

ICT TOOLS AND STUDENTS' COMPETENCE DEVELOPMENT

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ABSTRACT

In this paper I will present the rationale that motivates the study in an ongoing three-year project following students in school years 8 to 10. The aim is to develop the students' competence with use of ICT tools in mathematics in such a way that they will be able to choose tools for themselves, not rely just on the teacher telling them what to use for a specific task. Experiences and results from research emerging after more than two years will be discussed.

BACKGROUND AND AIM

Based on a constructivist view of learning, the curriculum guidelines for Norway (KUF, 1999), state as an aim that students should develop their knowledge and understanding of the subjects, and independence and self-reliance in their learning. The students should be stimulated to find solutions by explorative, experimental activities, be encouraged to ask questions and investigate different representations and present arguments during their work. Tools like a spreadsheet, a graph plotter and calculators are explicitly mentioned in the curriculum. We find similar recommendations in the NCTM Principles and Standards for school mathematics (NCTM, 2000) and other curriculum plans.

The aims stated in the curriculum guidelines form the background for an ongoing project over three years with students in school years 8 to 10. The students should develop their competence and self-reliance to choose suitable computer tools, not just rely on a teacher telling them what to use for a specific task. The students should learn when and when not to use computer tools, and which ICT tools to use.

The research aims to investigate how students develop their knowledge of the software tools and ability to judge choice of tools and to what extent, if at all, it is possible to achieve the goals in the curriculum guidelines. In this paper I will present the rationale and basic ideas for the project and outline the way we work to achieve our goals including illustrative experiences from classroom practice.

TOOLS FOR MATHEMATICAL TASKS

By ICT tools, or computer tools, in our project, we think of software that makes it possible to use computers to perform tasks that are planned and decided by the user. This means software that is open and flexible, not limited to pre-designed tasks. With such open-ended software tools we can provide learning situations where the students can experiment with mathematical connections, find patterns and be stimulated to develop mathematical concepts and understanding. These can be utilised both to learn mathematics, to learn to use and to choose appropriate ICT tools for problem solving.

Different kinds of technologies and tools have been used for centuries in mathematics. We can think of tools for measurement, calculations, mathematical notation, symbol systems and written language; cognitive technologies that helps transcend the limitations of the mind (Pea,1987). Computer software is an especially powerful cognitive technology for learning mathematics. This can take the form of an amplifier, which means doing more efficiently the same as before without changing its basic structure. Pea and Dörfler argue we should regard ICT tools as reorganisers. This have wide implications for the objects we work on, in our case mathematical objects, and lead to more activity on a meta level with more emphasis on planning and judging methods (Pea,1987; Dörfler,1993). ICT tools will be a part of the cognitive system: computer visualisations will extend and expand the students' cognition and should be available at any time. This has implications for the kind of software that we chose as tools in mathematics classrooms. Suitable software give opportunity to develop conceptual fluency, provide an environment for exploration and investigation, integrate different representations and stimulate reflection (Hershkowitz et al., 2002).

The CompuMath project which provides long time experience on the use of tools in curriculum development (Hershkowitz et al., 2002), in addition, emphasises the potential of the tool to support mathematization by students working on problem situations and the communicative power of the tool. All the criteria are closely related to the multi-representational nature of the tools, which make it possible to do manipulations of objects and transformations between different representations.

What would then be appropriate tools to use for the students in years 8 to 10 in schools? We think of tools that have more than one kind of use, tools that could be applicable to different content areas, and could be easily available. This means we would look for the generality of the tools, not software produced to cover specific limited areas in the curriculum. A spreadsheet is a good example of such a tool; it is easily available, can be used in many contexts and has become a standard tool in many working places. It can be used to store and analyse data, create number patterns and sequences by general rules and present data graphically.

