USE OF DIGITAL TOOLS IN MATHEMATICAL LEARNING ACTIVITIES IN THE KINDERGARTEN: TEACHERS' APPROACHES

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In this paper we study how kindergarten teachers used digital tools in mathematical learning activities in the kindergarten context. With digital tools we mean mathematical software for computers and ICT applications for digital white boards, mathematical games and memory games. Within this context we study the various approaches the kindergarten teachers took when orchestrating mathematical learning activities. Through analyses of these mathematical learning activities, we find that the kindergarten teachers took three different approaches in their orchestration, the assistant approach, the mediator approach, and the teacher approach. These approaches all carry qualities and potentials for children's learning of mathematics, but in different ways.

Keywords: Digital tools, Kindergarten, Teacher approaches

INTRODUCTION

The Norwegian kindergarten is regarded by OECD (2006) as situated within a social pedagogy tradition, i.e. an educational institution where core enterprises are upbringing, care, play, and learning. A new curriculum for kindergarten was launched in 2006 in which mathematics was comprised for the first time as a separate subject area (Ministry of Education and Research, 2006b). Additionally, policy documents as regards implementation of information and communication technology (ICT) in the kindergarten were made (Ministry of Education and Research, 2006a). However, the combination of mathematics and the use of ICT has been more or less left for the kindergarten teachers to elaborate and implement in learning activities.

With this as a background we initiated a project called ICT Supported Learning of Mathematics in Kindergarten. In this project we aimed at collaborating with kindergarten teachers to gain insights into children's mathematical learning processes when interacting with digital tools. We argue in accordance with Plowman and Stephen (2003) and Sarama and Clements (2004) that research is needed to identify the mathematics learning potentials of digital tools. Hennessy (2011) explored interaction possibilities when using interactive whiteboards (IWB) in teaching. She came up with affordances such as the multimodal nature of interaction possible and the opportunities for direct manipulation of objects.

In this study we are particularly interested in analysing the ways the kindergarten teachers use these digital tools and how they interact with the children in their

orchestration of mathematical learning activities. For the present study we have formulated the following research question: *What characterises kindergarten teachers' approaches when using digital tools in mathematical learning activities?* This question is interesting to pursue due to the fact that there is an insufficient amount of literature in this area of research.

THEORETICAL FRAMEWORK

In this study we adopt a sociocultural perspective on learning and development, a theoretical stance originating in the work of Vygotsky (1986) and further developed by socioculturalists such as Rogoff (1990) and Wertsch (1998). Two main concepts within this perspective are indubitably the notions *mediation* and *tool*.

Mediated action through the use of tools

In mediated action humans use several tools. Language, both oral, written, and body language, plays a fundamental role in mathematical learning activities (Goldin-Meadow, 2009; Roth, 2001). In order to communicate and interact, both adults and children use various kinds of language to collaborate, discuss, and make sense.

Relevant for the study reported here is the use of digital tools, i.e. in our case mathematical software engaged with by the children through their use of computers and IWBs. Following a sociocultural perspective, use of digital tools mediates mathematical ideas and concepts. Thus, learning becomes a process of mastering these tools and performing in appropriate ways when engaging with the applications, since "our mastery of such tools is a critical element of what we know" (Säljö, 2010, p. 62). By using digital tools in their orchestration of mathematical learning activities, the kindergarten teachers seek to mediate mathematical ideas and concepts for the children to make sense of. The kindergarten teachers' use of digital tools in mathematical learning activities thus establishes opportunities for the children to appropriate mathematical concepts, ideas, and actions.

Orchestration of mathematical activities

As already mentioned several times we view the kindergarten teachers' actions and communication through the metaphor of *orchestration*. Following Kennewell (2001), we see orchestration as managing "the visual cues, the prompts, the questions, the instructions, the demonstrations, the collaborations, the tools, the information sources available, and so forth… (p. 106). The notion of orchestration is thus used to describe what kindergarten teachers do when hosting mathematical learning activities using digital tools.

When considering teachers´ orchestration of digital tools for the benefit of learning mathematics, researchers have pinpointed many aspects. Goos, Galbraith, Renshaw and Geiger (2003) studied teachers´ orchestration of calculator use in mathematics teaching. They observed clear differences in the orchestration and argue for the importance of directing students to explore the tasks, use the digital tools to discuss

the solutions of tasks, teachers´ ability to hold back information and stimulate collaboration and discussion among students.

