Teachers' dealing with technlogy-enhanced mathematics in teaching practice

Mette Andresen
mea@ucc.dk
National Knowledgecentre for Math. Education, UCC
Morten Misfeldt,
mmi@dpu.dk
Danish School of Education, Aarhus University,

Abstract: The aim of the study is to throw light on how experienced, Danish upper secondary teachers deal with technology enhanced mathematics in their teaching practice. In particular, we find the relations between these teachers' personal view on mathematics and the use of ICT tools may be of interest.We have chosen the very first lessons with the new tool as object forthis study because explicit arguments and reflections on the use of ICT were most likely to be given by the teacher at these occasions. Besides, we expected the teachers to be especially aware of the students impression of the role of ICT when they prepared these first lessons and, thereby, revealing their viewpoints.
The study aims to contribute to the rich variety of examples of good practice, to inspration for colleagues with more or less experience themselves. In contrast, the study does not aim at setting up a strict correspondance between teachers' beliefs and their handling ICT in practice. Neither, we aim to rate different approaches or to assess them with regard to students' learning outcome.

1. Background for this study: "the world class math and science project"

During almost one decade, the introduction and use of CAS in mathematics (and, when relevant, in other school subjects) was subject to small scale research – and development projects, and teaching experients, in Danish upper secondary school. Main projects were 'World Class Math and Science I + II' 2000 – 2004 and 2004 – 2006, resp., and Danish Science Gymnasiums (DASG) 2006 - 2010 [1, 2, 3, 4, 6]. One of these projects' overall objectives was to initiate sustainable professional development for matheatics teachers locally, in their schools, with regard to integration of CAS and ICT tools into their mathematics teaching. In addition, the idea was to launch research – practice collaborations. For example, one goal of the World Clas Math and Science I was formulated like this (quoted from [2] p 25):

> ' ICT in mathematics:
> A number of reports point out, that inclusion of ICT in math teaching strongly influences the students' acquisition of mathematical concepts and methods.
> The intention is to inquire, whether math software makes the acquisition of the content possible in a way that ensures better understanding and makes applications within other subjects easier. (…)'

The evaluation of subprjoect A: use of CAS, part of the World Class Math and Science I project, was summarised in [2 p. 31]:

> 'The experiences from the World Class A project demonstrated that it was possible to teach almost as usual, even with the use of computer and CAS. Though, golden opportunities for radical changes of teaching mathematics and science were also demonstrated. The benefits in mathematics were clear: Use of CAS gave a lift. A large variety in students' attitudes towards mathematics was revealed: From students, who saw mathematics as a tool-subject of applications and widely included the use of

> computer in their mathematical activities, to students, who regarded understanding and overview based on proofs and based on hand-working as being the main issues. These differences did not solely reflect distinct teaching viewpoints as far as there were huge discrepancies between students from the same classes, taught by the same teachers.'

A common experience for the teachers during the projects was the hurdle, to overcome the students' initial resistance. When the teacher introduced for example MathCad, TI89 or n'spire, major parts of the students often were reluctant to invest time and efforts in the instrumental genesis. In such cases, the teacher had to be persuasive and, if necessary, force the students to start the process. It was also a common experience that in general, the students graduately developed a positive attitude towards the tool. Some of them even became entusiastic time after time. The following excerpt from the evaluation of the 'Danish Science Gymnasiums' project [4 p.11] (my translation from Danish) shows one example of this common experience:

> *– they believe it is cheating and they think, you know, we have things to do, we must start now! Here are some hurdles to overcome. Which really pays back. You have to invest, but it is hard for them to believe from the beginning.*
> *You know, I don't know if I handle it wrong, I think I do my best but it really is a hurdle! But they become very happy with it!*
> - *I totally agree!*
> - *Yes!*
>
> and
> *…And I totally agree with you, it is an investment and you alsmost experience an atmospherein the classroom of we-want-to-kill-the-teacher...*

Apparently, the issue of generating a new tool for learning and doing mathematics frequently engaged both teacher and students emotionally. This engagement is the outset of the present study.

2. Themes and relation to theory

The themes that we deal with in this paper are (1) teacher practice when introducing ICT in their mathematics classes, and (2) teachers conception of mathematics and the role of ICT in their mathematics teaching. The outset of the study is the observations from the world class project, described above, namely that students tend to resist this integration and teachers tend to insist that this integration occurs.

