THE USE OF ICT TO SUPPORT CHILDREN'S REFLECTIVE LANGUAGE

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The importance of language and learning with different artefacts in mathematics education is the focus in this paper. The language in a communicative situation or activity can be understood as a means of constructing meaning. The importance of context, different artefacts and communication in the teaching of mathematics is visualized through analyses of preschool, year 1 and year 2 in pupils´ work with numbers and place value. Through participation and interaction, in the dialogue and by using different kinds of artefacts, students develop new patterns of meaning that may facilitate their learning of mathematics.

Keywords: artefact, computer, tablet, reflecting, mathematics

INTRODUCTION

My interest is in how pupils in school learn or are taught number sense and place value problems. A socio-cultural perspective (Säljö, 2000: Vygotsky, 1986; Wertsch, 1991) on human development, reasoning and arguing implies using linguistic and physical tools to analyze and make claims about events in the world. Using this perspective, I am interested in how people reason and argue about how they quantify and mathematize. In particular, how mathematizing and reasoning are connected through making a claim or to proving a point in a conversation. This involves people moving between everyday discourse and analytical language. The focus of this paper is on how the language and physical tools in a communicative situation or activity could be understood as contributing to the construction of meaning. The importance of context, tools and communication in the teaching of mathematics is identified from analyses of first and second grade pupils´ work with number sense and place value.

In the new Swedish curriculum (Skolverket, 2011), pupils are expected to formulate and solve problems with mathematics, to formulate strategies and methods, to use and analyze mathematical concepts and relations between concepts and to use the language of mathematics in order to explain and justify what they have done. To see how different artefacts and communication affect the gaining of this knowledge is important for teachers. Learning and knowledge about the surrounding world begins in what can be called the life world. Nevertheless, there is a dissonance between the environment in and outside school, especially in regard to mathematics as a school subject. Consequently, pupils´ interpretations of real life problems may become obstacles to their learning in mathematics.

From a socio-cultural perspective, the question becomes one about how knowledge and information are learned and how this learning changes in new surroundings (Lave & Wenger, 1991). All activity, including the mental processes of thinking and

reasoning, is mediated by tools and signs. Knowledge is developed through the cultural tools that are in the society (Vygotsky, 1978). Pupils in school have an ability to use artefacts from the real world. The artefacts change the relationships between people and the world around them. For example, when teachers introduce signs and symbols in the teaching of mathematics they try to mediate from a real world to a mathematical model. The teachers use language, pictures, symbols, signs, words and so on, when working with physical tools in order to get pupils to understand the mathematizing. However, in spite of the use of these common artefacts, pupils often have difficulties in learning mathematics, because they are not able to use their knowledge and see mental pictures. In this study, I describe how pupils mediate with artefacts and each other and the relationship between different artefacts and types of pupil talk. From a socio-cultural perspective, the mediation is very important. Therefore, the research question is: how does the interaction between pupils and their choice of language change when they use different artefacts in mathematics?

DIFFERENT KINDS OF ARTEFACTS

Wartofsky (1979) describes three different kinds of artefacts which are used in learning. These are categorized as primary, secondary and tertiary (Wartofsky, 1979).

Primary artefacts can be tools like axes, clubs, hammers, pins, computers, and mobiles. They can be use directly in the production process and are based on utilizing people's strength to solve different kinds of problems. However, understanding how to use those artefacts involves understanding the special surroundings where they are used. In this way, they help people to understand their world and to participate in the lives that they lead. In schools, there are many primary artefacts, usually called concrete materials or manipulatives, used in the teaching and learning of mathematics. These can include stones, bottle tops and Cuisenaire rods. Primary artefacts can be used without knowing how they contribute to the task that they are used for. As well, they can be talked about without knowing how they perform the teaching and learning job that teachers expect of them. However, this complicates the teaching and learning process because the purpose of the tools remains implicit.

In the current era, it is necessary to understand how to use tools such as the computer and the tablet PC in order to learn how to live in the world. Thus, communication and knowledge change with these new artefacts. To use a mobile phone, the user has to understand how to handle it and therefore they have to study the instructions. This requires having the knowledge to comprehend what they are reading and then translating it into an understanding of how to use the mobile phone. Secondary artefacts are tools that provide models of how to use the related tools, such as the instructions for a mobile phone, and how to think about how to use those tools. They are externally embodied representations that collect and describe information. Secondary artefacts control decision making and planning processes. There are many of them in everyday life, such as recipes, drafts, designs and ways of classifying the world. In mathematics education, secondary artefacts are things such as mathematics

textbooks. The pupils learn how to study and also solve a mathematics problem from the textbook.

