TEACHERS' AND STUDENTS' FIRST EXPERIENCE OF A CURRICULUM MATERIAL WITH TI-NSPIRE TECHNOLOGY

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In a pilot research project, a curriculum material intended for two mathematics courses at Swedish upper secondary school has been constructed. The material is written for the use of TI-Nspire technology, with which it forms a dynamic system. Three teachers and three classes replaced their textbooks with this material during a half semester, and their experiences, as well as the general learning outcomes for the students, were investigated using various methods. This paper describes some of the main findings of the study, along with the more important conclusions that could be drawn.

CURRICULUM MATERIAL AND TECHNOLOGY

In mathematics instruction, textbooks can play a central role. This is especially true in Sweden, where it often defines the curriculum for both teachers and students. There exist strong beliefs among them that if you do not follow the textbook, you might not fulfil the curriculum and then you fail in the National Tests. These have to some degree rewarded the use of technology in mathematics education, but this has not yet provoked any more extensive changes of the textbooks. It is therefore of great interest to evaluate new types of material for classroom use that integrate technology in a more distinct way.

Within the project 'Nspirerande matematik', especially developed curriculum material was used for parts of the courses Matematik A and Matematik B at Swedish upper secondary school (student age 16-17). This material consists of both traditional texts and tasks, as in a common textbook, and of interactive material for the TI-Nspire technology. These interactive files give the students opportunities to discover mathematical principles and rules, to make conjectures and justifications, to exercise their skills and to make self-tests of what they have learned. Some tasks are especially designed as activities for inquiry and collaborative learning. The material has been used in three classes from the theoretical programmes at different schools in the middle and southern parts of Sweden during spring 2010.

Both teachers and students had full access to both handheld units and computer software within the TI-Nspire technology, including links between the two. The technology used was in the form of a computer algebra system (CAS). It is important to note that the students were familiar with the handheld units prior to being introduced to the curriculum material.

PILOT TEACHERS AND CLASSES

All the three teachers involved in the project were selected as well experienced and have taught mathematics for many years at upper secondary level. Technology in mathematics teaching was in no sense new to any of them at the initiation of the project. Graphing calculators have been standard equipment in all courses at upper secondary level in Sweden for many years, and skilful use of technology in different forms is especially promoted in mathematics curriculum. In the project, CAS was used in the curriculum material and also presupposed for solving some of the tasks and working with the special activities in the material. This, of course, could present different challenges to the teachers, depending on their prior experience of this technology (Weigand, 2007). A brief presentation of the teachers and their classes:

Anna is teaching at a school in the centre of a rather large city. The students at the school are very mixed, and the motivation and the ability of the students also vary to a great extent. Some students have considerable problems with their mathematics studies, at the same time as some have great ambitions. In the class, which studied their first year at the Social Science programme, the students represented the whole scale, and the curriculum material was therefore only presented in a smaller group (7-8 students). The material used was 'Nspirerande matematik – Ma A', more specifically the section with functions.

Carl and *Eric* are working at secondary schools in two middle-size towns. The students come from these towns and the surrounding rural areas, and both classes (≈ 25 students each) consist of combinations of those who study at the Natural Science and at the Technological programmes. The students are of mixed ability but generally rather motivated for studies in mathematics. The material used was 'Nspirerande matematik – Ma B', in the section with algebra and functions, which represents the larger part of the course, and with probability.

AIMS FOR THE STUDY

The intention was to make a first evaluation of the use of curriculum material for the two mathematics courses, which is specially designed for the interactive use of TI-Nspire technology, based mainly on the experience of teachers and students. Of special interest are the ways it was used in the classroom work and in the teachers' instructional practice, as well as how it affected the students' achievement. Both students and teachers had the opportunity to express their opinions of how well this material and this technology have functioned in a real educational situation. They have also been able to pinpoint possible problems and obstacles that they have encountered when using the material and/or the technology, as wells as how it has affected the students' own motivation, interest and self-confidence when working with mathematical activities.

