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Preschool children's Collaborative Science Learning Scaffolded by Tablets

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Abstract This paper reports on a project aiming to extend the current understanding of how emerging technologies, i.e. tablets, can be used in preschools to support collaborative learning of real-life science phenomena. The potential of tablets to support collaborative inquiry-based science learning and reflective thinking in preschool is investigated through the analysis of teacher-led activities on science, including children making timelapse photography and Slowmation movies. A qualitative analysis of verbal communication during different learning contexts gives rise to a number of categories that distinguish and identify different themes of the discussion. In this study, groups of children work with phase changes of water. We report enhanced and focused reasoning about this science phenomenon in situations where timelapse movies are used to stimulate recall. Furthermore, we show that children communicate in a more advanced manner about the phenomenon, and they focus more readily on problem solving when active in experimentation or Slowmation producing contexts.

Keywords Preschool · Tablets · Timelapse · Slowmation · Early childhood education

Introduction and Theoretical Background

This paper reports on a project aiming to extend the current understanding of how emerging technologies, i.e. tablet computers or tablets, can be used in preschools to support collaborative learning of real-life science phenomena. The importance of this stems from a *western problem*, which many scholars describe as the failure of current educational systems to respond to the needs of modern western societies. Educational systems are currently in need of reform (Fullan 2007; Thulin 2011; Tytler 2007). One long-standing problem is the artificial distinction between learning in school and real-life learning, which often inhibits the transfer of

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knowledge and skills and creates unwanted obstacles for re-instituting learning as a powerful motivator of innovation and problem solving capacity. The promotion of the latter is at the core of what is called a framework for twenty-first Century Skills, which despite the criticism, is an attempt to conceptualise how *learning* should be operationalized in current societies (Dede 2010).

Research on the potential of web-based technologies and use of ubiquitous technologies to support collaborative inquiry-based science learning (Redfors et al. 2013) is here continued by investigating the role of timelapse and Slowmation (Fleer 2013; Hoban 2007) in developing children's understanding of science phenomena. At the core of this work is the synthesis of specific and general domain-knowledge discussed by Eshach (2006) for children's science learning: content (concepts, explanatory models) and investigations (hypotheses, problematizing, questions, experiments).

Timelapse Photography and Slowmations

An increasing number of studies (Ainsworth 1999; Prain and Waldrip 2006) suggest that students' learning is enhanced when they create digital artefacts, such as representations of science concepts. Through this creation of an explanatory model, skills such as creativity, problem solving, communication and collaboration can be developed (Nielsen and Hoban 2015). Furthermore, Prain and Tytler (2013) state that constructing representations of scientific phenomenon supports many different forms of reasoning. These include; imagining processes, suggesting explanations and outcomes, or testing whether a verbal explanation seems reasonable also in 2D or 3D. When choosing how to represent a phenomenon, students are challenged in their understanding and thinking about the particular concept and they must learn how to select appropriate solutions for the representation. Ford and Forman (2006) state that there needs to be a purpose for reasoning in science and that active generation of representations strengthens the scientific knowledge in ways that formal reasoning, such as mere argumentation, does not. Creating a representation thus promotes discussion and debate about ideas, whether these are correct or incorrect, and potentially results in an understanding of the phenomenon (Prain and Tytler 2013). In this study, we therefore make use of timelapse photography and 'Slowmations', short for *Slow animations* (Hoban 2007). Timelapse photography is a technique that shows a slowly changing event in accelerated speed, and this is accomplished by photographing the event at certain intervals, such as every other second, every 5 minutes or once an hour, and when played at normal speed, the event seems much faster. This may give a pronounced overview of natural science phenomena such as flowers blossoming, or movement across the sky of sun, moon and clouds.

A Slowmation on the other hand is a stop-motion animation played in slow motion to explain a science concept (Hoban 2007). A stop-motion animation is usually played at a speed of 20–24 frames per second (frames/s), but since a Slowmation is played slower, at two frames/s, ten times fewer photos are needed. Models can be made in 2D and/or 3D, and many different materials can be used, such as playdough, drawings, natural materials (e.g. leaves or rocks). Students manually rearrange the materials and then use digital cameras and free movie-making software. A Slowmation involves the transfer of meaning from one representation to the next, referred to as a *semiotic progression*, and according to Hoban et al. (2013) learning about the content is a result of this cumulative semiotic progression (Hoban et al. 2013). Fleer and Hoban (2012) describe how Slowmation creation offers a window of opportunity for children and their teachers to become aware of scientific concepts and they point to two key features, making Slowmations suitable in early childhood settings. The first key feature is the wide range of materials, such as plastic toys and felt cutouts, already existing in preschool. The second concerns the Slowmation technique itself, which can be halted anytime, allowing the children and teacher to interact by discussing ideas at any step of the animation (Fleer and Hoban 2012). This shared sustained interaction between the children and their teacher(s) offers a collective imaginary situation, supporting extended activity, discussion and thinking (Fleer and Hoban 2012).

This project strives to further investigate verbal communication during children's work with science activities scaffolded by tablets. Its design, with preschool children sharing their versatile thoughts and ideas through the varied science activities, originates from the phenomenographic (Marton and Booth 1997) and developmental pedagogical (Pramling and Asplund Carlsson 2008) theoretical frameworks, as well as from an attempt to synthesise the specific and general domain-knowledge of science (Eshach 2006). There is still much to be learned about how young children talk and interact around a science phenomenon and to what extent the reasoning and learning can be supported, or hindered, during the work with tablet computers and timelapse/Slowmation productions.