However, when primary and secondary artefacts are used at the same time, then it could contribute to the teacher teaching in one way and the pupils learning in another. In the following example, the teacher provides a primary artefact such as tenths blocks which the students are expected to use to illustrate whole numbers and decimal fractions. The instruction is:

2,1	1,9	0,8	0,01	1,25

Use the material to represent these numbers, then have a friend write the amount that they see as numbers with decimal fraction parts. Discuss!

Write your own five numbers and let a friend put it in a place value table. Discuss!

The pupils listen to the teacher and try to translate the information into specific actions. To do this, they must position the material, primary artefact, appropriately, study written instructions, secondary artefact and discuss what they are doing. In the second part of the activity, they still use a secondary artefact, the written instructions, but this time they produce new numbers which a friend must then illustrate with the blocks. The exercise could be changed so that the pupils would need to use new tools. For example, the pupils could use an empty number line on which they would have to put their own numbers and find the difference between the numbers. Alternatively, they could work with computers to construct, change and compare the numbers and talk about what happens and why. When the pupils have used a variation of tools and language they can reflect and talk about their knowledge of decimals (Riesbeck, 2011).

Tertiary artefacts are tools that help people construct new knowledge through reflection and communication. In order to learn mathematics, pupils need to not only see and translate information but to know how to mediate knowledge with tertiary artefacts so that they develop their thoughts and representations of their understandings. Thus, it is important for teachers to understand how to move from having students use primary artefacts to developing their reflective skills from using tertiary artefacts.

For example, if pupils can construct geometrical figures using a computer program, they can think and talk together, including critically discussing issues as they arise and finding new forms of arguing. Communicating and language are very important to all human learning and it is through new language and tools that we develop new knowledge. Through using language as a tool, human beings understand and construct new knowledge (Säljö, 2005).

Wartofsky (1979) suggests that people are dependent of artefacts in their doing and thinking. Primary artefacts help when people want to have a better understanding of the physical meanings connected to the world. On the other hand, secondary artefacts

help us in our communication and understanding of the world and physical tools, whilst the tertiary artefact is a thinking and creative tool.

THE DIFFERENT LANGUAGES CONNECTED TO THE ARTEFACTS

The descriptions of the three kinds of artefacts suggest that all artefacts are needed for learning but the tertiary artefact has extra significance, because of the reflective language, associated with it and how this contributes to learning. The use of different artefacts affects what languages are used. As Vygotsky (1986) put it, thought and language are a parallel project. In this perspective, knowledge develops in interactions between people and between people and tools (Kozylin 1998; Vygotsky, 1978). Pimm (1987) suggested that in any mathematics classroom there are many languages. Pupils use conversational language which they learn at home or with friends. Pupils also use a more mathematical language to talk to each other when they use concrete materials to learn and do mathematics. The symbolic language of mathematics is used when pupils incorporate mathematical concepts into their arguing about how to solve the problems. There is also evidence of a reflective language when the pupils discuss and answer questions about why a specific answer is correct or if a solution is sufficient (Verschaffel, 2002). Therefore, when pupils learn mathematics they use different languages depending on the kind of mediating tools they use.

In mathematics education, when pupils are expected to learn only through textbooks, their language and thinking are connected solely to that of the secondary artefact. Pupils can work with primary artefacts, such as the book, doing the same type of exercises without thinking or reflecting (Johansson, 2005). If they can translate the text into actions, they can become familiar with the problems in the text book, thus the textbook becomes a secondary artefact.

However, when the goal is to learn mathematics, pupils need to talk about what they had read and to understand the new knowledge specified in the curriculum (Hunter, 2007). A dialogic discourse, where pupils learn to question, argue, explain, justify and generalize will be achieved through the models provided by teachers and others in interactions with different artefacts (Riesbeck, 2008). Through using different kinds of reflecting questions, classrooms of mathematical inquiry which support language and thinking can develop (Hunter, 2007). For this to happen, it is necessary to work with tertiary artefacts.