As being a pilot study, its intention was furthermore to form a basis for a larger evaluation study, which can involve more teachers and classes, and can stretch over a longer time period. In such a study, it can be possible to in other ways do research of more subtle outcomes of education, such as deeper understanding of mathematical concepts and methods and how robust knowledge is over time.

THEORETICAL FRAMEWORK

The theoretical background for this study 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 (cf. 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.

A tool can develop into a useful instrument in a learning process called *instrumental genesis* (Verillon & Rabardel, 1995; Guin & Trouche, 1999). This process requires time and effort from the user. The user must develop instrumented action schemes that consist of a technical part and a mental part (Guin & Trouche, 1999; Drijvers & Gravemeijer, 2005). 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 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.

Affective factors have been found to 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. Especially the intentions and goals for the mathematical education that students and the teacher have are vital (Hannula, 2002). They are not always coinciding, and this 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, 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). This is especially true for CAS, which also has the problem of becoming legitimized within the school culture (Kendal & Stacey, 2002).

RESEARCH QUESTIONS

The research questions of the evaluation study are structured into three groups in accordance with the didactic triangle, and are generally based on the theoretical background and the aims for the study:

Effects on teaching practice and learners. How is the integrated system of technology and written content used in the classroom by teachers and students? What effects on classroom dialogue, student-student and teacher-student, can be detected when working with it?

Teacher experience of the system. How has the 'Nspirerande matematik' resources supported new approaches to teaching for the teachers involved in the project? Which examples of difficulties or obstacles with using the material and/or the technology can be found?

Learning outcomes. How do the teachers in the project estimate the effects of the curriculum material on students' development of conceptual understanding? How does the use of the material together with the technology affect students' motivation, interest and self-confidence when working with mathematical activities?

RESEARCH METHODS AND DATA COLLECTION

This pilot study has the intention of giving a first and rather general view of the outcomes of the use of the curriculum material and the TI-Nspire technology, both in terms of students' and teachers' views of these and of possible learning results that can be connected with them. Thus a pragmatic use of mixed research methods has been appropriate, mainly focussing on qualitative approaches, but also with some quantitative elements concerning the ways the material and the technology are used in the classrooms.

The classes and the teachers that participated in the project were each visited twice during the project, and the methods used were the following:

Teacher lesson evaluations and observations. The teachers should fill in one form or log for each lesson in which they have used the material and the technology.

Teacher interviews. A deep, semi-structured interview with the teachers was made in connection with each visit at the schools. All interviews were transcribed.

Classroom observations. With each visit a lesson was to be observed by the researcher, using a special observation protocol.

Student interviews. Two students were chosen from each class to be interviewed in connection with the observed lesson at each visit, and these were also transcribed.

Teacher questionnaire. After finishing this pilot project each teacher was presented with questions concerning their overall experience of using the material and the technology in school instruction.

The teachers and the students used the material full time from an introductory meeting in March until the end of the semester. Visits were made as planned at the three schools by two occasions, one near the end of April and one near the end of May, at which time interviews were made and recorded. The three teachers as well as the students 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 progress and their shortcomings with the material and the technology, and they reflected on what they had done in class, both in the middle of the project and at the end of it.

MAIN FINDINGS AND CONCLUSIONS

The acquired data from this study will not be presented in detail here. Instead some of its main findings are briefly stated and partly compared with other research.

Effects on teaching practice and the learners

The teachers made no essential alterations of their approaches or their working styles due to the system. Their lesson logs showed that they used essentially the same lesson plans and organisation of instruction during the project as before (mainly based on whole-class teacher's presentation, individual or cooperative students' work with teacher's support and finally a summary of the lesson). Maybe this was to be expected in such a short period, but the material opens for change in many ways. For one of the teachers, this material was in line with what she was used to, but for the others it presented a challenge. However, some signs of progress and change could be detected at the end of the project for one teacher, in the direction of more exploring activities for the students. This could imply a partial change of attitude to the ways mathematics education can be performed (cf. Brown et al, 2007).

