education sciences

Article

Early Years Physics Teaching of Abstract Phenomena in Preschool—Supported by Children's Production of Tablet Videos

Andreas Redfors *, **Marie Fridberg**, **Agneta Jonsson** and **Susanne Thulin**

Faculty of Education, Kristianstad University, SE-291 88 Kristianstad, Sweden; marie.fridberg@hkr.se (M.F.); agneta.jonsson@hkr.se (A.J.); susanne.thulin@hkr.se (S.T.)
* Correspondence: andreas.redfors@hkr.se

Abstract: In 2011, a renewed national curriculum for preschools in Sweden introduced explicit pedagogical tasks concerning chemistry and physics. This article is about the analysis of physics teaching supported by video productions with tablets, part of a three-year professional development programme on collaborative inquiry teaching of chemistry and physics in Swedish preschools. The temporal case studies reported here were focused on children's and teachers' communication during extended teaching sequences with three- to six-year-old children in two Swedish preschools. Eleven children and two teachers participated in this study. The children worked in small groups with one teacher. Results indicate that children's video productions by tablets contributed to children's learning, with differences indicated for children's experiences of objects of learning in physics at different levels of abstraction. Consequences of the results for future teaching of early years physics are discussed.

Keywords: preschool; early years physics; digital technologies; tablets; teaching

Citation: Redfors, A.; Fridberg, M.; Jonsson, A.; Thulin, S. Early Years Physics Teaching of Abstract Phenomena in Preschool—Supported by Children's Production of Tablet Videos. *Educ. Sci.* **2022**, *12*, 427. https://doi.org/10.3390/educsci12070427

Academic Editor: Michelle Neumann

Received: 10 May 2022
Accepted: 20 June 2022
Published: 22 June 2022

1. Introduction

Since 2011, the pedagogical task concerning chemistry and physics for Swedish preschool teachers has continued to be reinforced, and in 2019 the current national curriculum [1], also strengthening the use of digital tools, was introduced. Even so, teaching of chemistry and physics is a comparatively short tradition in preschool and is often viewed as difficult to handle by preschool teachers [2]. Therefore, a school district decided to dedicate time to a three-year PD programme focusing on chemistry and physics teaching.

We report here on a video analysis of teaching activities that were supported by children's production of digital videos, and part of the three-year professional development (PD) programme on collaborative inquiry teaching of chemistry and physics in Swedish preschools. The PD programme involved all preschools in a school district in a mid-sized Swedish town encompassing both rural and central areas. All seven preschools with 140 staff members and six headmasters were part of the PD programme.

The renewed national curriculum in 2011 initiated discussions about the goals for science content in preschools and consequences for preschool teachers' education [3–6]. There is no consensus about what science teaching in early years should be, but it is realised that early-years teachers need both content knowledge and competence to support children's science learning [6–14]. Fleer et al. [15] argue that a 'sciencing attitude' has great potential for science teaching in preschool, and teachers embracing children's perspectives [13,16,17] can enact teaching activities where 'mutual simultaneity' in teacher–child intercommunication can be established [12,17,18]. This means that the teacher simultaneously creates links to the science content and takes the children's perspective into account. Mutual simultaneity helps children to experience new science phenomena [12,17,18].

In the PD programme, a semantic view of theoretical models in science, with focus on their explanatory powers [13,19], was introduced. Science is here viewed to describe real-world phenomena by organizing explanations based on presuppositions through theories and theoretical models generated by people, and where observations and experiments are viewed as embedded in theory and 'theory laden' [20], see Figure 1.

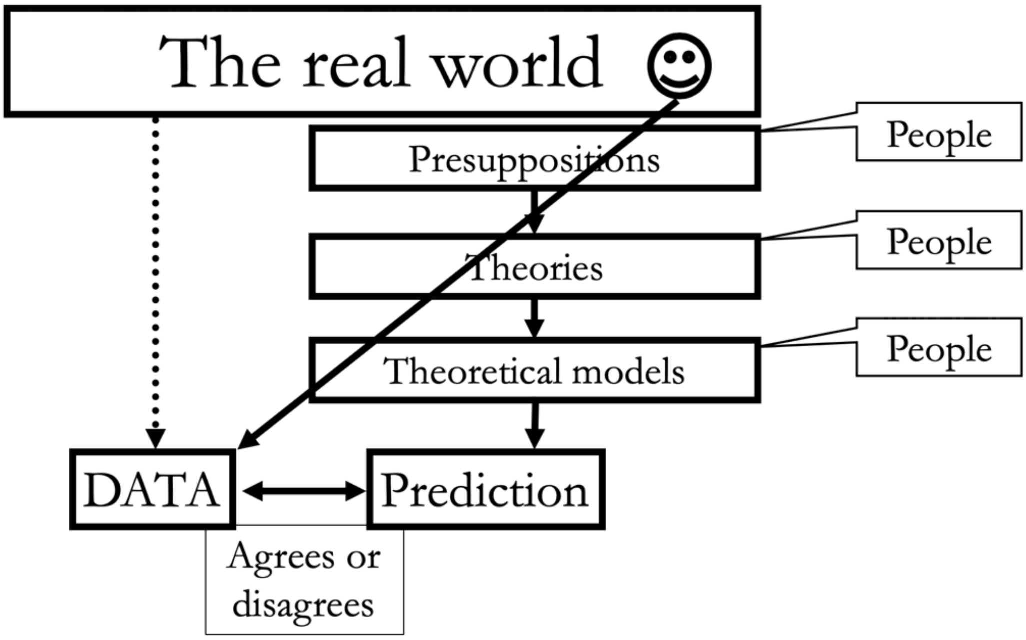

Figure 1. Observation of real-world objects and events is viewed as theory laden [20]. Predictions and observations made by a person to obtain data are seen as "filtered" by theoretical models generated from established frameworks formulated by people. Adapted from [21].