The concepts of context, mediation and artefacts are central to the sociocultural perspective. The concept of context can be described as being the environment where the action takes place. Mediation implies that human beings interact with external tools in their perception of the world around them. Linguistic as well as physical artefacts are created by people to perform actions and solve problems. Using semiotic tools, one can demonstrate how a linguistic element is connected to its meaning.

METHODOLOGY

The research question was how does the interaction between pupils and their choice of language change when they use different artefacts in mathematics? The most appropriate way to describe the languages connected to different artefacts is by using the semiotic triangle. The semiotic triangle, as seen in Figure 1, is made up of thoughts, artefacts and symbols which illustrate the possibilities for mediation. In this study, it is used when analysing student interactions when they are talking about numbers with different kind of artefacts. The semiotic triangle is a tool to analyse the material in this study. As the teacher and pupils use different artefacts, the language and thinking is changing depending on which artefact they use. This means that the teacher chooses an artefact for the children, such as a situation from a story or blocks on the computer that they can use to understand place value. Their talk in this situation can be analysed for the symbols or concepts that they use.

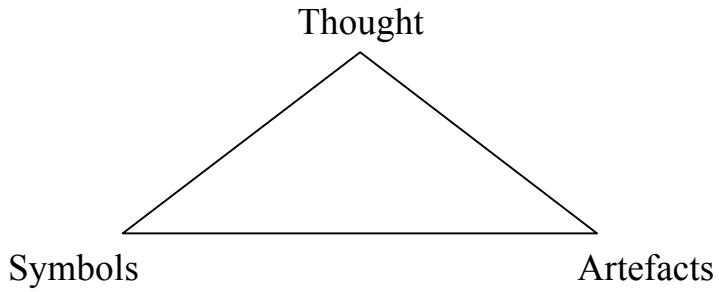

Figure 1. Mediation

The study investigates the same set of pupils and their teacher as they moved between grade 0 (förskoleklass), 1 and 2 in a Swedish school for three years. Audio and video recordings were used to collect the discussions in interactive situations between the teacher and the children or between a child and another child.

RESULTS

The children were six years old when the study began. The recorded lessons were about numbers and the teacher stood at the front of the class and used an interactive whiteboard. The number five appeared on the interactive white board. The teacher and the children talked about this number and their interactions were about the pictures of different symbols. The children went up to the board and moved things like rabbits, numbers and symbols whilst they counted one, two, three, four and five. Then they sat in groups working with concrete material and talking about them. The teacher followed this activity up by returning to the interactive whiteboard and showing a film about the number five. After this the children sat in pairs in front of computers putting lines for five dividing II and III and IIII and I. This lesson illustrates the use of primary, secondary and tertiary artefacts. During this preschool class year, lessons using the interactive whiteboard and the computer and the teacher having a dialogue with the pupils about numbers happened every week.

In the following year, when the children were seven years old, the teacher started one lesson about the little zero. Pictures from an actual book and on the interactive

whiteboard are shown. The following transcript is an excerpt from that lesson. In the transcript, L stands for the teacher whilst E stands for pupils.

L: Do you remember the book we read about the little zero? How was the little zero? How did the little zero feel in the beginning? Tell me! (Kommer ni ihåg när vi läste en bok om den lilla nollan? Hur var det med lilla nollan? Berätta för mig).

E: It felt very lonely. (Den kände sig ensam).

L: How did the little zero feel when he had said hello to everybody in the houses? What did all the other numbers say to him. (Hur kände sig lilla nollan där mot slutet när han hade hälsat på I alla husen? Vad sa de andra siffrorna?

E: That he was nothing. (Att hon var ingenting).

E: You are only a zero. (Du är ju bara en nolla).

L: What happened later on? Where did the little zero go? The zero walked away to places where none of the other numbers could go. Where did the zero go? (Men vad hände sen? Vart gick nollan sen? Nollan var ja ganska modig och vågade gå dit där ingen annan siffra vågade gå. Vart gick nollan)?

E: Into the cave. (I grottan).

E: The zero was so upset. (Nollan var jättearg).

L: Why? (Varför)?

E: He could not find a zero so he could count his money. (Han saknade en nolla för att kunna räkna sina pengar).

L: The zeros stand after the numbers so we can recognise big numbers. If a number stands for himself he isn´t worth as much. But if you put several numbers together they can be worth much more. (De nollor som kunde stå där efter siffrorna bildade då jättestora tal. Om en siffra står alldeles själv är den inte värd så mycket. Men om man sätter flera siffror tillsammans så blir de värda ganska mycket).