Two of the teachers did not use the calculators as tools for students own learning and exploring to any larger extent. Balling (2003) distinguishes between the use of calculators as calculating tools, teaching tools and learning tools. In the project, these two teachers mainly used them as extensions of the calculators they had used before, which means as calculating and teaching tools. The CAS technology also proposed problems for especially one teacher, who even doubted the positive impact on students' learning. This is also in accordance with what Pierce and Ball (2009) write about teachers' attitudes. Using CAS can by the teacher be considered as an extra burden, especially for weak students, and distract them from core mathematical learning.

The curriculum material replaced the usual textbooks and was printed out as compendia. In their evaluations of the material both teachers and students compared it with the textbooks in all details. In those cases where differences could be seen, many of the students, and also their parents, questioned if the material could provide the 'right' knowledge for the course, and there were worries about the results in the National Tests. Also the attitudes from colleagues and/or the principal for the school could have been of importance for the pre-attitudes (see Pierce & Ball, 2009).

The combination of the calculator and the material promoted students' discussions and presented opportunities to cooperate. In all three pilot classes, the students were used to working in pairs or in spontaneous groups. Much of the material was challenging for some students, in ways that the usual textbook did not match sufficiently. The technically advanced calculators also called for cooperation in acquiring proper action schemes (Drijvers & Gravemeijer, 2005). These two factors together created good opportunities for the students to develop a dialog on a rather advanced mathematical level, both with the teacher and with other students. Students from Erik's class:

F: Sometimes you want to work by yourself to get into it and understand, but it is very good to be able to help each other.

M: Yes, most of the time more will be done when you work in pairs. It is easier when you don't know.

Teacher experience of the system

During the project, no mayor obstacles or difficulties with the calculators appeared. Neither the teacher nor the students mentioned any larger problems with the technique or in the way the calculator software appears. Interesting was the description some students gave of the instrumental genesis with its different parts (Guin & Trouche, 1999) they had experienced, and what this also had taught them in terms of mathematics.

Anna's (female) student: I have no problems with new technology. I understand the calculator very well! The only thing is that you must remember all the steps, but the calculator in itself is quite simple to understand.

One teacher criticised the way CAS technology was used in the material. His impression was that this was written for the use of CAS and not for the mathematic knowledge.

Erik: For the understanding of the concepts, I abandoned the technology. It is typical that CAS do it in this way, and therefore the material is adjusted for that. CAS in the centre. It rules over the material.

Belfort and Guimares (cited in Dick & Burrill, 2009) give a list of four possible shortcomings in constructing technology-based material, of which the first is: 'The author's interest is on mastering the use of the technology where the mathematics is secondary' (p. 11). However, none of the other two teachers gave the same critique, and this might be misdirected in this case. The problem could instead lie in the fact that the use of CAS may change the classroom practice, which can be perceived as a threat (Pierce & Ball, 2009).

The content of the material in combination with the technology caused problems for some students. The long texts and explanations with alternating sections of tasks were perceived as difficult by some students. This was especially true for students with lesser mathematical ability, for whom the longer activities or tasks became obstacles.

> Erik's student: It is frustrating if you are in a class and others have difficulties but not I. Then it takes very much time to get it to work for all students in the group.

Research points in different directions there. Ruthven and Hennessey (2002) report that access to technology enables less-able students to participate in exploration, while Tynan (2003) concludes that the technical overhead, when learning new technological features, could be an extra burden for these students. This is also mentioned as an obstacle by two of the teachers in the project, while the third instead has seen this category of students succeed quite well with such activities.

The opinions of how easy a teacher who is rather new to technology could start using it together with the material varied. One of the teachers perceived it as being fairly easy, calling for only a shorter introduction, another that a more thorough course was needed. The third teacher said that it was easier than he thought. One explanation to this could be that the material was used in different ways by them, and that the demands of certain knowledge therefore differed. This is in line with what other researchers have found (e.g. Ball, 2004), especially in the connection with the implementation of CAS into the classrooms. All three teachers also mentioned the need for an extensive teacher's guide accompanying the material and that different kinds of support, mainly in the start of using the material, would facilitate this implementation. Implementing in a larger scale has been researched for example by Ball (2004), and Pierce and Ball (2009). One conclusion these authors have drawn is: 'The responses to this survey confirm that professional development for teachers needs to address attitudes and perceptions as well as technological skill development' (p. 315). This is also the experience as expressed by the teachers in the present study.