Swedish Preschool

This project focuses on the role of tablets for science learning in the less formalised learning environments of preschools. Early childhood education in Sweden is named preschool. It is a voluntary and separate school form, and its activities are regarded as education and teaching. A renewed national curriculum with learning goals to strive towards regulates the educational activities (Skolverket 2011).

Municipalities are obliged to provide a place in a preschool for all children from age 1 to 6 years: the last year for 6-year-old children is called grade F. The cost of preschool is nationally subsidised. Compulsory school starts with year 1 for 7-year-old children, but is preceded by the voluntary year F. According to national statistics, 84% of 1–5-year-olds and 97% of 6-year-old children participate in preschools (Skolverket 2014).

Preschool teachers (3.5 years university studies) are pedagogically responsible. They plan pedagogical activities enabling children to create, explore and learn. The activities take place, for instance, through playing, cooperating with others, painting, building and singing. The composition of child groups aims to reflect the community concerning intercultural perspectives such as gender, class and ethnicity.

Theoretical Framework

From a theoretical framework primarily based on phenomenography, a variation theory (Marton 1981, Marton and Booth 1997) focusing on developmental pedagogy (Pramling Samuelsson and Asplund Carlsson 2008), this work aims to develop a category-based framework for the analysis of science learning processes scaffolded by tablets in preschools.

Studies of small children show that learning presupposes an object as well as an act (Pramling 1990, 1994; Marton and Booth, 1997), and in preschool, the object of learning is the least focused of the two. Developmental pedagogy, as depicted by Pramling Samuelsson and Asplund Carlsson (2008), takes into consideration the importance of a teacher who supports and encourages the child's willingness to make sense of the world and a teacher capable of tuning into the child's world to share the same learning object for communication and thinking. In order to help a child develop its perception and understanding of the world, the teacher's approach should be one of variation (Marton and Booth 1997). For example, for a child to understand the concept of flowers, the child must discover what critical aspects separate a flower from grass or a tree. The child needs the experience of a variety of flowers in order to distinguish the essential features constituting a flower and gradually, he or she will become able to understand what defines a rose, as compared to other flowers (Pramling Samuelsson and Asplund Carlsson 2008). Developmental pedagogy defines learning as the variety of ways in which one child produces variation and the variety of ways a group of children think about one and the same phenomenon or concept. Accordingly, the teacher uses variation as a strategy to make a particular phenomenon visible to a child. As several children think in various ways about a concept or phenomenon, comparing and discussing these thoughts may make different meanings and features appear to the child/children (Pramling Samuelsson and Asplund Carlsson, 2008).

According to Eshach (2006), science could be thought of as comprising two types of knowledge: domain-specific knowledge and domain-general knowledge/strategies. The former refers to the knowledge of a variety of phenomena (e.g. atoms, forces, magnetism, chemical reactions) or in other words the knowledge of theoretical models of real world objects and events. The latter refers to skills needed for reasoning about science in terms of, for instance; experimental design or evidence evaluation; skills such as observation; formulation of hypotheses; data collection, and represention of data with graphs or diagrams (Keys 1994; Schauble et al.1995; Zimmerman 2000). Domain-specific knowledge and domain-general knowledge together contain conceptual and procedural aspects of science. However, as mentioned above, underlying this paper is the need to synthesise the knowledge of content (concepts, theories, theoretical models) and investigation (hypotheses, problematizing, questions, experiments) for young children's effective science learning.

Also Vygotsky (1987) argued that research tends to focus on the end product of the process, rather than on how the concept formation begins and develops. As Fleer (2009) concludes, studying the dynamic process as opposed to the child's definitions of a particular concept, or *end product*, offers a new direction for science education research, especially for researchers who, like ourselves, are interested in how young children pay attention to and extend their understanding of scientific concepts.

Aim and Research Questions

The aim of this work is to analyse and describe children's verbal communication during learning activities concerning the different water phases, especially during different learning contexts with and without the use of computer tablets. More specifically, the research questions guiding this project are the following:

- How are young children communicating during work with the water phases?
- How is this communication influenced by different learning contexts and tablet use?

Design

This project methodology is based on the idea of design-based research (Barab and Squire 2004), thus, trying to bridge the often disconnected worlds of theory and educational practice.

The iterative and participatory philosophy of design-based research can foster the development of sustainable, empirically tested practices. A teaching and learning sequence consisting of a set of science activities was developed together with the teacher. The activities were multi-faceted and always aimed to take a starting point from the children's experiences. Researcher, teacher and a dialogue with the children led to the choice of phases and phase changes of water as the science content.

The activities were set around collaborative group work and uses of tablets through timelapse and Slowmation animations. The idea was to introduce a science phenomenon in a variation of ways and make it ubiquitously available to the children through timelapse photography. Thus, the children's experiences can be brought forward in discussions and challenged during the subsequent production of Slowmations. The activities with the children were set up with four different organisational forms, i.e. four learning contexts.

- Group discussion (GD)
- Stimulated recall in group (SR)
- Production of Slowmations (PS)
- Experimentation, without (E) and with timelapse photographing (Et)

The group size varied between two and seven children for the four contexts, see Table 1.