In the first part of the teacher-pupil interaction the language is about the real world and they are talking about the little zero's feelings. Then, the teacher developed the ideas further by talking about where to put the zero and what happens to the value of the money. The class in moving towards a more mathematical language and from a primary to secondary artefact, when working with the interactive board.

In the next extract, the teacher and the pupils are working with the interactive whiteboard in a programme showing blocks of one and blocks of ten. The pupils put the numbers under correct number of blocks.

L: I put in one and two. What is the number? (Jag sätter in ental och tiotal. Vad blir talet)?

E: The number three. (Talet blir tre).

L: Yes if you put it together. But I mean if you write it together as a number. What is the number? (Ja om du lägger ihop det. Men jag menar om du skriver det samman till ett tal. Vilket är talet)?

E: The number is twelve. (Talet är tolv).

L: How many tens are there in twelve? (Hur många tiotal är där i tolv)?

E: One ten and two ones.(Ett ental och två tiotal).

L: But you can also write another number with those numbers.(Men du kan också skriva ett annat tal med dessa siffror).

E: Three (Tre)

E: 21 (Tjugoett)

L. How many tens are there in twenty? (Hur många tiotal är där I tjugo)?

E: Two (Två)

L: How many one? (Hur många ental)?

E: One (Ett)

The teacher provided several similar lessons, in which she worked with the interactive whiteboard and the pupils. The pupils began to develop the secondary language of mathematics through using the whiteboard artefact, the software program on the interactive board and by talking with the teacher and the other pupils.

In another lesson, the children sat in pairs in front of a computer, working on the same program as was on the interactive whiteboard but now they began to work on addition and subtraction. The calculations was 56+23. First they recognised 50 and stated that it was five tens and move five ten-blocks on the computer together. Then pupils say twenty and put two ten together to show each other and then they put together six and three ones-blocks. On a piece of paper, they wrote down the answer and stated how they got the answer.

In the computer program, the pupils showed how they placed the numbers in the correct place value column and talked about them. The different kinds of artefacts changed the pupil´s use of language.

Another example from the class is when the pupils used tablets. In pairs, they had to explain place value using mathematical words and the computer program and then they filmed their explanations with the tablet computers. They practiced giving their explanations several times and when they were ready they used the tablet as a video camera, to film each other. This communication had to be perfect, so they worked

hard and filmed each other several times until they thought it was good enough to show the teacher and the rest of the class.

The next transcript is one boy's explanation of place value in relationship to addition and subtraction that he recorded on the tablet as the teacher was watching. The tertiary artefact led him to use a different kind of mathematical language which illustrates his reflection of these ideas.

E: Hello my name is Adam and I´ll will show you how I´ve learnt place value. (Hallå, mitt namn är Adam och jag vill visa hur jag har lärt mig platsvärde).

E. The addition is 78+21. (Additionen är 78+21).

E: I first take seven tens and then eight ones and then I take two tens and then it is 98 and after that I add one ones and then it is 99. (Först tar jag sju tiotal och sedan åtta ental och sedan tar jag två tiotal och sedan är det 98 och efter det adderar jag ett ental och är det 99).

E: The subtraction is 49-36. (Subtraktionen är 49-36).

E: First I take four tens and then 9 ones and then I take away three tens and then I have 19 and after that, no I don´t know. We do it again! (Först tar jag fyra tiotal och sedan 9 ental och sedan tar jag bort tre tiotal och därefter har jag 19 och efter det , nej jag vet inte. Vi gör det igen)!

L: But you have 19 and you should take away 6 ones. (Men du har ju 19 och du ska ta bort 6 ental).

E: But I made it in a wrong way. (Men jag gjorde det på fel sätt).

The pupil recorded his explanation again.

In the next transcript, another pupil counted while talking in front of the tablet.

E: I first take 4 tens and then nine ones and after that I take away 3 tens and then it is 19 and then…..(Jag tar först 4 tiotal och sedan nio ental och efter d et tar jag bort tre tiotal och sedan är det 19 och sedan…)

L: And then you are going to take away six ones. (Och sedan måste du ta bort sex ental).

E: But I never put them in there. (Men jag la aldrig till dem där).

L: You got 49 from the beginning and take away three tens. (Du hade 49 från början och tar bort tre tiotal).