Mathematics teachers' activities when using technological tools in the classroom is discussed by Monaghan (2004). He argues that to integrate technology in mathematics teaching is a complex undertaking, and teachers experience multifaceted processes when integrating the use of digital tools in their teaching. These arguments have also been advocated by Zbiek, Heid, Blume, and Dick (2007). These authors coin two roles mathematics teacher take when implementing technology in teaching, called Technical Assistant (The teacher assists the students with software and hardware difficulties) and Counselor (The teacher is familiar with the mathematical ideas and concept addressed in applications and supports the students upon request).

As mentioned, Monaghan (2004) also studies roles mathematics teachers take in technology-based lessons. He describes two roles teachers take when interacting with the students, the mediator role and the facilitator role. The former role is used about teachers who play "an active part in the students' learning" (p. 329) through social interactions. The latter role is described in a similar way as Zbiek et al.'s notion Technical Assistant.

These studies identify teachers' roles when interacting with students at school. As will be seen later in the paper our identified approaches taken by kindergarten teachers differ from the labels coined by Zbiek et al (2007) and Monaghan (2004). From the analysed data we needed to divide the Counselor/Mediator role of these authors in two, the Mediator approach and the Teacher approach, since these approaches more distinctively address the studied kindergarten teachers' interaction with the digital tools and the children.

METHODS

In our project we collaborated with three kindergartens called Bee Pre-school centre, Swan Pre-school centre, and Frog Pre-school centre. As methods of data collections in the project we used video data of 12 sessions where kindergarten teachers orchestrated mathematical learning activities by the use of digital tools. Video recordings of the 12 sessions, each of approximately 30 minutes of duration, where complemented by observations and field notes. From initial analysis of these sessions and our general discussions regarding our experience within the project, a hypothesis emerged concerning the kindergarten teachers' approaches to the use of digital tools. Secondly, based on our reasoning, we returned to the video data and looked at some sessions more in depth. Guiding our analysis was the communication between adult and children and to what extent they engaged with mathematics. From this process, we were able to characterise three approaches the kindergarten teachers used. Thirdly, we returned to the data in order to identify episodes which illustrate these three approaches. The three excerpts chosen are meant to illustrate these three approaches.

Conversations with the kindergarten teachers, meetings in kindergartens and a workshop at the University were also arranged. However, data from these events are not particularly used in the study presented here.

ANALYSIS AND RESULTS

The data we present comprises video data from three kindergarten teachers, one from each of the three kindergartens. In the excerpts below the kindergarten teachers used digital tools covering applications with mathematical elements such as counting, comparing sets, measurements, and shapes. We have identified three different approaches the kindergarten teachers took, the Assistant approach, the Mediator approach, and the Teacher approach. After describing these approaches, examples of adult-child interaction will be analysed to justify the identification of the three approaches as well as point to what these approaches encompass.

The Assistant approach (ASS)

When the kindergarten teachers take an Assistant approach to their orchestration we characterise what they do as assisting the children with minor issues such as starting and running the software; they organise the activity so that one or two children interact with the digital tools at a time, they point at places where to touch the screen or keyboard, i.e. keystrokes, to answer software inherent questions and tasks. In one of the sessions we videotaped, the kindergarten teacher made small remarks regarding where to press the various buttons at the IWB to navigate and choose different games to play. The kindergarten teacher led the session, by pointing at what children should do to engage with the ICT application and by asking the children whether they wanted to play another game.

The Mediator approach (MED)

The second approach that we have identified is the approach called Mediator. When the kindergarten teachers took the Mediator approach they orchestrated the mathematical activity by being more active in interpreting the digital tools the children engaged with. The Mediator approach is further characterised by the kindergarten teachers reading text within the applications, and they supported the children in interpreting the screen. The teachers helped the children to become aware of crucial elements and parts of the screen.

The Teacher approach (TEA)

The third approach the kindergarten teachers took when orchestrating mathematical learning activities involving interaction with digital tools, we have called the Teacher approach. This approach is characterised by the kindergarten teachers' use of questions and comments with respect to the children's interaction with the applications. When taking the teacher approach, the kindergarten teacher actively chooses what applications for the children to engage with and monitors the pace of children's interaction with the digital tools.