In order to sharpen our look at the teaching-learning situation we use some concepts from the theory of didactical situations [5]. This means that we use the concept of *didactical contract* to describe the mutual expectations between teacher and learners, the distinction between didactical situations (controlled by the teachers instructions) and adidactical situations (controlled by the students voluntary and selv directed interaction with the learning environment and problem situations) to describe the inteplay between teacher control and students self directedness.

We will also adopt the notion of "obstacle" to describe the specific challenge that students meet in their work. Broussau distinguishes between didactical obstacles (due to the way a topic is taught, should in general be avoided) and epistemological obstacles (due to the nature of the the topic taught, these are more or less necessary for learning to occur).

In order to describe the teachers role in the more loosely framed "reform paradigm" for educational planning we lean on an extension of the notion of forced autonomy as introduced by Skott [8]. We

return to this notion in the section below concerning the teachers' insistence on students' generation of new, pesonal tools. Before that, we clarify the meaning of the term personal tool:
In order to describe the influence of technology on mathematical activity we will use the instrumental approach developed by Luc Trouche [9], partly from the discipline cognitive ergonomics (Verillion & Rabardel, [10]), and partly from the theory of conceptual fields (Vergnaud [11]).
The basic premise of the instrumental approach is that people use artefacts for various purposes and hereby create personal instruments. An artefact is a material or abstract object, aiming to sustain human activity. An instrument is what the subject builds from the artefact. [9 p.144]. The process of building an instrument from an artefact is referred to as instrumental genesis (fig. 1) and consists of two simultaneous processes, instrumentation and instrumentalisation. Instrumentalisation is the process where the subject gets to know and control the artefact and applying it to ones own very specific needs. Instrumentation the process where that artefact shapes the subject in the sense that the subject adapts to the new possibilities and constraints the artefact posses.

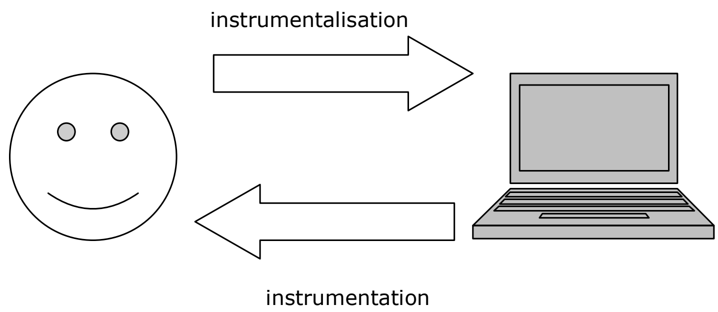

Fig 1. Instrumental genesis

The result of the instrumental genesis will be referred to as a *personal instrument*.

3. Observed phenomenon's

From the World Class project we have the observations of students resistance against development of personal tools and that teachers attempt to push this process. In the following subsections these observations is related to existing knowledge and preliminarily explained.

Students' resistance towards generation of a new tool

Creating personal instruments can be a hard process that takes time and efforts. Therefore, it does not surprise that some students will resist this change. But apart from being intellectually challenging, the process of creating personal instruments may also challenge ones conception of what mathematics is. So, in our interpretation, one possible reason for the students' reaction could be the close relationship between one's personal view on mathematics on the one hand, and one's beliefs about the best or desirable ways to learn and do mathematics on the other hand, meaning that a new tool might influence or change satisfactory elements of these activities in negative direction. For example might a student, enjoying to make a pretty graph by hand, based on calculations etc., get angry if he or she was asked only to do graphs using a graphic calculator. Or a student, skilled in calculations by head, might feel disappointed when the calculator overrules this skill.
In addition, Povey and Ransom [7] describes students resistance towards the use of technology in mathematics education. Their empirical observations suggest two main reasons for this resistance,

namely that technology can be a threat to understanding, and can result in a feeling of being out of control:

> *We found that, for some, such use of technology can feel a threat to understanding, can provoke a sense of being out of control and can appear to involve a waste of the power and potential of being human.* [7 p. 60]

Within an instrumental approach, it is not surprisingly that students to some extend resist this introduction. It is a consequence of the theory that the student, when developing a personal instrument, must change his or her scheme of the mathematical problem situation including the mathematical concepts involved. One can easily imagine that such a process can be experienced as threatening understanding.