E.: And take away six ones. (Och tar bort sex ental).

Most of the pupils were doing this in pairs and they were filming until they were convinced that everything was perfect. To use a tablet to film each other explaining their understanding of place value is one step for pupils towards using a tertiary artefact to reflect on what they know and why they know it.

The different artefacts, such as the interactive whiteboard, the computer and the tablet showed how the pupils, in different contexts, changed their language when they used different kinds of artefacts. In the mathematics, the pupils showed that they shared the mathematical language and understanding of the signs and symbols of mathematics and they could use them in their talk about tens and hundreds.

SUMMARY

If teachers are to support students using more abstract language and thoughts in mathematics, then there is a need to understand the impact of different artefacts in the classroom. When teachers use primary artefacts like concrete materials, they have to think of the dialogue they want to develop. Information and communication technologies, such as interactive whiteboards, computers or tablets, also affect pupils' language. If the material is to be translated to a secondary artefact, then the students need to learn how to translate from the concrete material to the mathematical concepts. They have to learn to write and reflect on their knowledge and ask questions like why is this answer right or describe the process they used and their decisions for using a particular model. The students must actively engage with the language and artefact at the same time through dialogue. Then it is possible to say that pupils have started to learn mathematics. Figure 2 summarises how using an artefact can support students developing their knowledge of mathematical concepts. Before moving to the middle, with tertiary artefacts and reflective language, pupils must know things from the other blocks.

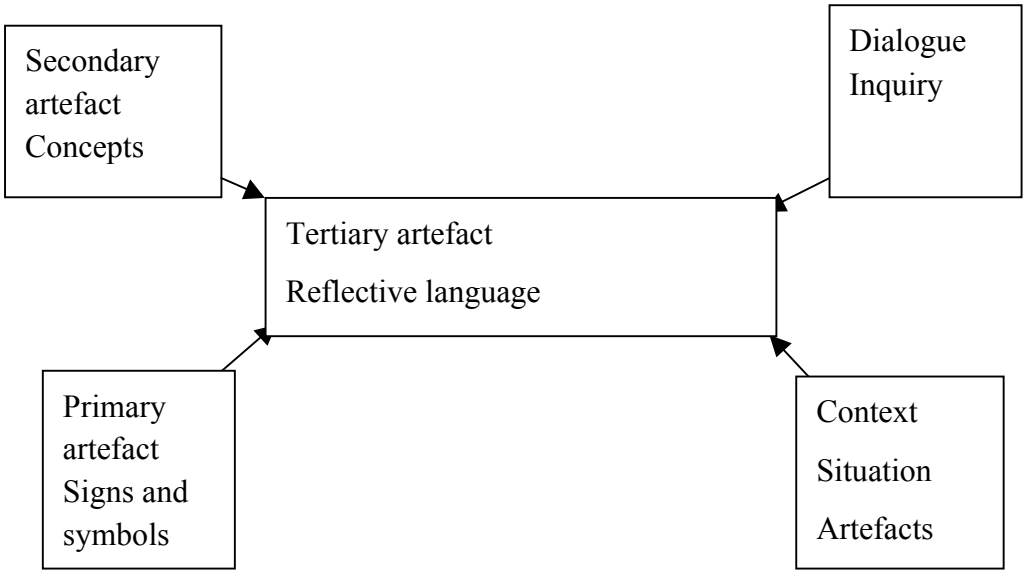

Figure 2. The reflective language as a tertiary artefact

In the middle is the tertiary artefact where the teacher and the pupils are reflecting and talking together, using mathematical language. Here they use signs, symbols and concepts from mathematics and the artefacts like computers and tablets help them to achieve this reflection. In this study, the teacher and pupils worked with different artefacts that supported their use of reflective language. The pupils began to develop

a language to talk about why the process or the product was as it was and to also document their new knowledge in mathematics.

The use of a tertiary artefact can be recognized in the qualities of language, tools and knowledge both from having a picture from the every-day world and also from the mathematical sphere. In this context, quality means that pupils communicate around a sign, a concept and a situation by looking critically at it, putting forth arguments for and against and document their own learning. As furthering their acquisition of new knowledge becomes an issue of learning to apply abstract and complex intellectual and practical tools, the more essential it becomes to engage in communicative practices with different tools (Riesbeck, 2011).

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