Children's Experiences of Evaporation

From a design-based perspective and guided by the theoretical framework described above, the project started with the teacher and one researcher interviewing the children in small groups to find a science phenomenon from the children's everyday world to study and to capture the variety of ways the children thought about the phenomenon. Children's ideas about tablet computers and nature of science were discussed, and the children were asked what phenomenon they would be interested in working with. Repeatedly, water, in terms of water you can drink, snow melting etc., were mentioned. From the discussions, it was clear that the idea of water evaporating did not exist among the children. When asked about where they believed rainwater in water pools disappears to, the children answered that the water sinks into the ground. When asked what they believe happens with rainwater on surface such as asphalt or paving stones, the children believed the water disappears down through cracks. Four distinct stages in children's progression of understanding of evaporation and condensation have previously been described (diSessa 1988; Driver 1989; Galili and Bar 1997; Tytler 1998a), where the first stage is the notion that water disappears, the second that water is absorbed into surfaces, the third that water is transferred to another, upward location, such as clouds or air. This third stage view typically occurs around age nine but could appear earlier with the boiling phenomenon where evaporation followed by condensation are visualised, when evaporated water is cooled down and droplets form. The fourth stage is the view that water disperses in the air, associated with a phase change (Tytler 2000). Further, Lindner and Redfors (2007) showed in their longitudinal study of children's view on physical phenomena that 6-year-old children found it hard to grasp how water ends up on a glass lid placed over a glass (i.e. through evaporation) and they had several ideas about how this may have happened. These included water floating upwards but also the view that warm water rises while cold water does not.

Table 1 Description of the eight observations and participating children

Observation	Children participating	Activity
1 a	Ellie, Amanda, Markus, Filip, Hanna, Simon, Frida (3–5 years)	Ice cubes were put in plates in room temperature, outside at 8°C, and in a drying cabinet. A timelapse movie of the ice melting and evaporating in room temperature was created.
1 b[a]	Emilia, Johanna (5 years)	Ice cubes were frozen previously by the younger children, and Emilia and Johanna examined the ice while reasoning about what happens to melted water.
2	Emilia, Johanna (5 years)	Water was boiled in a kettle with a glass lid, stimulated recall was performed with a timelapse movie of water evaporating from a glass bowl in room temperature[b], and Slowmation production was discussed.
3	Emilia, Johanna (5 years)	Stimulated recall was performed with a timelapse movie of water evaporating from a glass bowl. Two Slowmations, one of water evaporating from a glass bowl and one of boiling water, were produced. Material: playdough
4	Ellie, Amanda, Markus, Filip, Hanna, Simon, Frida (3–5 years)	Stimulated recall was performed with a timelapse movie of water evaporating from a glass bowl. Water was boiled in a kettle with a glass lid, and a timelapse movie of the experiment was created.
5	Amanda, Markus, Simon, Frida (3–5 years)	Stimulated recall was performed with the timelapse movie of boiling water made during observation 4, and a Slowmation of boiling water was produced. Material: playdough
6	Ellie, Hanna (4 years)	Stimulated recall was performed with a timelapse movie of water evaporating from a glass bowl. Slowmation of water evaporating from a glass bowl was produced. Material: playdough
7	Amanda, Hanna (4 years)	Stimulated recall was performed with a timelapse movie of boiling water made during observation 4, and a Slowmation of boiling water was produced. Material: LEGO©

[a] Observation 1b was made immediately after 1a, on the same day. The other observations are made on separate days

[b] The original timelapse movie created by the children was used once, not noted here, but the teacher and researcher decided to not use it further. This was due to that the plate with the ice was placed at the kitchen sink in the hall where the children spent most of their indoor preschool time. Several unwanted events showed up on the timelapse movie, including hands, toys, the plate was moved between photos taken, etc. The researcher therefore made another timelapse movie of water evaporating from a glass bowl in room temperature, and this was used for the stimulated recalls described here

Method

Data Collection, Participants and Setting

The project follows a mixed methods approach with both qualitative and quantitative data analysis (Bryman 2001), where the empirical material in the analysis comes from a video and audio recording during the teaching and learning sequence that comprised eight science activities in a preschool in a small town (~3000 inhabitants), part of a metropolitan area in Sweden. A group of nine children (aged 3 to 6 years, six girls and three boys) and their teacher were engaged in a water project where they worked with, and discussed, the phase changes of water, i.e. melting/freezing and evaporation/condensation. The focus of the teaching and learning was evaporation, since initial interviews with the children revealed that the concept of water evaporating was unknown to them.

One typical observed activity lasted between 0.5 and 1 h and started with a group discussion between the children and the teacher. There were two groups, one with two and another with up to seven children present around a table or on the floor, see Table 1. The discussion was followed by a teacher-led experimentation/demonstration, involving situations where the children participated practically and *hands-on* in varying degrees. This refers to the children freezing or thawing water or the teacher demonstrating evaporation by boiling water on the stove with the children around him. In both situations, the children were practically involved by investigating the ice or the water condensed on the lid over the kettle, for instance. These experimentations/demonstrations were performed with or without timelapse photography (Software: Lapse It 2.2, Interactive Universe) with the tablet (iPad). Another typical activity started with a group discussion or a stimulated recall, where the children watched a timelapse movie or Slowmation with focus on evaporation, made previously or at the same occasion, by them and the teacher (Software: myCreate 2.0.11, iCreate to Educate). These group discussions/stimulated recalls were typically followed by either another experimentation/demonstration or a Slowmation production, where the children used playdough or LEGO© to recreate the evaporation situation just visualised in the timelapse movie. The eight observations are described in further detail in Table 1.

The research adheres to the ethical guidelines of the Swedish Research Council (2011). All participants and children's caregivers are informed and have agreed to voluntary and anonymous participation with a right to abandon participation at any time. Pseudonyms are used in analysis and reports.

Data Analysis

Audio and video recordings of child-child and child-teacher verbal communication have been analysed from a phenomenographic perspective with an aim to produce qualitatively different and hierarchically structured categories. Each video recording was transcribed, and each utterance of a child was considered as one or more statements (a statement being a full sentence or part of sentence). A subsample of the statements was read repeatedly and grouped in qualitatively different groups. The grouping was discussed among the researchers, and some adjustments were made. This cyclic process was repeated for a larger subsample, and the process continued until no further refinement could take place, and saturation was reached. The final communication categories described in the Results section had evolved. The categories came to describe the quality of the talk from the perspective of the two types of science knowledge (content and investigations) discussed by Eshach (2006).