Teachers' insistence on students' generation of new tools

In a sense teacher insistence on the use of ICT can be seen as merely and answer to the students resistance. In order to make ICT a part of the mathematical activities in the class the teacher might need to persistently insist that the students use it.

The issue of ICT integration became urgent when recently, formal requests were introduced for integrating ICT in upper secondary school mathematics. There was no clear statements, though, to define the terms ICT and integration. It is now decided at school level, whether the students are provided with/requested to bring with them shared computers, personal laptops or handheld CAS calculators. In some schools, tools even in the same class can be mixed between laptops and handheld calculators. Very often, it is up to the school's group of teachers to decide, who will teach the laptop classes, the handheld classes and the computer-lab classes, respectively.

Furthermore, there is no formal regulations for ICT use in Danish secondary school stating a syllabus or pointing out guidelines for neither the design nor the content of teaching and learning mathematics with ICT; only the goals are stated in broad terms. According to the goals, the students are not supposed merely to become familiar with the use of one or two tools for standarised or algorithmic problem solving whereas, ideally, they must end up being able to decide when and how it is appropriate to use ICT tools, to choose amongst availble tools and then, subsequently, to use them for solving the problem in question and to document their reasoning and their tool use. Thus, in our interpretation the students are supposed to reach a meta perspective on the use of ICT tools, in accordance with the constructivist's view on learning which is pervading the regulations. It follows that the teacher must fulfill the same requests and furthermore, he or she has to find a way to ensure that the students aqquire these new competencies, and to evaluate the process[1].

The actual way for teachers to meet these requests is highly influenced by the circumstances described above. So, in our study we lean upon the notion of *teachers' forced autonomy* and an extension of this notion, discussed by Jeppe Skott [8 p. 239]. Like in Skott's study, the new formal requests of ICT use leave the upper secondary mathematics teacher in a situation, where *'expected classroom practices and lerning outcomes* (are) *formulated outside the classroom, but there is no set of well-defined methods for the teacher to carry out and only vague hints as to what kind of practice a certain situation may require.* '. Skott argues in his study, that the notion of forced autonomy, based on the conceptions of mathematics and mathematical learning, should be extended to encompass not only the roles of the teacher when supporting students' learning in classrooms, but also the multitude of other obligations that emerge in the course of the classroom interactions, which further complicate teacher decision-making. An extended notion of forced autonomy may,

[1] in Denmark teachers are obliged, yearly, to grade the students' daily work. In upper secondary mathematics, the students daily written and oral s are graded separately

according to Skott, serve as a better means for researchers to understand the teachers role for the enacted curriculum. But also, referring to one of the cases in Skott's study, provide the teacher and his colleagues with an understanding that prevents them from oscillating between either facilitating mathematical learning or pursuring broader educational aims. Our experiences from the Danish projects mentioned above, point in particular to a complexity of forced, extra obligations, related to different aspects of the introduction of ICT tools into the classroom.

4. Aims of this study

Our research curiousity about the emotional engagement related to the introduction of math software have lead to this study. The aim of the study is to throw light on how experienced, Danish upper secondary teachers deal with technology enhanced mathematics in their teaching practice. In particular, the relations between these teachers' personal view on mathematics and the use of ICT tools may be of interest for example for in service training of other teachers. The reason for us to choose the very first lessons with the new tool as object for study was, that explicit arguments and reflections on the use of ICT were most likely to be given by the teacher at these occasions. Besides, we expected the teachers to be especially aware of the students impression of the role of ICT when they prepared these first lessons and, thereby, revealing their viewpoints.

In contrast, the study does not aim at setting up a strict correspondance between teachers' beliefs and their handling ICT in practice. Neither, we aim to rate different approaches or to assess them with regard to students' learning outcome. The study aims to contribute to the rich variety of examples of good practice, to inspration for colleagues with more or less experience themselves.

Our study encompass inquiry of two cases of lessons in mathematics, containing the teachers'very first introduction of n'spire from Texas Instruments and of Mathcad, respectively, to the students. The lessons were examined with the aim to see and understand relations between on the one hand, the teacher's presentation to the students of the new tool and his/her efforts to initiate students' generation of an instrument from this new tool, and, on the other hand, the teacher's personal view on mathematics and on the use of CAS and ICT for learning and doing mathematics.