The case of Ann

In this excerpt one child is engaged with an IWB in a mathematical learning activity with the use of a digital tool involving numerals and counting (implicitly). The application was designed for the kindergarten age group and it was called "Labbe Langøre" [1]. Three children were present. Sound is included in the digital tool, giving the child instructions of what to do at various places and stages within this short excerpt. In this application numerals are shown on a poster. Four trees are also shown, each of them having a numeral posted on them. The child is supposed to identify similar numerals.

Ann (ASS): Your turn [Judy walks towards the IWB and up on a bench] Do you want me to move that bench?

Judy: Yes

Ann (ASS): Then you can press the START button [Judy chooses an application called 'Memory']

Ann (TEA): Can you choose 'the Mathematical Cat'? [Judy chooses that application, and she presses the correct numeral. Two snakes emerge on the screen]

Ann (MED): Press the cat and see what happens [When pressing the cat, the software confirms whether the answer is correct or incorrect]

[Judy does that and the cat confirms that she is right. Then a new task shows up]

Ann (TEA): Can you count them [the animals] when they appear?

[The numeral 5 is shown on the poster, and Judy presses the numeral 5 on one of the trees. Five frogs emerge and Judy points at one after another while Ann counts loudly]

Ann (MED): One, two, three, four, five

The orchestration could be described by the kindergarten teacher having responsibility for hosting the session. From the excerpt it is evident that Ann is shifting between all three approaches. Ann serves the children by managing the computer and the software, assisting Judy in her interactions with the applications. The digital tool took care of much of the necessary information the child was in need of since oral sound was included in the applications. The Mediator approach was thus not so often needed in this case. Ann seems to adapt her interventions, comments and questions with respect to both the child in action and the actual application the child interacts with. Ann also took the Teacher approach in her goal-directed instruction of Judy to choose the mathematical application and Ann addressed the mathematics implicitly present in the application.

The case of Egil

In the following the kindergarten teacher ran an application on an IWB from the software named "Salaby" [2]. The application concerned the clock – the attention was

on the relationship between written time slots such as 11:00, the hour hand and the minute hand. In this particular episode, all the minute hands were fixed at 12. The application presented twelve different clocks which represented twelve different time slots. The written time slots should be dragged and dropped to the corresponding clock symbol. Egil starts the application in front of 15 children and one other adult. Egil shifts between different approaches during the excerpt.

Egil (MED): Herman, try one o'clock. [After some hesitation, the child points at the clock symbol that represents one o'clock.]

Egil (TEA): How did you see that this was one o'clock?

First, Egil supported Herman in interpreting the application and Egil continued with a question which requested an argument. This may indicate that Egil wanted to promote a learning goal beyond just interacting with the application. Additionally, an important part of the mediation is to describe what is visible at the screen:

Egil (MED): The hour hand points at one and the big minute hand points straight up. It points straight up in every clock here: Twelve, twelve, …., twelve [He points at every clock on the screen, one after another until he has pointed at all twelve clocks]

Egil (MED): But, on which of this clocks does the hour hand point at eleven? Raise your hand if you believe that you know the answer.

Apparently, the mediation approach changes suddenly when Egil asked the question that give us association to a normal classroom conversation. However, the content of the question draws attention to the meaning of the application. In order to respond correctly, the children have to identify the correct clock symbol. We claim that this question is part of Egil's mediation approach.

There is a blurred border between the Mediation approach and the Assistant approach. The Mediation approach is linked to the message the software brings and the Assistant approach is linked to the physical and organising part of the software. For example, Egil selected what child who was supposed to use the software, and he adjusted the children's behaviour and made them focus at the screen. Use of IWB gave the children challenges related to the touch technology within the screen. A typical Assistant approach that we observed was when the adults helped the children with the drag-and-drop functionality.

The case of Unni

In the observed lessons at Bee Pre-school centre, the children were organised in groups of two children and one adult sharing a portable computer. Below two episodes are presented with one adult, Unni, and one child, Trine, aged 5 years. The software used is again "Salaby" [2]. In the application at stake here, cars are supposed to be elevated into different numbered garages (numbered 2, 4, 6, 8, 10 and 1, 3, 5, 7, 9 respectively on each side from bottom to top of the garage). In order to

drive a car into correct garage, first an addition task such as 2 + 3 is supposed to be solved. Then the user needs to correspond that sum with the correct symbol, 5.