The categorisation made it possible to calculate the relative frequencies of statements belonging to the different communication categories, in the different learning contexts. The teacher's utterances were not included in the analysis: however, when he asked a child to clarify an utterance by asking "Did you mean x?" and the child agreed with a "Yes", that yes was coded as the category the teacher's question referred to. Further, if a child's utterance was repeated by several of the other children in the group, one after the other, these repetitions were left outside the analysis. If one child's utterance was followed by another child's "Yes!" or "I think so too", the second child's agreeing statement counted into the first child's statement category. A certain kind of statements was novel and reflective the first time a child uttered them, but when the child's idea or solution for something became widely acknowledged and used in the child group, the following mere mentioning of that idea or solution was coded as belonging to another category. For example, the first time a child suggested that blue clay balls should be made to represent bubbles in boiling water, this was considered as belonging to a more advanced category, as compared to when the idea was accepted by the group and the same child, or another child, later made a remark about the bubbles. Left outside the analysis were incomplete statements that could not be understood by the researcher and therefore not categorised as belonging to any of the six categories described below.

Results

Here, we report on the analysis of the video recordings of the children during the four different learning contexts constituting the entire teaching and learning sequence. The focus of the analysis is the verbal communication in the different contexts described above.

The following categories concerning verbal communication about the science phenomenon emerged. The categories 1–6 form a hierarchical order, with more advanced statements or reflections belonging to categories 1 or 2. The quotes are from the analysed video transcripts and exemplify the different categories. The category 6 captures all statements mentioning the tablet. Context/Category, name, age and observation are stated within brackets.

1. Synthesising Reflections, Including More than One Aspect of the Phenomenon, or Representations (S)

   This category includes the most advanced reflections, and statements where more than one aspect, concept or representation related to the phenomenon or practical work are considered.

> One builds a kettle and then one can put some water in it, then throw some fluff or so like smoke. (PS/S, Johanna, 5 years, observation 3)
>
> They (the plates) are really cold, then how can they (the ice cubes) melt? (Et/S, Simon, 3 years, observation 1a)
>
> Ah, then the water disappears! (E/S) When the bubbles disappear, then the water disappears. (E/S, Johanna, 5 years, observation 2)

2. Reflection Including Hypothesis (R)

   This category includes reflections and hypotheses concerning processes or explanations connected to the science phenomenon or to practical work, e.g. with Slowmation production.

> It (the water) melted into the plate. (GD/R, Hanna, 4 years, observation 4)
>
> It disappeared into the table. (SR/R, Johanna, 5 years, observation 2)

How will this playdough be able to go into that bowl? (PS/R, Ellie, 4 years, observation 6)

3. Process

   This category includes statements connected to processes of practical nature with or without explicit reference to the phenomenon and is therefore further divided into the following:

   a. **Phenomenon (Pph, Pphs)**

      Talk of processes related to the science phenomenon and theoretical explanatory model. Utterances regarding something the children experienced during the experiments, with (Pphs) or without (Pph) sequential character.

There were bubbles. (GD/Pph, Amanda, 4 years, observation 5)

There's water underneath (the lid). (E/Pph, Johanna, 5 years, observation 2)

   b. **Practical (Pp, Pps)**

      Talk of doing something practical. Statements with (Pps) or without (Pp) sequential character.

We boiled water. (GD/Pp, Frida, 5 years, observation 5)

First, they made a drawing and then they made a film of it. (PS/Pps, Johanna, 5 years, observation 2)

4. Concepts Mentioned or Briefly Described (C)

   This category includes statements where concepts related to the science phenomenon are mentioned, or shortly described.

Water (answer to teacher's question "What was in there?"). (SR/C, Ellie, 4 years, observation 6)

Warm (answer to teacher question "How warm is it in here?"). (GD/C, Filip, 3 years, observation 1a)

5. Other (O)

   This category includes statements not connected to processes or the studied phenomenon and "Don't know" answers.

I remember the time N fell off the chair. (GD/O, Ellie, 4 years, observation 5)

I have to go to the bathroom. (GD/O, Simon, 3 years, observation 1a)

6. Tablet (T)

   This category involves statements about the tablet and includes talk about settings, photo angles, Slowmation names etc. The category may or may not be combined with any of the other categories, depending of the nature of the statement.

And then take a photo. (PS/Pp,T, Markus, 4 years, observation 5)

We should probably turn it. (PS/Pp,T, Amanda, 4 years, observation 7)

Now I know! "Water, take away, under the bowl" (name for Slowmation). (GD/T, Ellie, 4 years, observation 6)

The Learning Contexts and the Verbal Communication

The four different learning contexts and the distribution of the identified verbal communication categories within them, their content and boundaries, will in the following be closely presented. The prevalence of each category in the different learning contexts is presented in Table 2, with the major findings highlighted in the text.

Learning Context: Group Discussion

Group discussions occurred in seven of the eight observations and as mentioned previously, the discussions took place with the teacher and two to seven children, around a table or on the floor, with the children sitting in a half circle around the teacher. The discussion was often the start of an activity, preceding experiments or Slowmation production. The teacher asked for the children's recall of previous activities and their experiences around the water phenomenon, or for the children's hypotheses prior to experiments. During the discussions, the teacher had a leading role and enticed the children to think and reason. No practical activities took place in this context.