The questions to the two cases were:

How do the teachers introduce the new tool (in the meaning of artefact)?

How is the students immediate reaction to the introduction?

What kind of obstacles might the students face in this case, which could support their resistentance?

How is the teacher's introduction related to his/her personal view on mathematics?

In both cases, teaching materials, videorecordings and field notes from observations of the first three lessons were analysed. Each of the teachers A and B was interviewed about his/her view upon mthematics and the teaching of mathematics with and without ICT. In the following, only a brief view of this materials and the analysis is presented, since the presentation serves to illustrate raher than document the two teachers' different approaches.

5. Teacher A

Personal view on mathematics and mathematics teaching

Teacher A is, according to the interview, fascinated by the inner structures of mathematics and mathematical proof. A is convinced, that her teaching reflects the fascination. Besides, A underlines the importance of mathematics as a usefull tool in many contexts. In her teaching, A often takes authentic problems or tasks from newspapers etc. as the starting point, to demonstrate for the students that mathematics is usefull and to let them learn to use mathematics. In A's opinion, the goal for the teacher is, that the students can do calculations, manage curriculum and pass the

examination but it is also important for her, that they learn to like mathematics. Summing up, A sees mathematics as beautiful and coherent body of knowledge that is extremely applicable in many situations.
Teacher A sees it as the major advantage of using ICT in mathematics that a larger number of students may have good experiences with doing mathematics even if they are less skilled in calculations etc. Another great advantage is the potentials for change of working style supported by tool which allow a quick test of new ideas or strategies. Finally, it is possible to introduce new subjects like statistics.
New tool should, preferably, be introduced explicitly to the students according to A, who believes that the time spent on learning to use the tool pays back.

First lessons with n'spire from Texas Instruments

The class was on second year, and they had had graphic calculators from Texas Instruments during the first year. The n'spire was under development at the time, and teacher A had signed up for a trial version for this class.
In the beginning of the first lesson, the class voluntarily split up: the students were supposed, in self organised groups, to solve a set of tasks and groups which wanted to stay close to the teacher for help could stay in the classroom whereas the other groups could go to the working areas outside the classroom. Half of the students left the classroom – one of these groups, were observed. Three girls and two boys formed the group which was well performing and showed very good working style. The tasks' topic is calculus: The first four tasks concentrate on determination of minimum and/or maximum of bodies in 3D, number five (the last one) ask for the exression for an eksponentially growing function based on a table of values. For this study, it is relevant to notice that when solving the first two tasks, the students managed to set up the right expression and find the derivative without troubles, changing fluently between paper and pencil and the handheld (n'spire). They all five made the calculations and compared their results, for example considering whether 5,84 was the same as 5,85 in different aproximations which lead one of them to do the exact calculation with the result 6. Another example is their comparison of the function's graph to the result, when they found the derivative, equaled to zero and pressed solve. The third task was more challenging: a figure in 2D was drawn in the text, the task was to determine the maimum area but the text did not reveal an appropriate choice of variable. The group spent long time on discussion of the expression for the area of the figure, composed by a halfcircle and a rectangel. They formulated an expression, but since they did not all known realtions between lenghts of sides etc., the expression contained too many unknowns. The students were not aware of this, whereas they conidered the troubles being a question of communication with the handheld, i.e. declaration of the unknowns as variables before solving th eequation. The discussion revealed this uncertainty: one girl asked: *but the calculator does know Π, doesn't it?* They came through, managed to remember the formulars needed, but one of the girls still experienced problems with the declaration of a new unknown. One of the boys succeeded, and passed the handheld around in the group.
In this group's work, the use of ICT can be characterised as close to 'invisible', meaning that the handheld attracted very little attention even if it was used appropriately. The girl's question about Π demonstrates, however, that the students were on thin ice, not at all used to the handheld.
Next step in the introduction was the next lesson's demonstration of solutions in the classroom.
The teacher's plan was to let individual students, on a voluntary basis, present solutions of the five tasks, using a view screen connected to the n'spire. One student conducted the presentation, A helped with commands, made comments etc. Once, for example, A mentioned: *one advantage now is, that we do not need to calculate this product and take the risk of making errors...* (about the expression for the function to be derivated). There was very little light on the viewscreen, though,