In the project we use a spreadsheet, Excel, a graph plotter, Grafbox, and dynamic geometry, Cabri. These tools all have the sufficient openness and flexibility to give opportunities for experiments and explorations, which we see as important in developing mathematical concepts according to a constructivist based environment. We also included the use of Internet resources, mainly thinking of collecting information and data to use when that is appropriate.

THE ICT COMPETENCE PROJECT AND METHODOLOGY

Three schools with six teachers and six classes participate in the project with me as researcher. The project leaders, a teacher and I, provide some ideas and material for use in classes, both new and existing material. Software tools, experiences and new ideas have been discussed in project meetings every term. The teachers are

responsible for what and how they implement material in their classes. To some extent the teachers also develop their own material, like prepare spreadsheet models for tasks, and make them available for the rest of the project group.

The schools were selected because we knew they had some experience using computers in mathematics classroom before. But still, some teachers had limited experience and few ideas how to use computer tools in open tasks and admitted they had to learn from others. The project also provides a good opportunity for this.

The activities in the project classes were integrated in the ordinary lessons, and the mathematics teachers are responsible for planning activities.

The project builds on constructivist and social constructivist views of learning and the methodology of the project has aspects of action research and developmental research. Development of teaching ideas for use of the software and support for teachers' competence development was important to support the research and give opportunities to study students' competence development. The research focus implies use of qualitative methods of data collection.

I and a research student visit classes during their work on computers acting as a participating observer and helping teacher. We write field notes and record with audiotape. The teachers write short reports from their use of ICT in classes, including what tasks they used and short comments. Students' material in written and on computer files are collected. This material are analysed and compared with observations. In the last part of the project we plan a period of close observation of students' work and interviews with some students of different ability, using audio or videotape. A questionnaire will be given to all students.

As part of the project we investigate methods of analysing the data and categorise outcome concerning students' competence in stages as described in next section. The final evaluation will take place after this paper is written, but some experiences and results can be reported here.

STAGES IN DEVELOPMENT OF COMPETENCE

It is necessary to learn some basic features of the software tools. Insight in what is possible and some fluency with the tools is necessary for students to be able to judge what to use. We need to build this competence over time, and not just leave it to the last part of the students' education. Based on our work in classrooms and recent literature, I, in consultation with the teachers, have designed a developmental framework in three stages.

1. Basic knowledge of the software tools. The students can utilise the functionalities of the software to solve simple tasks prepared for it, when they are told what software to use. For example this could be to make formulas in a spreadsheet when the main outline of the task is given or to use a graph plotter to plot a function when the formula is given.

2. Develop simple models. The students can make the layout of text, numbers and formulas to plan a model for a spreadsheet. For a graph plotter they could judge what functions to draw, use different scales on axis, zoom in or out. Be able to use dynamic geometry to make constructions that can resist dragging, i.e. the figure do not fall apart when parts of it, points or line segments, are moved.
3. Judge the use of tools for a given problem. The students should be able to think of different ways and means for solving a problem, which software is most appropriate to use or when other methods are better.

Development of mathematical competence is involved in all stages. In preparing a formula on a spreadsheet, students gain experiences expressing mathematical connections and further experiments often require use of variables or parameters. In order to develop models or drag resistant geometrical constructions, they have to analyse the situation and build a model according to mathematical rules. The use of computer tools gives the students access to ways of expressing their mathematical models and experimenting with them.

In order to develop their competence the students need experience with different kinds of models and modes of using the software. A variety of applications that use similar patterns can help to form general models for using the software. For example, on a spreadsheet, many problems can be solved using a model similar to a shopping list, the “shopping list model”. Another is the “number pattern model”: number sequences that can be adjusted using fixed reference to a parameter that is important in the model, and experiment with this. Some basic techniques are necessary, and experience from several applications will help to generalise and build knowledge of models.

Introduction of new tools changes the teaching and learning situation. We can not just introduce a new tool and expect everything to be the same (Pea, 1987; Dörfler, 1993). Good use of the tools implies change in teaching and working style and in the tasks presented to the students. In the next section I will discuss teaching principles we developed and intend to use in the project together with some results.