As presented in Table 2, the predominant communication category during the group discussions was *Process*. It constituted more than half of the group discussion statements, divided evenly between practical or phenomenon character, with slightly higher frequency for statements connected to the phenomenon:

> No, they were… It happened that they revolved a little (the bubbles in the boiling water). (GD/Pph, Amanda, 4 years, observation 5)

Reflection and *Synthesising reflection* constituted 11% and 2%, respectively, of the statements during the group discussions. Although reflections could be of either a practical or a phenomenon character, they were most often about the nature of the phenomenon, with very

Table 2 Mean values of percentages of coded statements in the communication categories for the different learning contexts are presented. The percentages given for each context are mean values for all observations of that context. The total number of coded statements for each context is given in parenthesis

Learning context				
Categories	Group discussion (320 statements) %, mean of 7 obs.	Stimulated recall (167 statements) %, mean of 6 obs.	Production of Slowmations (793 statements) %, mean of 5 obs.	Experimentation (306 statements) %, mean of 4 obs.
Synthesising reflection	2	0.3	7	6
Reflection	11	27	21	17
Process				
Phenomenon	28	32	6	34
Practical	26	33	55	30
Concept	10	1	1	4
Other	17	8	7	7
Tablet[a]	10	8	14	9

[a] Some statements are categorised as only Tablet (T), some as both T and another category. Therefore, the sum of each column exceeds 100%

few exceptions. Together with the teacher, Johanna and Emilia performed the experiment with the boiling water and the girls concluded that warm water is able to rise up in the air. When they were discussing the fact that the water in the drying cabinet also disappeared, Johanna reflects:

> Then all water must have turned into smoke (vapour) (GD/S). All water has risen up, then it disappeared (GD/S). That's how it disappeared. (GD/S, Johanna, 5 years, observation 2)

A little later in the discussion, Johanna asked "Is smoke from airplanes water?" (GD/S). All synthesising reflections in the context of Discussion are of this phenomenon character.

Statements about the *Tablet* in the Group discussion context were heard in observation 4, where the children and teacher recalled what they had been using the tablet for previously (making a timelapse movie), and in observation 5 (Table 1), where the children and the teacher discussed the boiling water Slowmation just created by them. Focus was here on number of photos, what speed the Slowmation should be played back at and what the Slowmation should be named:

> I know, it (the Slowmation) could be named "Leris" (playdough). (GD/T, Frida, 5 years, observation 5)

> That one (the tablet) changed the picture all the time. (GD/Pp,T, Markus, 4 years, observation 4)

In conclusion, most talk during Group discussion involved practical and phenomenon processes. The children kept their focus on the topic, water phases, throughout the discussion and the most advanced reflections made by them concerned, with few exceptions, the nature of the phenomenon.

Learning Context: Stimulated Recall in Group

The context *stimulated* recall in group was present in six of the observations and involved the children and teacher recalling the water phenomenon by looking at timelapse movies or Slowmations previously made by them. This context was used both prior to experiments or Slowmation production and sometimes also directly after these activities, to reflect on the movie produced. The stimulated recalls thus involved Slowmations or timelapse movies, representing water disappearing from a bowl or boiling water with water steam. One exception occurred in observation 2, where a timelapse with a burning candle was used and discussed, in addition to the water bowl timelapse. The reason for the use of the burning candle timelapse was a discussion the teacher and two 5-year-old girls had about evaporation not being restricted to water; melted stearin (wax) also evaporates into the air.

During the *stimulated* recall context, the majority of statements concerned *Process* (65%), evenly distributed between being of a practical and a phenomenon nature (Table 2).

> The ice cube disappeared. (SR/Pph, Markus, 4 years, observation 4)

> Frida removed it (the playdough). (SR/Pp, Amanda, 4 years, observation 5)

Interestingly, *reflection* was the second largest category within this context and of these statements, the vast majority, with few exceptions, were about the phenomenon. This was especially true when the stimulated recall was by use of timelapse movies:

> Then it (the water) must be able to slip… down in the table. (SR/R, Johanna, 5 years, observation 2)

To the contrary, when the children watched their Slowmations, the reflections tended to involve processes of practical or phenomenon character. Often, the two coincided when they talked about their Slowmations, since the children constructed the phenomenon in playdough or LEGO©:

> We put in bubbles. (As answer to the teacher's question about the order of events in the Slowmation just made by the children) (SR/Pphs, Amanda, 4 years, observation 7)

Some talk about the tablet occurred when the children looked at the Slowmations or timelapse movies they had created, and the statements were mainly about at what speed the film should be played back in:

> Next we take the quick one! (SR/Pp,T, Markus, 4 years, observation 5).

To conclude, when the children commented on their timelapse or Slowmation movies, they tended to focus on processes of practical or phenomenon character. Interestingly, the stimulated recall also promoted many reflective statements, almost exclusively about the phenomenon.

Learning Context: Production of Slowmations (PS)

The Production of Slowmations (PS) context took place in five of the eight observations. These situations typically started with a stimulated recall where the teacher showed the children the timelapse movie about either the water in the glass bowl or the boiling water. The children commented and explained the content to the teacher, and they were afterwards asked to recreate what they had seen, in playdough (three occasions) or LEGO© (one occasion). In observation 2, no Slowmation production took place in practice, but the children watched a Slowmation movie on YouTube and discussed with the teacher how the movie had been created and how they, in the next step, could make their own Slowmation.