so it was almost impossible for the students to see what was going on. A kindly asked the student to say laud what buttons he pressed. About two thirds of the students followed the instructions, using their own handhelds. Task number three, which caused the group troubles the day before, seemed to be difficult for the rest of the students too. Many students raised their hands for help. Their problems, apparently, were a complex mix of too many unknowns in the equations and uncertainty or lack of knowledge about how to declare variables on n'spire, besides the invisble viewscreen. A switched to the blackboard and wrote the appropriate expression. A and the student reached to give a complete explanation before the lesson was finished.

6. Teacher B

Personal view on mathematics and mathematics teaching

Teacher B, who is an experienced user of Mathcad, was the author of teaching sequences for self study in Mathcad [2]and a co-author of a, partly web based, textbook system for upper secondary school also using Mathcad.Teacher B, according to the written answers to the interview guide's questions (in Danish, my translation), consider mathematics composed of theory and practice. In his teaching, B puts weight on both oral and written communication and he wants to leave the impression by the students of wel-structured, goal directed, relevant and engaging mathematical activities. In B's opinion, the goal of teaching mathematics is that everybody sees mathematics in connection with other school subjects. Depending on the individual student's level of talent and interests, he or she must be offered support to reach learning goals varying from the nation's highest to everyday understanding and use.

B sees the pervasive use of ICT in his mathematics teaching as one way to appear up-to-date and as a means to differentiate the teaching activities according to the individual student's needs. Another advantage is the introduction of new approaches like for example 3D geometry or regression. The introduction of new tools in mathematics should, according to B, take place during the mathematics lessons whereas a more general course for students who needs help with searching, updating and downloading etc., offered at school level, would be desirable. B agrees that the time students spend on learning the ICT tools in mathematics pays back, but this is an issue of discussion at his school.

First lessons with Mathcad

The class was on first year, all students had a laptop and used this textbook. The introduction of Mathcad had to take place in the computer lab with use of the school's computers, because the students' own laptops were set up with vista which was not compatible with Mathcad14. The first lesson started in the classroom. B gave a demonstration of the solution of a task on his own laptop, using Mathcad and the projector. The method was presented to the students, followed with advices and explanations about Mathcad and reflections on the use of Mathcad, like for example: *Learning Mathcad is a hurdle you have to overcome.* B gave detailed information about format, graph, toolbar and other ocmmands. Told the students, that they had to reconstruct the same solution on their own in the computer lab. The class moved to the computer lab, formed pairs or triples around the compuers, started up etc. This break would have been avoided if the laptops had been ready but unfortunately, the schools' ICT resources were insufficient for that. The students were well disciplined, only a little smalltalk. Two pairs were observed, they managed to reconstruct the solution of the first task. They came through a number of different commands and got a feeling of Mathcad being a good tool. B went around in the lab and helped, told for example one pair of girls that *we cannot say what went wrong – sometimes you just have to try again.* A little later, B told another pair that they had to change the order of equation and variables, but *that was the only*

[2] Excerpts from this materials will be demonstrated during the presentation of this paper

mistake you made. The atmosphere was good, relaxed and kind but focused on work. The pairs were helpfull to eahother and apparently, most students were satisfied with their work and results.
Next step in the introduction also started in the classroom and continued in the computer lab. The students allready appeared more experienced. Some groups were too big, for example in one group of six persons only half of them were able to reach the keyboard.
B deliberately offers his students solution sheets with most of the homework tasks. The idea is, that nobody should get stuck in trying to solve a task. The individual student must (learn to) be responsible for his or her own intellectual development. In discussions with colleagues and others, who regards the students' use of solution sheets while making homework tasks cheating, B claim that such kind of cheating only harms the student's own learning and consequently, the students must show responsibility and give themselves a chance to learn by trying on their own hand before they might use the solution sheets.