TEACHING STRATEGIES AND EXPERIENCES

In order to develop competence to choose suitable computer tools, some main points should be emphasised in a teaching strategy. These emerge from analysis of data in the project and from other research dealing with ICT and students’ work experimenting and exploring with mathematical connections.

Motivation. A scrutiny of the data analysis suggests that motivation is a crucial point for the students to engage in a problem. We have seen variation in from students’ engagement in tasks that they need to see there is a problem of interest. Challenges appear more interesting than routine and tasks with easy solutions. Cognitive conflicting situations and surprising results can be utilised in this connection (Fuglestad, 1998). I observed several times, when students made a figure using Cabri,

and tested by dragging, they had surprises and were challenged to further experiments. There were a lot of discussions and sharing of ideas among students of how to solve the problems. Generally, I observed that many students at the start were motivated to use computers, but this only lasted if the tasks involved also were interesting to them. In a study by Hölzl (2001), presenting an open task, with opportunities for experiments and less obvious answers, the students became strongly involved in investigations. I often observe similar activity with children's learning to use mobile phones with text messages. The high motivation stimulate them overcome the technical difficulties.

Basic features and step by step. It is necessary to know basic features of the software in order to utilise tools. These can be taught in connection with interesting tasks. Our experiences supports the idea to build knowledge from the simple models, step by step without jumping to more sophisticated solutions before the students have experience to understand. For example instead of building a formula with several operations, we have introduced more columns in a spreadsheet to tackle the challenge. Interesting problems can be faced even with limited facilities of the software. We need tasks designed to cover the most common models used for example in a spreadsheet, and the most common properties of geometrical constructions in dynamic geometry.

The topic of some lessons was economics, calculations of salary and taxes. The teacher prepared a file to load into Excel with the framework given and necessary information about the rules for calculations. The students' task was to understand the rules and complete the model by putting in the correct formulas. The tasks aimed at giving some experience using a model and making formulas on a spreadsheet, learning how to use a spreadsheet, and in this way covering parts of necessary basics of a spreadsheet. At first it seemed that most students worked well and some of them were able to make the formulas they needed. However, when I observed closer and discussed with some students, I discovered that the model was complicated and they needed help to develop the formulas. The main problem was that more than one operation was necessary in order to prepare the formula in a given cell. I would suggest giving more intermediate steps in some calculations. The model itself seemed to be more complicated than using the spreadsheet for these students. The task also revealed that some students had problems of understanding how to calculate percentages and proportions of an amount. Similar experiences were observed in other lessons and in my previous research and support the teaching strategy of building from simple models step by step.

Same problem, different tools and methods. Different tools can be used for a problem and different methods using the same tool gives the opportunity to judge and discuss what would be a good solution. In this way students can learn about the suitability of different tools or consider the alternative using just paper and pencil. From an analysis of computer files from students' work on Cabri, I found very different solutions to make the same figure. The students were requested to write a description of their methods, so we could understand their thoughts. We also

observed that students engaged a lot in discussions about their solutions and shared ideas. Using different tools for the same problems have been less explored in the project, but some ideas were developed.

Limited knowledge concerning students' choice of tools is perhaps due to the fact that the tasks are often presented together with the representations and tools that should be employed (Friedlander & Stein, 2001). This seems to be the case in many classrooms, and can be confirmed by looking into school textbooks, official examination tasks and other material. Different methods supplement each other and show a variety of models and representations of the concepts. Students own questions gave good starting points for problems to explore, with computer software as a powerful tool to make sense of information and examine different approaches to problems (Moreno-Armella & Santos Trigo, 2001). In their study a problem posed by a student, was solved in three different ways using computer tools, and later discussed in the class.

Themes and open tasks. We have used open tasks that could be interpreted and solved in different ways with different tools to give the students the option to choose and try out different tools.