The most frequent category within the context was *Process*. However, as presented in Table 2, the vast majority of statements belonged to the subgroup *practical* and not to *phenomenon*. It seems that when the children are busy creating in playdough or with LEGO©, their focus is on practical issues and how to solve those:

> We start with one colour, then we take a new, then we take a new, how big it will be. (PS/Pp, Johanna, 5 years, observation 3)

The second largest communication category when the children were making Slowmations was *reflection*. Most of the reflective statements concerned practical issues of the following kind:

> (Gesture towards the tablet where she just watched a Slowmation on YouTube) That's what they've done, they have filmed! (PS/R) (…) One can make a film with an iPad or a camera. (PS/R, T, Johanna, 5 years, observation 2)

The above example is one of *tablet* characters too. The tablet statements constituted 14% of the total statements in the Slowmation context and were most often combined with practical statements, like exemplified above, or about where to put the tablet for the best photo angle, etc.

Except for these reflections of a more practical nature, the children also reflected around the phenomenon, and in this case, practical problem solving and phenomenon features often coincided when the children communicated around Slowmation making:

> Then one has to draw water (PS/R). And ice cubes. (PS/R, Johanna, 5 years, observation 2)

Seven percent of the statements in the Slowmation producing context were of *synthesising reflection* character. These involve how the children choose to stage different features of the phenomenon, in playdough or LEGO©:

> Then it can disappear small amounts of blue playdough. (PS/S) (…) One can do it really carefully. (PS/S) One can take crunches and continue like that. (PS/S, Johanna, 5 years, observation 3, about how to illustrate the disappearance/evaporation of water from the glass bowl.)

The following discussion took place during observation 6 when the children were asked how they could recreate the water going into the bowl, i.e. their explanation for the evaporated water:

> Hanna: Now I know, one can put it under. (Points to the bottom of the playdough bowl) (PS/S)
>
> Teacher: One can put it under, how do you mean? That you..?
>
> Hanna: One moves it like this, underneath. (Takes some blue playdough (water) from the bowl and shows how she plans to put it under the bowl.) (PS/S)

During observation 7, the children made a Slowmation about the boiling water but this time with LEGO© as material, instead of playdough:

> I was thinking, can't we have this as, like smoke? (PS/S, Hanna, 4 years, observation 7, talks to the teacher and refers to some grey LEGO© plates she holds in her hand).

In another sequence in observation 7, the teacher and children talked about the 'smoke', that is, the water steam from the boiling kettle:

> Teacher: What happens now? Is the smoke staying there? (refers to the water steam seen in the kettle)
>
> Amanda: No. (PS/Pph)
>
> Hanna: Goes up in the air. (PS/Pph)
>
> Teacher: It goes up in the air. How are we going to show that?
>
> Amanda holds grey, LEGO© sticks above her head as high up as she can.
>
> Amanda: Hold up. (PS/S)
>
> Teacher: Yes, but the kettle is over there?
>
> Amanda: Ehm. It flies around in the whole room. (PS/R)

In summary, the Slowmation producing context, when the children worked hands-on with creating representations for their movie, clearly stimulated talk about practical issues. In addition, many statements were reflective and connected to these representations of the phenomenon.

Learning Context: Experimentation, with and without Timelapse Photographing

This context occurred in four of the observations and involved the children working more or less hands-on with the phenomenon. In one observation (1a), they put ice cubes in different plates to observe how long these take to melt when the plates are at room temperature, outside at 8°C, or in a drying cabinet in use. Another experiment was performed by the teacher when he boiled water at the stove with the children standing on chairs or sitting on the kitchen sink next to him. Because the teacher was the more active person in the situations, one could argue that this activity was more of a demonstration than an experiment from the children's point of view, but we choose to describe it as an experiment since the children are active in investigating the water steam on the glass lid with their fingers, or telling the teacher what to do next (put on the lid, take it off, turn that lamp on, etc.). During two activities, the experiment with the ice cubes in the plates and one of the boiling-kettle-events, the tablet was present and timelapse movies were created.

When the children communicated during the above mentioned experiments, the most prevalent category was *process*, which constituted 64% of the total statements (Table 2). These *process* statements are mainly about the phenomenon, both with and without the tablet present for timelapse photography:

> They are about to melt and that one has melted. (E/Pph, Emilia, 5 years, observation 1b)

However, when the children experimented and produced timelapse movies of melting ice and boiling water, respectively, the process statements were more evenly divided between being about the phenomenon or practical. If anything, the practical statements were somewhat dominating the communication within the process category and this was to a large part due to the tablet. The children discussed angles, settings etc.:

> I think I know where it (the tablet) could be placed. (Et/Pp,T, Frida, 5 years, observation 4)

The second most common category of statements in the experimentation context was *reflection*. These were exclusively about the phenomenon, no reflective statement concerned practical issues:

> I know! Maybe it's just there? (Shows with his finger in the plate, as an answer to the teacher's question about what will happen to the water once the ice has melted.) (Et/R, Filip, 3 years, observation 1a)

Seven percent of the statements during experimentation involved *synthesising reflection*, and these were focusing the phenomenon:

> I see, then the water disappears! (E/S) When the bubbles disappear, water disappears. (E/S, Johanna, 5 years, observation 2)

A little later in observation 2, the following dialogue between the teacher and the children took place. They had just concluded that there was smoke in the kettle and on the lid:

> Teacher: Then I removed it (the lid) from the kettle and then there was..?
>
> Johanna: Water. (E/Pph)
>
> Teacher: Then there was water.
>
> Johanna: So smoke is actually water! (E/S).
> (…)

Johanna: Okey, then there's water around us! (E/S).

Emilia: Invisible water. (E/S)

To sum up, *process* statements were the most prevalent during this context but experimentation clearly promoted reflective talk around the phenomenon as well. The children stayed focused on evaporation both with and without the tablet, used for timelapse photography, during the activity.