In the episode below, Trine started by choosing the car to the right where the task is 5 + 5. She was able to move the car into the elevator and then the episode below appears. Unni showed the numbers with her fingers (5 + 5) and Trine was able to respond orally with correct answer and to recognize how ten is written. This we consider as evidence that K3 after a brief mediator comment adopted a Teacher approach helping the child to understand why the car should be placed in garage number 10.

Unni (MED): Now you have to wait a little bit. Where is it supposed to be parked?

Trine: There (Trine points to the car with her finger, appears to be in doubt).

Unni (TEA): Yes, where will you park the car? How many fingers do I have on my hand (Unni shows her left hand to Trine)?

Trine: Five

Unni (TEA): Yes, and then you add 5. How many fingers will that be?

Trine: Ten

Unni (TEA): How does number ten look?

Trine: (Trine points to the correct numbered garage 10).

An indicator of Unni's concern and judgment for the mathematics at stake is also visible in an episode occurring immediately before the one displayed above. Unni seemed to be reluctant to Trine's choice to park the car on the right and suggests she chooses the car on the left. We believe this suggestion from Unni came based on a judgment that Trine rather should start with an easier task to solve. However, Trine decided to keep her choice and Unni then accepts this and adapted her support.

Unni (MED): Which car do you want to park?

Trine: (Trine points to the car on the right hand side where the task is 5+5)

Unni (TEA): Maybe you rather take the other one (Unni appears to think that the other car with the task 2 + 3 might be a more suitable task for Trine).

Trine: (Trine still points to 5+5)

Unni (TEA): You want that one. Which number will that be? 5+5, how much is that?

Trine: (Trine drives the car into the elevator)

These two episodes were brief and the time spent from Unni was to engage in mathematics with the children. We argue that episodes presented illustrate a typical pattern in Unni's approach to orchestration of the sessions. Unni spent most of her time taking a Teacher approach. Unni uses many questions indicating that she adapts

what mathematical challenges the children should deal with. We also found a few utterances where Unni explains the technical actions with the tool taking a Mediator approach.

DISCUSSION

In this study we have seen that the kindergarten teachers orchestrate children's engagement with the digital tools differently. We agree with Monaghan (2004) and Zbiek et al. (2007), that it is a complex endeavor to implement the use of digital tools in mathematical learning activities. We have identified three different approaches the kindergarten teachers took when orchestrating the activities and interacting with the children. This is not to say that other approaches were not taken, but the three identified approaches were the most dominant ones. We have identified these approaches and called them an Assistant approach, a Mediator approach, and a Teacher approach. The approach called Mediator has several similarities with what Zbiek et al. label Counselor. Our description of the Assistant approach shares similarities with what Zbiek et al. call 'Technical Assistant' and what Monaghan labels 'facilitator'. However, what we call the Mediator approach differs slightly from what Monaghan labels mediator role taken by teachers. We interpret Monaghan's mediator role as encompassing a broader perspective than how we use the label mediator in this study.

The way Monaghan (2004) uses the term we interpret as comprising what both what we call Mediator approach and Teacher approach. Our use of the Mediator approach is more in line with what Zbiek et al. (2007) call Counselor role. These discrepancies might be due to the fact that Monaghan and Zbiek et al. studied mathematics teachers at school level. We have, on the contrary, studied teachers at kindergarten level. By taking the Mediator approach, the kindergarten teachers become a bridge between the digital tool on the one side and the children on the other side. The kindergarten teachers support the children in order for them to make sense of the digital tools and for them to know what to do at various places when interacting with the applications. Thus, the kindergarten teachers mediate what the applications are about and come up with questions that make the children pay attention to relevant elements within the tools.

When taking the teacher approach, the kindergarten teachers purposefully decide for the children what digital tools to engage with. This approach initiates mathematical reasoning amongst the children, since the comments and the questions request predictions and justifications on behalf of the children. Thus, the kindergarten teachers utilise the digital tools to mediate mathematical ideas and address mathematical learning goals.