7. Discussion

Both of the teachers, in this study express that they feel an obligation to specifically teach the students how to use the mathematical technology to the students. In the classroom episodes, however, they approach this task very differently.
Teacher A allows the new technology to be included in the class problem work in a natural way, and not surprisingly, the appropriate use of this technology is rather sparse in these first lessons.
In our interpretation, teacher A simulates an adicdactical situation with regard to use of 'spire during her teaching of the students' first lessons with the handheld, meaning that focus is on strategies for solving the tasks, on the organising the group work and on the mathematical content of the task, i.e. on calculus. Technology may be regarded just as a part of the environment in teacher A's class. It is one of the choices and solution strategies that the students can choose to use.
Teacher B, on the contrary, uses the first lessons with the new technology to get acquainted with the technology. In teacher B's class the introductory use of technology is very much of a didactical situation, in our interpretation. The students are asked to work and learn the tool, and trust the teacher when he claims that it will pay of in the long run.
We can see advantages and disadvantages of both these approaches:
The 'adidactical' way chosen by teacher A gives the students an opportunity to develop his or her personal strategies and methods for use of the tool, in accordance with his/her existing strategies and preferences based on earlier experiences with mathematics. Such opportunities may support the individual students'genesis of the handheld as a personal tool. On the other hand, the 'adidactical' approach challenges the teacher who's help may be requested any time when one of the students needs technical, technological, strategic or mathematical advises.
In classes where technology was introduced through a purely didactical situation, as teacher B did in the case, the teacher can push the students towards the technology and directly instruct them in how to use it. Apparently, this is one way to overcome the students' resistance and to avoid the risk that they never get to know the technology and develop a personal instrument. One big challenge to the teacher to deal with within this approach is the risk, that the hard work the students need to go through in order to use ICT competent and develop a personal instrument, can be experienced mainly as a kind of didactical obstacle, having to do with curriculum and the teacher's claim, rather than to with getting directly involved with mathematics.

8. Conclusion

At a first glance, the two teachers A and B in our case seem to have very different appraoches to the use of technology in mathematics: A, apparently, takes the 'invisible' point of view meaning that

focus should be on mathematical content, strategies and applications etc., whereas B, besides the mathematical content, focus on the tool, it's potentials, techniques and technological language.
But scratching the surface, we find that the two teachers' conception of what mathematics is and what it is to teach mathematics do not differ significantly. When it comes to the use of ICT in mathematics education the main difference in their viewpoints, has to do with the extend to which the students need to learn to calculate without the use of ICT, and even here the differences are not large (teacher A emphasises the need to be able to calculate more than teacher B).
In our interpretation, we see no discrepancies between the personal views on mathematics, on teaching mathematics or on the role of technology in mathematics by each of the two teachers on the one hand, and the choices they had made for the introductory lessons on the other hand, in our study. The study may serve to explain, then, what made the two teachers, sharing similar ideas about mathematics and the teaching of it, realise so different approaches to the design of ICT-introducing lessons? We have identifyed three factors of different types:
1) One factor of importance, obviously, is the extend of expected use of the software: working with Mathcad necessarily encompas preparation of written documents (homework tasks etc.) whereas n'spire might be used only in addition to paper and pencil in written homework etc. In our interpretation the n'spire teacher expect the students to gradually progress in the process of instrumental genesis with his/her own speed in a self-regulating manner. In this case one could expect a balanced genesis of the instrument, where the instrumentation and the instrumentalisation parts of the process were equally weighted. In contrast, it would be too much of a bite for the students to develop skills on their own, sufficient to fulfil the request of MathCad homework tasks. Hence, the instrumentation part of the instrumental genesis, in this case, dominated the introduction on the behalf of the instrumentalisation.
2) Another factor, which concerns the teacher's view on students rather than the view on mathematics etc., is the expected emergence of students' motivation, which raises the question whether it is the teacher's obligation to motivate the students for learning to use the tool, or if the social norms of the classroom will initiate and support development of motivation? The construction of a suitable, didactical contract may follow different paths according to these different expectations by the teacher. This second factor may serve as an example of what Skott argues to include into the notion of teachers' forced autonomy, namely an example of the multitude of other obligations that emerge in the course of the classroom interactions.
3) The last factor we want to point out, based on our study, concerns the complexity of forced, extra obligations, related to different aspects of the introduction of ICT tools into the classroom, which in particular, in our opinion, should also be included into this notion. In the first part of the case, teacher A had planned to go through the solution of tasks using a viewscreen as a medium for communacation in the classroom. The viewscreen would, according to teacher A's plan, have served as an important means for sharing students' experiences and developing skills in handling the handheld and, thereby, as a means for motivating the students to learn to use the handheld. Unfortunately, the viewscreen did not work. Firstly, the teacher asked the student in stead to tell what he did, but secondly teacher A, realising that this was far too complicated for the students, decided on the spot to skip technology and finish the task using the balckboard. In this way teacher A managed to: finish the task with clear explanations, end the lesson in a good atmosphere and demonstrate to the students, that even if they might walk on thin ice, the teacher was there to rescue them in case. In the second part of the case, the teacher had planned to introduce Mathcad to the students in the classroom, with the projector ready for shared demonstrations and calculations with related classroom discussions. But, unfortunately, the laptops were not ready for this, so the student shad to start in the classroom and then break up, leave the classroom with the projector and go to the computerlab. The teacer B managed to compensate by walking around in the lab and give

