ja, till viss del

Inte på något avgörande sätt

8.
Om du svarat ja på fråga 7, beskriv på vilka sätt deras arbetssätt ändrats.

9.
Har du upplevt några svårigheter med användningen av TI-Nspire? Flera alternativ kan markeras.

Ja, tekniska problem, t.ex. med installation eller överföring av filer.
Ja, problem med hur TI-Nspire är uppbyggt, med menyer, olika sidor, verktyg m.m.
Ja, med att eleverna tycker det är svårt att använda i det ”vanliga” skolarbetet.
Ja, övrigt…
Nej, det har inte varit några större problem.

10.
Kommentarer till fråga 9:

11.
Vilka möjligheter och positiva effekter med TI-Nspire har du upplevt i projektet? Flera alternativ kan markeras.

Det är lättare att gå igenom nya matematiska begrepp och demonstrera dem för eleverna.
Eleverna kan lättare åskådliggöra matematiska objekt, t.ex. grafer, och även undersöka dem grundligt.
Det ger fler möjligheter inom problemlösning och eleverna kan klara svårare uppgifter.
Eleverna verkar tycka att det är roligare att arbeta med matematik när kan använda TI-Nspire.
Eleverna verkar bygga upp en djupare förståelse för matematiska begrepp och metoder med TI-Nspire.
Det är lättare att kommunicera matematiska uppgifter med eleverna, både när du ska ge dem nya uppgifter och när de ska redovisa lösningarna.
Annat: …

12.
Kommentar till fråga 11. Beskriv gärna något konkret exempel som du iakttagit under projektet!

13.
Har du upplevt några hinder och negativa effekter med TI-Nspire i projektet? Beskriv dem så utförligt som möjligt.

14.
Vilka iakttagelser har du gjort kring hur eleverna lärt sig använda TI-Nspire? Markera gärna flera alternativ!

De flesta har varit beroende av mina genomgångar av verktyg, menyer m.m.
Eleverna hjälper ofta varandra med hur TI-Nspire fungerar och hur man ska använda det i matematiken.
Några elever har haft svårigheter med att lära sig använda TI-Nspire, och de har fortfarande brister där.
Det har i princip inte varit några svårigheter för dem efter den första introduktionen.
Några elever vill gärna utforska TI-Nspire för att hitta nya, intressanta saker där.

Många elever vill ogärna prova nya saker i TI-Nspire, och håller sig till de metoder du eller boken föreskriver.
De flesta elever har utvecklat sitt sätt att arbeta med TI-Nspire en hel del under terminen.
Det finns elever som inte alls vill arbeta med TI-Nspire.

15.
Kommentar till fråga 14:

16.
Under projektet har mina elever använt TI-Nspire
på laptop (dator)
som handenhet (räknare)
både på laptop eller dator och med handenhet (räknare).

17.
BESVARAS OM ELEVERNA BARA ANVÄNT LAPTOP: Vilka av följande påståenden stämmer med din uppfattning?
Det är tillräckligt att använda laptop. Handenhet (räknare) är onödig.
Jag skulle även ha velat att eleverna haft en handenhet (räknare) under matematiklektionerna.
Det gick bra att använda laptop på det nationella provet. Räknare är onödig.
Det var besvärligt att använda laptop på det nationella provet.
Det fungerar bra att samarbeta med andra under matematiklektionerna när eleverna har laptop.
Det är lätt att kommunicera med eleverna via nätet.
Det har varit problem med kommunikationen via nätet.

18.
BESVARAS OM ELEVERNA BARA ANVÄNT LAPTOP: Beskriv så utförligt som möjligt hur du löste problemet med villkoren för att använda laptop vi de nationella proven.

19.
BESVARAS OM ELEVERNA BARA ANVÄNT LAPTOP: Uppstod det några problem med användningen av laptops under de nationella proven? Beskriv dem i så fall så noga som möjligt.

20.
BESVARAS OM ELEVERNA BARA ANVÄNT LAPTOP: Vad är bra och vad är dåligt med att arbeta helt med laptop i matematiken? Och tillför det något extra om eleverna även har en handenhet?

21.
BESVARAS OM ELEVERNA BARA ANVÄNT HANDENHET: Vilka av följande påståenden stämmer med din uppfattning?
Det är tillräckligt att använda handenhet. Laptop är onödig.
Jag skulle även ha velat att eleverna haft en laptop under matematiklektionerna.
Det gick bra att använda räknaren på det nationella provet. Laptop är onödig där.
Det var besvärligt att använda räknaren på det nationella provet.

Det är lätt att kommunicera med eleverna i matematiken via nätet, fast de har räknare.
Vi har använt kablar för att kommunicera och tanka ner filer. Det har gått bra.