We argue that all three approaches to orchestrating mathematical learning activities in the kindergarten carry qualities and potentials when it comes to the children's opportunities for appropriating mathematical tools and actions. By taking these three different approaches the kindergarten teachers adapt to the situations and contribute

with their support as the children and the situations request. With respect to the sequentiality of the interaction, the different approaches are needed to a differing degree. Typically, within the initial phase of interacting with the digital tools the Assistant approach is often needed in order to keep the activity going. However, when children are engaging actively with the mathematics within the digital tools, the Mediator approach is needed to support the children's sense making of the digital tools. Eventually, the Teacher approach carries affordances as regards the children's mathematical learning opportunities. The applications are used to serve mathematical learning goals formulated by the adults.

The main difference between the Mediator approach and the Teacher approach is that when using the Teacher approach, the adult focuses particularly on the mathematics implicitly present within the applications to serve pre-formulated mathematical learning goals. Thus, when taking the Teacher approach the kindergarten teachers are seen to orchestrate the children's mathematical learning process.

From our analyses it is also relevant to discuss the quality of the digital applications the kindergarten teachers used in terms of the mathematics learning opportunities created and whether the applications became utilised as tools, in a sociocultural parlance, for mathematics learning. The quality of the applications used, we argue, cannot exclusively be judged from the outset, since we believe their quality heavily depends on the competent utilisation of the applications by mathematically and didactically competent kindergarten teachers.

NOTES

1. The software "Labbe Langøre" is a DVD manufactured by http://www.kallekunskap.se/

2. The software "Salaby" is manufactured by Gyldendal, http://www.gyldendal.no

REFERENCES

Arcavi, A. & Hadas, N. (2000). Computer mediated learning: An example of an approach. *International Journal of Computers for Mathematical Learning*, 5, 25-45.

Goldin-Meadow, S. (2009). How gestures promotes learning throughout childhood. *Child Development Perspectives, 3*(2), 106–111.

Goos, M., Galbraith, P., Renshaw, P., & Geiger, V. (2003). Perspectives on technology mediated learning in secondary school mathematics classrooms. *The Journal of Mathematical Behavior, 22*, 73-89.

Hennessy, **S**. (2011). The role of digital artefacts on the IWB in mediating dialogic teaching and learning, *Journal of Computer Assisted Learning*, 27, 463-489. DOI: 10.1111/j.1365-2729.2011.00416.x

Kennewell, S. (2001). Using affordances and constraints in evaluate the use of Information and Communications Technology in teaching and learning. *Journal of Information Technology for Teacher Education, 10,* 101-116.

Leont'ev, A. N. (1979). The problem of activity in psychology. In J. V. Wertsch (Ed.) *The concept of activity in Soviet psychology* (pp. 37-71). Armonk, NY: M. E. Sharpe.

Ministry of Education and Research (2006a). *Framework plan for the content and tasks of kindergartens* [Rammeplan for barnehagens innhold og oppgaver]. Oslo: Ministry of Education and Research.

Monaghan, J. (2004). Teachers' activities in technology-based mathematics lessons. *International Journal of Computers for Mathematical Learning, 9,* 327-357.

Ministry of Education and Research (2006b). *Thematic booklet on "ICT in the kindergarten"* [Temahefte om "IKT i barnehagen"]. Oslo: Ministry of Education and Research.

OECD (2006). *Starting strong II. Early childhood education and care*. Paris: OECD Publishing. Retrieved February 24, 2011, from http://www.oecd.org/dataoecd/14/32/37425999.pdf

Plowman, L. & Stephen, C. (2003). A 'benign addition'? Research on ICT and pre-school children. *Journal of Computer Assisted Learning, 19,* 149-164.

Rogoff, B. (1990). *Apprenticeship in thinking. Cognitive development in social context.* New York: Oxford University Press.

Roth, W.-M. (2001). Gestures: Their role in teaching and learning. *Review of Educational Research, 71* (3), 365-392.

Sarama, J. & Clements, D. H. (2004). Building blocks for early childhood mathematics. *Early Childhood Research Quarterly, 19,* 181-189.

Vygotsky, L. S. (1986). *Thought and language*. Cambridge, MA: The M. I. T. Press.

Wertsch, J. V. (1998). *Mind as action*. New York: Oxford University Press.

Zbiek, R. M., Heid, M. K., Blume, G. W. & Dick, T. P. (2007). Research on technology in mathematics education. In F. K. Lester, Jr. (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 1169-1207). Charlotte, NC: Information Age Publishing.