Learning Outcomes

Two of the pilot teachers would not draw any certain conclusions about their students' development of deep conceptual understanding of mathematics. One given reason for this is the fairly short time-span of the project. To the teachers' meaning, such effects can only be detected in the longer perspective. However, their estimation was that the more mathematically able students have taken advantage of the material and the calculators in a way that in fact has made it possible for them to develop this deeper understanding of concepts. At the same time, the lesser able students might be at the risk of having learned less than with the usual textbook.

One of the pilot teachers declared that her students had shown clear signs of a deeper conceptual understanding. This was also confirmed in the interviews with the students, who gave detailed descriptions of the laborious process to obtain this understanding. The students' results in the National Test gave more evidence that they really had understood mathematics at a more advanced and also deeper level, and so did also the mathematical texts that the students must hand in to the teacher. It is important to note that these students are not among the most mathematically able ones.

Anna: The material is more stimulating than 'ordinary' books, and the interaction with the calculator develops a more investigating and inquiring attitude.

Anna: Before, I thought that you had to use the pencil to understand, but I see many today who 'think' with the keys.

The calculators have been stimulating for the interest, motivation and curiosity towards mathematics. This is common for all three pilot classes, even if it was not true for all individual students. It is also in accordance with what most research of the use of technology in mathematics education shows (see e.g. Persson, 2009). For most students, it was also their first contact with a more advanced calculator. In one of the groups, the students' attitudes and feelings towards mathematics had changed dramatically. Their comparison was mainly with what they had experienced of mathematics instruction at compulsory school. The details in the interviews give evidence that it at least to some degree was the text, the tasks and the activities in the material that caused this change. The students found the mathematics there interesting, challenging and useful, and solving the problems gave them better self-confidence and self-esteem (cf. Hannula, 2002).

Anna's (female) student: This material has been extremely good and incredibly useful. Before, I had a hard time with maths, but now I have Anna and the material and new ways of thinking. So now I got a 'Pass with special distinction' at the National Test, which I had never dreamed of getting before. So it has improved my and the whole class' attitude towards math. And you have to think in new ways all the time, otherwise you don't find the right solutions.

Presently, a continuation of this pilot study has been initiated, in the form a larger study involving more classes and teachers. It will take place during a whole semester, and the learning outcomes of the students will be in special focus (cf. Artigue & Bardini, 2009). What are the conceptual and affective effects of using this kind of technology and curriculum material (now available at Nspirerande matematik, 2010), especially compared to common textbooks and the material linked to these?

REFERENCES

Artigue, M. & Bardini, C. (2009). New didactical phenomena prompted by TI-Nspire specificities – The mathematical component of the instrumentation process. In V.

Durrand-Guerrier, S. Soury-Lavergne, & F. Arzarello (Eds.). *Proceedings of the Sixth Congress of the European Society for Research in Mathematics Education* (pp. 1071-1180). Lyon: INRP.

Ball, L. (2004). Researchers and teachers working together to deal with the issues, opportunities and challenges of implementing CAS into the senior secondary mathematics classroom. *Zentralblatt für Didaktik der Mathematik*, 36(1), 27-31.

Balling, D. (2003). *Grafregneren i gymnasiets matematikundervisning – Lærernes holdninger og erfaringer* (in Danish). Doctoral thesis. Aarhus: Syddansk universitet.

Brown, E. T., Karp, K., Petrosko, J., Jones, J., Beswick, G., Howe, C., & Zwagnig, K. (2007). Crutch or catalyst: Teachers' beliefs and practices regarding calculator use in mathematics instruction. *School Science and Mathematics*, Vol.107, No.3, 102-116.

Cobb, P. & Bauersfeld, H. (Eds.) (1998). *The emergence of mathematical meaning – Interaction in classroom cultures, Vol. 2*. Hillsdale, N.J.: Lawrence Erlbaum.