With EURO in the pocket, planning a journey was the theme of work in several lessons in two classes. The students had to plan a journey through five countries in Europe, with a commission to accomplish, but with no specific tasks. They had to set the tasks like to convert between currencies, make budgets, make travel plans using a map and timetables and other tasks related to their specific task description. The information could be found on the Internet and they could choose a spreadsheet to prepare tables and make calculations. Observations revealed that some students had problems getting started. After some lessons the teachers reported good activity, and were quite satisfied with the results from some of the groups. Generally the task appeared too open at this stage, giving limited help to get started. The students needed to get used to this way of working and discover the mathematics involved.

Another class had visited a local chemical factory as part of a project work over some weeks. Back in class the students were given four pages with some data and information about the production and Internet links to resources about the factory. There were no questions given, just the challenges for the students to set their own tasks and use the data and material provided, and with encouragement explore what they can do with given data using computer tools. I observed their work and data files were collected and later analysed to look for students' solution methods.

I observed a good working climate and good motivation. Students made tasks on different levels of difficulty, with the possibility to extend the tasks for students who could manage. The observations revealed a variety of tasks and at different levels and some tasks were quite demanding. In some cases students looked at their peers to get ideas, and were challenged by what other students suggested. They shared their ideas and discussed solutions. A similar working method have been used in this class both

before and after, with similar experiences. In a local examination set by the class teacher two weeks later the students were given tasks from the same material and some simple geometrical figures to draw. I observed the students explained their work and found to a large extent they were able to explain their ideas and results. They also discovered their mistakes and seemed to learn from explaining their results.

Reflection and discussion. We found that reflection and discussion are necessary in order consolidate and be sure the students understand the main points in question. In this connection students were be requested to write down their hypothesis before they start exploring patterns and connections and report findings and new questions. In work with Cabri they were requested to describe their constructions. Reflection does not usually occur spontaneously but have to be initiated and writing reports give good help in this connection (Hershkowitz et al., 2002). Drawing conclusions and revising the results are important to get the full value out of the work.

Teachers' intervention: We found in our research, although the teachers had some experience, they expressed they needed help to develop their competence about the software and of how to design teaching modules and tasks utilising ICT tools. In particular, an extra course was set up, and project meeting we discussed the implementation in classes. Developing teachers' competence became an important part, and I think we need more development of this in further work. The teachers' role changes with the introduction of ICT tools and their influence can be crucial at some critical stages in the lessons. Introduction and motivation with examples and challenges at the start and summary and reflection at the end is necessary, not just presenting the solution, but drawing on students' work to reflect over the hypothesis and results (Hershkowitz et al., 2002). During the work, at some important steps, the teacher might intervene, ask questions and point to certain examples to try. Students may not discover important cases to try and in such cases an extra question or suggestion could be the clue to further discoveries e.g. (Fuglestad, 1998). In my observation and interaction with students, I often experienced there was need for just small hints for them to go on in their work, not to give answers but ideas how they could find out themselves. To develop competence to choose tools, the students need to have the option and challenge for that. The presentation of problems and representations of mathematical concepts and choice of tools have deep influence on students' concept development and learning, and implications for later use of ICT tools (Kendal & Stacey, 2003). During the observations and from teachers' report, we had some cases where students also clearly expressed their choice or preference of a tool over another, but so far not many cases.

CONCLUSION

Can the kind of tasks and working methods presented here help students later to judge ICT tools as an option for their problem solving? If at all, to what extent is it possible to see that students achieve a competence to use ICT tools and decide which one is suitable for a particular mathematical problem. We found the description

giving stages in development, although fairly rough; can help to judge the results. At this stage, a few months before finishing their year 10, most students' competence can be described like stage 2 and a few on stage 3.

From the observations so far, and teachers' comments, there is still more to learn to develop students' independence and self-reliance in these matters. In particular, in a new project we have to focus more teachers own competence development.

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