Comparison of Communication Categories in the Different Learning Contexts

In search of responses to research question two, we have compared the distribution of the communication categories for the different learning contexts. It appears that the hands-on activities, i.e. production of Slowmations and experimentation, promoted verbal communication of a reflective kind, while stimulated recall with the timelapse movies created by the children foremost generated reflections and supported communication about the phenomenon.

The children are more or less physically active during the different learning contexts. The group discussion and stimulated recall in group represent the two less physically active contexts, while experimentation and Slowmation production represent the more active contexts. When these four different learning contexts are compared, patterns in the communication are emerging, as can be seen in Table 2. *Process* is the most common category in all of them. When producing Slowmations, the children focus their *process talk* around practical issues and this can also be seen in the experimental situations where the tablet is included and timelapse movies produced. Talk about the tablet is most often heard in the Slowmation context, as compared to the other contexts where this communication topic constitutes about 10% of the statements (Table 2).

The children's talk during experimentation and Slowmation production is similar, in terms of the most and least prevalent communication categories. During these learning contexts, children are occupied with *hands-on* activities, which result in the major communication topic to be process oriented and the second most common category being *reflection*. However, within this category, the reflective statements differ somewhat in character between experimentation and Slowmation production. Reflections and *synthesising reflections* in the experimental situation are exclusively about the phenomenon, while when making Slowmations, the children reflect mainly on purely practical issues, such as which colour of playdough to use for the bowl, etc. Also, practical and phenomenon statements coincide in this context, since it is the phenomenon the children are staging in the Slowmations, see Table 2.

The most reflective statements during Stimulated recall with the timelapse movies involve the phenomenon itself, while when the stimulated recall is by use of Slowmations, the reflective remarks are more about practical issues. Reflections of a joint practical and phenomenon kind are observed also in the stimulated recall context, where the children watch and talk about the content and practical solutions for illustrating the phenomenon, in the timelapse or Slowmation movies produced by them. During group discussion, as during experimentation, the reflective remarks are focused around the phenomenon itself.

In the context of stimulated recall, the synthesising reflections are absent, except from one remark in observation 2 where Johanna compares evaporating steam to evaporating water, while in group discussion, the rather few synthesising reflective remarks are about the phenomenon.

The communication categories classified as the least advanced by us, *other* and *concept mentioned or briefly described*, are more common during group discussions compared to the other contexts. The latter of the two is distinctly unusual in other contexts.

Discussion and Conclusions

The working process designed and performed in this study aimed at starting in the world of the children and synthesising the specific and general domain-knowledge described by Eshach (2006). That is, content (concepts, theories, theoretical models) and investigations (hypotheses, problematizing, questions, experiments) for young children's effective science learning. From the results, it was evident that the physically active contexts of *experimentation with and without timelapse photography* and *production of Slowmations* promoted the children's more advanced reflections about both the natural phenomenon, i.e. water phases, and creative representations and problem solving. We therefore conclude that the working process, i.e. group discussions followed by experimentation, stimulated recalls and production of Slowmations, is a fruitful setup when working with preschool children and natural phenomena.

In all the learning contexts studied, the major communication category was *process*. Most statements made by the children hence involved the process of practical work or processes connected to the phenomenon studied. The communication about the latter, i.e. water phases and phase changes, was more focused during the group discussions, stimulated recalls and experimentations and less focused during the Slowmation productions when the children were more active. The Slowmation context seemed to promote communication about practical issues such as how to represent the phenomenon, problem solving, or small talk about the playdough, colours etc. However, as stated in the *result section*, the phenomenon coincided with the practical statements in cases when the children discussed how to represent the phenomenon in playdough or LEGO©. The fact that both experimentation and Slowmation production enhanced more advanced reflections about both the phenomenon and creative problem solving supports previous research and the findings of Fleer and Hoban (2012). They conclude that a key feature of using Slowmations is the discussion created through social interaction around the technology and the physical construction of the concept. When the children give new meaning to objects used in the film, they enter a shared imaginary situation around the natural phenomenon studied (Fleer and Hoban 2012).

The highest number of reflective statements is found in observation 2, see Table 2. Here, reflection is more prominent than the process category, while in the other Slowmation producing contexts it is the other way around. What differed in observation 2 was that the children were only discussing production of Slowmations, they were not active in creating them, and this points to a more process oriented communication when the children are actively working with producing Slowmations.

When the seven group discussion occasions are compared, it is evident that observation 4 displayed more practical talk, compared to the other observations. The reason could possibly be explained by the fact that observations 4 and 5, where a rather high portion of practical talk also occurred, had seven of the younger children (3–4 years) participating. It was also apparent, albeit not visible in the communication results focused in Table 2, that the contexts where four children or more participated got more stressful and somewhat rushed. The children talked at the same time, more time from the teacher was spent on keeping the discipline and arranging who was to sit or stand where, etc. When the teacher worked with only two children during experimentation or Slowmation production, the atmosphere was calmer and the children had more time to think about their ideas. This was evident in observations 3 and 6 where only two children participated during the Slowmation production, and they took more time to rearrange the playdough between every photo. A few *water bubbles* were added, a photo taken, more bubbles added, etc. In observation 5 where four children worked together, the situation was more hectic, the children were almost competing about adding bubbles and less time was used for reflection and thinking ahead, even if the teacher repeatedly encouraged the children to reason and think before doing anything. This is addressed by Johansson and Pramling Samuelsson (2006) who state that teachers need room for improvisation and for communication and interaction with the children, something easier accomplished in smaller groups. Our results concur with this and raise questions about how learning situations in preschool are arranged, both from a pedagogical and a structural perspective.