DeBellis, V.A. & Goldin, G.A. (1997). The affective domain in mathematical problem solving. In E. Pehkonen (Ed.), *Proceedings of the 21st conference of the international group for the psychology of mathematics education, Vol. 2* (pp. 209-216). Lahti: Helsingfors Universitet.

Dick, T. & Burrill, G. (2009). *Tough to teach/tough to learn: Research basis, framework, and principles for a practical application if TI-Nspire technology in the Math Nspired series.* Dallas, TX: Texas Instruments Inc.

Drijvers, P., Doorman, M., Boon, P., Reed, H., & Gravemeijer, K. (2010). The teacher and the tool: instrumental orchestrations in the technology-rich mathematics classroom. *Educational Studies in Mathematics*, 75(2), 213-234.

Drijvers, P. & Gravemeijer, K. (2005). Computer algebra as an instrument: Examples of algebraic schemes. In D. Guin, K. Ruthven & L. Trouche (Eds.). *The didactical challenge of symbolic calculators: Turning a computational device into a mathematical instrument* (pp.163-196). Dordrecht: Kluwer Academic Publishers.

Guin, D. & Trouche, L. (1999). The complex process of converting tools into mathematical instruments: The case of calculators. *International Journal of Computers for Mathematical Learning*, 3(3), 195–227.

Hannula, M. (2002). Attitude towards mathematics: Emotions, expectations and values. *Educational Studies in Mathematics*, 49, 25-46.

Heid, K. & Blume, G. (2008b). Technology and the teaching and learning of mathematics: Cross-content implications. . In K. Heid & G. Blume (Eds.), *Research on technology and the teaching and learning of mathematics: Vol. 1*. Research syntheses (pp. 419-432). Information Age Publishing.

Kendal, M. & Stacey, K. (2002). Teachers in transition: Moving towards CAS-supported classrooms. *Zentralblatt für Didaktik der Mathematik*, 34(5), 196-203.

Mariotti, M. A. (2002). The influence of technological advances on students mathematics learning. In L. English (Eds.), *Handbook of international research in mathematics learning* (pp. 695- 723). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Nspirerande matematik (2010). (In Swedish) Retrieved 2010-11-29 from http://education.ti.com/ebook/

Persson, P-E. (2009). Handheld calculators as tools for students' learning of algebra. *NOMAD, Nordic Studies in Mathematics Education*, 14(2), 101-129.

Pierce, R. & Ball, L. (2009). Perceptions that may affect teachers' intention to use technology in secondary mathematics classes. *Educational Studies in Mathematics*, 71, 299-317.

Ruthven, K. & Hennessey, S. (2002). A practitioner model of the use of computer-based tools and resources to support mathematics teaching and learning. *Educational Studies in Mathematics*, 49, 47-88.

Steinbring, H. (2005). Analyzing mathematical teaching-learning situations – The interplay of communicational and epistemological constraints. *Educational Studies in Mathematics*, 59, 313-324.

Trouche, L. (2005). An instrumental approach to mathematics learning in symbolic calculators environments. In D. Guin, K. Ruthven & L. Trouche (Eds.), *The didactical challenge of symbolic calculators: Turning a computational device into a mathematical instrument* (pp.137-162). Dordrecht, NL: Kluwer Academic Publishers.

Tynan, D. (2003). Student caricatures in a CAS classroom. In B. Barke, A. Bishop, R. Cameron, H. Forgaz, & W. T. Seah (Eds.), *Making mathematicians. Proceedings of the 40th Annual Conference of the MAV* (pp. 311-319). Melbourne: Mathematical Association of Victoria.

Verillon, P. & Rabardel, P. (1995). Cognition and artifacts: A contribution to the study of thought in relation to instrumented activity. *European Journal of Psychology in Education*, 10(1), 77-101.

Vygotsky, L. (1978). *Mind in Society*. Cambridge, MA: Harvard University Press.

Weigand, H-G. (2007). Teaching with a symbolic calculator – The first years of a long-term project. In D. Pitta-Pantazi & G. Philippou (Eds.), *Proceedings of the Fifth Congress of the European Society for Research in Mathematics Education*, (pp. 1540-1549). Larnaca: University of Cyprus.