similar help, explanations and challenging questions to all the groups of students. Discussions around a shared solution mediated by the projector, though, was missing.

To sum up: Our study shows that even if two teachers share a certain view on mathematics, and on teaching and lerning mathematics with and without ICT, this view may be expressed in two very different ways of introducing ICT in the mathematics lessons. This serves to underline the need of expanding the notion of teachers' forced autonomy to encompass not only the teacher's conceptions of mathematics and of learning mathematics, but also of the multitude of other obligations that emerge in the course of the classroom interactions. In particular, we see a need to include the complexity of forced, extra obligations, related to different aspects of the introduction of ICT tools into the classroom.

References

[1] Andresen, M. (2006a). *Evaluering af delprojektet Matematik med CAS – matematik i 3.g* (In Danish) (Evaluation of the sub-project Mathmatics with CAS – mathematics in 3rd year) both located 1 juli 2009 on www.matnatverdensklasse.dk

[2] Andresen, M. (2006b). *Taking advantage of computer use for increased flexibility of mathematical conceptions.* Danish University of Education. (Ph.D. thesis)

[3] Andresen, M. (2007a). Modelling with the Software 'Derive' to Support a Constructivist Approach to Teaching. 15 pages. I: *International Electronic Journal of Mathematics Education,* 2(1). ISSN: 1306-3030 http://www.iejme.com

[4] Andresen, m. (2007b). *Midtvejsevaluering af delprojektet CAS og IT i matematikundervisningen del i projektet Danske Science Gymnasier*(In Danish) (Midway evaluation of he subproject CAS and IT in mathematics teaching, part of the project: Danish Science Gymnasiums) http://www.emu.dk/gym/tvaers/sciencegym/evaluer/cas2007.pdf loc 30 july 2009

[5] Brousseau and Balacheff (1997) Theory of didactical situations in mathematics, Kluwer academic publishers Dordrecht Netherlands

[6] Petersen, A. W., Pawlik, E. and Andresen, M. (2004). PC'en i brug: Erfaringer fra gymnasiets højniveau i matematik, fysik og kemi (in Danish) (The PC in use: Experiences from upper secondary high level in mathematics, physics and chemistry)

[7] Povey, H. and Ransom, M. (2000). Some undergraduate students' perception of using technology for mathematics: tales of resistance. In International Journal of Computers for Mathematical Learning 5:47-63. Kluwer Academic Publishers. Netherlands

[8] Skott, J.(2004). The forced autonomy of mathematics teachers. In: Educational Studies in Mathematics 55: 227-257, 2004. Kluwer Academic Publisher. Netherlands.

[9] Trouche, L. (2005). An instrumental approach to mathematics learning in symbolic calculators environments, in the didactical Challenge of Symbolic Calculators, turning a computational device into a mathematical instrument, Guin, Ruthven and Trouche. Springer.

[10] Verillion, P. & Rabardel, P. (1995). Cognition and artifacts: A contribution to the study of thought in relation to instrumented activity. European Journal of Psychology of Education, 10 (1).

[11] Vergnaud, G. (1996) The theory of conceptual fields. In: L. P. Steffe, P. Nesher, P. Cobb, G. Goldin, B. Greer (eds), Theories of Mathematical Learning. Lawrence Erlbaum, pp. 219-240.