Another finding worth mentioning, outside the verbal communication categories in Table 2, is that a lot of the work going on with the tablet is silent. The children move the tablet, adjust it, change settings etc., without it being recorded in words. Little research has been made to explore the viability of young children's work with tablets, but a study by VanderScoter et al. (2001) has shown that *how* the technology is used with young children is important. The researchers recommend applications that give the children opportunities to explore, imagine, solve problems, and choose between different options. The touchable interface of tablets makes them rather easy to handle for children, and in addition, our observations show that another benefit with working with a tablet when creating Slowmations is the attention it automatically gets from the children. They are interested in the tablet and seem to feel comfortable and appreciative when working with it as a tool.

In the work with evaporation in this study, our main focus was not on the actual learning of the children: for them to provide the right scientific explanation was in other words not our primary goal. Instead, our focus was on the verbal communication itself and the children's reasoning and thoughts, whether right or wrong. However, worth discussing in relation to timelapse photography is our reflection that different natural phenomena may be more or less suitable to work with. In the case of evaporation, the timelapse movie where the water evaporated from a glass bowl in room temperature mislead the children into holding onto the previously stated view that the water sunk into the bowl. That notion was strengthened by vision of the fast sinking amount of water in the glass bowl and brings forth the need for careful reflection on phenomena suitable for a timelapse, when the goal is the actual learning about its features. In our case, the next step of activities included the teacher and the children boiling water in a kettle and here, the children realised that water evaporates up in the air. The next step, although not performed in this study, could be to cover the glass bowl with a glass lid or plastic, to capture droplets of evaporated and condensed water (Lindner and Redfors, 2007). From here, the discussion with the children could be continued and with the help of the teacher, fruitful discussions on water evaporating also in room temperature could evolve.

Thulin (2011) found that when a teacher was involved with children in examining life in a tree stump, this practical and goal-oriented work promoted a more even interaction between the teacher and the children. The teacher still took the initiative and led the work but the children talked more, and their experiences were taken into consideration in a different way by the teacher, compared to when the children were not as active (Thulin 2011). In our study, we also observed a change in the teacher's role when he communicated with the children in the contexts of group discussion, Stimulated recall in group, and experimentation, as compared to the more active context of production of Slowmations, from the children's point of view. In the three former contexts, the teacher showed a tendency to question the children in a more leading way about their recollection of their previous experiences. In the Slowmation producing context, however, the children were given a freer, more creative role in the communication. The teacher supported them by recalling the phenomenon and by asking them about their different representations and practical solutions, hence, helping them focus on the important features in what they created, but still allowing the children to come up with solutions and ideas themselves. Eshach and Fried (2005) point to the role of a teacher as one that demonsrates how a comb will deflect a stream of water after the comb has been run through one's hair, rather than speaking of static electricity. This *mere looking* presupposes the teacher's ability to resist premature explanations and to separate the exposure to phenomena from the interpretations of it (Eshach and Fried 2005). A challenge, since it might open up for misconceptions, but as Eshach stresses, well-designed science education can help students look while maintaining an openness needed to ultimately give them a more refined world perspective (Eshach and Fried 2005).

The analysis of collaborative learning situations supported by ubiquitous computing reported on here shows that children's work with constructing and discussing timelapse and stop-motion sequences of science phenomena can be seen to have an impact on the observed communication. The production of timelapse and Slowmation movies stimulate the children to engage and discuss hypotheses and reflect jointly. While timelapse photography supports the children in noticing features of scientific and natural phenomena, Slowmation production *forces* the children to reflect about explanatory models for the same phenomena and how to represent these in the movie. We therefore share the view of Fleer and Hoban (2012) that Slowmations provide a sense of purpose for exploring scientific concepts. When the children make a narrated animation, their actions and ideas are turned into a concrete and visible product, through new meaning making of objects in an imaginary way that they are familiar with through play.

Worth mentioning is the non-verbal representations which were abundant when the children were creating the Slowmations and interacted with each other. There were a lot of discussions about how to illustrate the actual phenomena, but also non-verbal representations. For example, when they created the lid and the *smoke* from the cooking experiment, the *smoke* was represented by either holding up playdough water bubbles in the air in front of the tablet camera to photograph, or by holding grey LEGO© sticks over the kettle. The water disappearing into the bowl was in one of the Slowmation movies illustrated by *playdough water* being removed from inside the bowl and put underneath the bowl instead. Interesting is how the children discuss when choosing artefacts/tools for the specific phenomena they wanted to illustrate. Aspects like choice of colour, size and position say something about how they understand the actual phenomena and the situation they intend to illustrate.

In summary, our study points out timelapse and Slowmation production as beneficial and effective tools in synthesising the specific and general domain-knowledge discussed by Eshach (2006); i.e. content (concepts, theories, theoretical models); and investigations (hypotheses, problematizing, questions) for young children's science learning. The software used is easily accessible at either no or low-cost, and our working model could therefore be implemented in almost any preschool. We emphasise that the use of technology in preschool should not be disconnected from content and children's everyday experiences. Future studies will aim at investigating the interaction between teacher-children and children-children from a broader perspective and beyond the verbal expression. Focus then would be on a more inclusive communication, during timelapse and Slowmation production. Children's learning of different science phenomena in the process and their free choice of materials for representations should also be further analysed. Another aspect not in the forefront of this article is the teacher's perspectives and actions. Opportunities and challenges envisioned by the teachers for the proposed work model is something that need further investigations in the future. Especially, studies using an inclusive framework for teachers' competences encompassing not only teachers' experiences of science and science education, but also their experience of children, children's learning, and the role they perceive for themselves during science learning activities. All, which we agree with e.g. Fleer (2009), is reflected in children's possibilities to learn.

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