22.
BESVARAS OM ELEVERNA BARA ANVÄNT HANDENHET: Vad är bra och vad är dåligt med att arbeta helt med räknare i matematiken? Och tillför det något extra om eleverna även har datorprogrammet?

23.
BESVARAS OM ELEVERNA ANVÄNT BÅDE LAPTOP ELLER DATOR OCH HANDENHET: Vilka av följande påståenden stämmer med din uppfattning?
Det är bra att ha både dator och räknare. Man kan välja det som bäst passar för tillfället.
Det är onödigt att ha båda. Jag vill helst bara ha laptops i undervisningen.
Det är onödigt att ha båda. Det räcker med att bara ha räknare.
Det gick bra att använda räknaren på det nationella provet. Laptop är onödig där.
Det är lätt att kommunicera med läraren och med kamraterna i matematiken via nätet, och sedan överföra till räknaren.
Det har varit problem med kommunikationen via nätet.

24.
BESVARAS OM ELEVERNA ANVÄNT BÅDE LAPTOP ELLER DATOR OCH HANDENHET: Har dina elever fått använda laptop vid de nationella proven? Beskriv i så fall så utförligt som möjligt hur du löste problemet med villkoren för att använda laptop vi de nationella proven.

25.
BESVARAS OM ELEVERNA ANVÄNT BÅDE LAPTOP ELLER DATOR OCH HANDENHET: Om du svarat ja på föregående fråga, uppstod det några problem med användningen av laptops under de nationella proven? Beskriv dem i så fall så noga som möjligt.

26.
BESVARAS OM ELEVERNA ANVÄNT BÅDE LAPTOP ELLER DATOR OCH HANDENHET: Vad är bra och vad är dåligt med att både ha dator och räknare i matematiken? Tillför det något extra utöver att bara ha det ena eller det andra?

27.
TILL ALLA: Tycker du att deltagandet i detta forskningsprojekt varit utvecklande för dig i din undervisning?
Ja, på flera sätt
Ja, till viss del
Inte på något sätt jag själv kan märka
Nej

28.
Kommentar till fråga 27:

29.

Har du några övriga allmänna kommentarer om TI-Nspire och dina erfarenheter av projektet?

30.
Har något varit oklart i denna enkät. Vad i så fall?

TACK FÖR DIN MEDVERKAN!

Appendix I: TI-Nspireprojektet: Elevenkät maj 2011

1.
Vilken skola studerar du vid?

- Angeredsgymnasiet
- Filbornaskolan, Helsingborg
- Nynäshamns gymnasium
- Pauligymnasiet, Malmö
- Polhemsskolan, Lund
- Rudbecksgymnasiet, Tidaholm
- Bruksgymnasiet, Gimo

2.
Jag är

- Kvinnlig elev
- Manlig elev

3.
Vilka av följande påståenden om matematikämnet stämmer med din uppfattning? Markera ett eller flera alternativ.

- Matematik är ett viktigt ämne för kommande jobb.
- Matematik är intressant.
- Matematik är användbart i andra ämnen och i vardagen.
- Matematik är svårt.
- Matematik är tråkigt.
- Inget av ovanstående

4.
Hur har användningen av ett avancerat hjälpmedel som TI-Nspire ändrat din uppfattning om matematik och hur man arbetar med matematiska problem? Markera ett eller flera alternativ.

- Matematik är intressantare med TI.Nspire.
- Man klarar av svårare problem än man skulle ha gjort annars.
- Det är lättare att undersöka t.ex. funktioner och deras grafer med TI-Nspire.
- Man samarbetar mera vid problemlösning.
- Matematik är roligare att arbeta med när man kan lösa svåra algebraiska problem enkelt, t.ex. med Solve-kommandot.
- Användningen av TI-Nspire har inte ändrat min uppfattning om hur man arbetar med matematik.

5.
Vilka av följande svårigheter har du någon gång upplevt med TI-Nspire? Markera ett eller flera alternativ.

- Svårt att förstå hur det fungerar och hur man hittar i menyer.
- Svårt att använda olika verktyg, t.ex. för funktioner och grafer.
- Ibland svårt att veta hur man ska börja när man ska lösa en uppgift.
- Svårt att ladda ner färdiga tns-filer och att spara dem.
- Ibland svårt att tolka svaren i räknar-delen, t.ex. när man använt solve-kommandot.
- Jag har inte upplevt några större svårigheter.

6.
Vad är ditt totala intryck av TI-Nspire när du nu använt det c:a en termin? Markera ett alternativ.

- Mycket bra.
- Bra.
- Ganska bra.
- Mindre bra.
- Dåligt.
- Mycket dåligt.

7.
Har du några kommentarer till fråga 6? Skriv dem här:

8.
Jag har under terminen använt TI-Nspire

- på laptop (dator)
- som handenhet (räknare) (Hoppa sedan till fråga 11!)
- både på laptop eller dator och med handenhet (räknare). (Hoppa sedan till fråga 13!)

9.
FRÅGA FÖR DIG SOM BARA ANVÄNT LAPTOP:
Vilka av följande påståenden stämmer med din uppfattning? Markera ett eller flera alternativ.

- Det är tillräckligt att använda laptop. Handenhet (räknare) är onödig.
- Jag skulle även velat haft en handenhet (räknare) under matematiklektionerna.
- Det gick bra att använda laptop på det nationella provet. Räknare är onödig.
- Det var besvärligt att använda laptop på det nationella provet.
- Det fungerar bra att samarbeta med andra under matematiklektionerna när man har laptop.
- Det är lätt att kommunicera med läraren och med kamraterna i matematiken via nätet.
- Det har varit problem med kommunikationen via nätet.

10.
FRÅGA FÖR DIG SOM BARA ANVÄNT LAPTOP:
Vad är bra och vad är dåligt med att arbeta helt med laptop i matematiken?
(Hoppa sedan till fråga 15!)

11.
FRÅGA FÖR DIG SOM BARA ANVÄNT HANDENHET (RÄKNARE): Vilka av följande påståenden stämmer med din uppfattning? Markera ett eller flera alternativ.

- Det är tillräckligt att använda handenhet (räknare). Laptop är onödig.
- Jag skulle även ha velat ha haft en laptop under matematiklektionerna.
- Det gick bra att använda räknaren på det nationella provet. Laptop är onödig där.
- Det var besvärligt att använda räknaren på det nationella provet.
- Det fungerar bra att samarbeta med andra under matematiklektionerna när man har räknare.
- Det är lätt att kommunicera med läraren och med kamraterna i matematiken via nätet, fast man har räknare.
- Vi har använt kablar för att kommunicera med läraren och tanka ner filer. Det har gått bra.

12.
FRÅGA FÖR DIG SOM BARA ANVÄNT HANDENHET (RÄKNARE): Vad är bra och vad är dåligt med att arbeta helt med räknare i matematiken?
(Hoppa sedan till fråga 15!)

13.
FRÅGA FÖR DIG SOM ANVÄNT BÅDE LAPTOP ELLER DATOR OCH HANDENHET (RÄKNARE): Vilka av följande påståenden stämmer med din uppfattning? Markera ett eller flera alternativ.

- Det är bra att ha både dator och räknare. Man kan välja det som bäst passar för tillfället.
- Det är onödigt att ha båda. Jag vill helst bara ha laptop.
- Det är onödigt att ha båda. Det räcker med att bara ha räknare.
- Det gick bra att använda räknaren på det nationella provet. Laptop är onödig där.
- Det fungerar bra att samarbeta med andra under matematiklektionerna när man har både dator och räknare. Man kan välja det som bäst passar för tillfället.
- Det är lätt att kommunicera med läraren och med kamraterna i matematiken via nätet, och sedan överföra till räknaren.
- Det har varit problem med kommunikationen via nätet.

14.
FRÅGA FÖR DIG SOM ANVÄNT BÅDE LAPTOP ELLER DATOR OCH HANDENHET (RÄKNARE): Vad är bra och vad är dåligt med att både ha dator och räknare i matematiken?

15.
Har du några övriga kommentarer om TI-Nspire och dina erfarenheter under terminen?

Appendix J:

MALMÖ HÖGSKOLA

Project meeting for *Teaching and learning mathematics at secondary level with TI-Nspire technology.*

Friday, March 11, 2011, 10.30 AM – 4.30 PM

Malmö University, School of teacher education, room F 211 (nr 1 on map of the university)

Program:

10.30 – 11.15	Welcome! Information och questions about the project. Coffee is served during this. *(Raffaella, Bengt, Per-Eskil)*	(English)
11.15 – 12.00	Experiences and examples I Each teacher/school is given c:a 15 min for discussion of their experiences of the project so far. Especially are good examples of activities that have been used of interest. *(Per-Eskil, Bengt)*	(English)
12.00 – 13.00	Lunch	
13.00 – 14.00	Experiences and examples II We continue the discussions. *(Per-Eskil, Bengt)*	(English)
14.00 – 15.15	Activities with TI-Nspire Demonstration of and discussion around different activities that are suitable for mathematics education *(Bengt)*	(Swedish)
15.15 – 15.30	Coffee break	
15.30 – 16.15	What does research say about technological resources in mathematics education? Recent research is presented and discussed, especially what is known of how TI-Nspire can be used in teaching. *(Per-Eskil)*	(Swedish)
16.15 – 16.30	Next steps in the project Short information about the questionnaires and of the teaching experiment that is planned for the second visit. *(Per-Eskil)*	(English)

The meeting day is without costs for all participating teachers. Travels, hotels lunch and coffee are paid for by Texas Instruments.