Therefore, efforts were taken to communicate the necessity for all science teaching in the PD programme to be set up to involve both an everyday phenomenon from the real world, with chemistry or physics constituents, and a suitable theoretical model. Time was spent on discussions of the importance of the teachers' own experience of the science phenomena and the influence of their experienced theoretical models on how they would talk about selected real-world phenomenon, as depicted in Figure 1. Hence, a need for the work teams to develop mutually shared theoretical models to underpin the teaching was emphasized. A set of chemistry and physics phenomena related to both children's and the preschool teachers' everyday experiences, with accompanying suggested theoretical models, were introduced in the PD. It was found to be important to emphasize the connection of the chosen phenomena to daily life in order to help instigate positive attitudes towards the content. Furthermore, teaching in Swedish preschool is by tradition project oriented and inquiry procedures are well suited. Hence, the two domains discussed for children's science learning—content and investigations [22]—were both emphasised in this project.

The role of multiple representations in science teaching has been given attention during the last decades [23,24]. Other studies have reported on use of digital tools in early years education [7,25,26]. In a pilot study, we reported on preschool children's work with evaporation of water [27]. A multi-step teaching sequence, with group discussions, experimentation, and the children's documentation in the form of timelapse and slowmation production [28], was analysed with focus on the children's verbal communication, and it was concluded that use of timelapse movies to stimulate recall helped the children to concentrate and reflect during the discussions. The children's production of slowmation on computer tablets, a form of stop-motion animation characterized by a science content [28], made the teacher aware of the children's explanatory models, and made continued teaching easier [29]. The pilot results suggest that the creation and use of video productions by tablets, with content involving a science phenomenon, can be helpful, and that computer tablets in preschool can be used to scaffold learning of specific science content.

In the PD, the science teaching activities, scaffolded by tablets and based on a consensus theoretical model of the chosen science phenomenon, were developed by teachers and researchers in design groups. Variation theory [30,31] and developmental pedagogy [32] were put forward as the combined theoretical framework for the teaching activities. In this theoretical perspective, teaching and learning are always directed at something specific (here: constituents of the theoretical model related to the phenomenon, or skills). This 'something' is called the object of learning and 'learning' is viewed to cause a qualitative change in the learners' way of experiencing the object of learning, and their future ways of acting [33]. The object of learning is dynamic and understood as (1) *intended object of learning* planned by the teacher, (2) *enacted object of learning*, referring to how the teacher enables experiences of the object of learning in teaching situations, and (3) *lived object of learning*, what the students experience, which may differ between learners depending on previous experiences [33]. Developmental pedagogy is a theoretically informed model of learning, like variation theory, grounded in phenomenography and developed to study and promote young children's learning [34].

The objects of learning we are focusing on here involve physics phenomena with different levels of abstraction. Theoretical models of the investigated real-world phenomena involve the movement of invisible particles in air, water, and water vapour. Note that theoretical models involving a particular nature of matter have earlier been reported on as challenging, but also, with special consideration, feasible for young students to learn and use [35–37]. Other abstractions that have been reported on as inherently difficult to appropriate by learners are concepts involving quotients in physics, so called intensive quantities [38].

The aim of the analysis reported on here was to develop knowledge about how children's video productions by tablets can be used during a teaching sequence to scaffold learning and contribute to children's experiences of objects of learning in physics at different levels of abstraction. The research questions guiding the analysis are:

1. How can video productions by tablets contribute to experiences made by children of a specific object of learning in physics, during a multi-step science teaching sequence in preschool?
2. How does the abstract nature of the objects of learning in physics influence experiences made by children during the teaching sequence?

2. Methodology and Analysis

Three work teams from the involved school district in the PD volunteered for the data collection presented here. The science activities were designed to be scaffolded by computer tablets and followed the teaching sequence below with five steps. The fifth step was added to the four previously tested in a pilot [29].

1. Introductory discussion with children of the jointly chosen real phenomenon.
2. Collaborative inquiry real-world experiment documented by tablet (timelapse or slow-motion movie depending on characteristics of the phenomenon).
3. Group discussion scaffolded by stimulated recall from the tablet movie.
4. Collaborative production of slowmation by the children scaffolded by teacher and.
5. Children demonstrating and explaining the slowmation movie to one of their preschool teachers, preferably one not involved in the production—Retell.

The fifth step introduced a strategy for elucidating the lived object of learning, i.e., that the children demonstrate and explain their slowmation to a familiar preschool teacher that had not been involved in the production. This step gives rise to data from which the lived object of learning can be inferred. Also, the reader should note the difference between the words 'slow-motion' in step 2 and 'slowmation' in steps 4–5. While the first refers to a video sequence played back more slowly than it was recorded, so that the real phenomenon appears slower, the latter refers to a type of stop-motion video.

The age and number of the children, and the respective object of learning for the investigated work teams in preschool 1 and 2, are described in Table 1. For various reasons the third preschool left out the video production (timelapse or slow motion) in step 2, which made the teaching sequence differ from in the other two preschools. To maintain a consistency in methodology, only preschool 1 and 2 are presented here. During a time span of one to two weeks, teachers were video recorded while enacting science teaching (30–60 min sessions) with a group of children (see Table 1) following the steps of the teaching sequence (see above). The children demonstrated and described their accomplishments after the implementation during the fifth concluding step. The work team and the involved children jointly chose from the set of physics phenomena highlighted in the PD, i.e., phenomena that were established as related to both the children's and the teachers' everyday experiences, to focus on during the teaching activities, and the work team formulated an object of learning linked to their mutual theoretical model. This process was supported by the researchers. The two different objects of learning involve different levels of abstraction in their theoretical models.

Table 1. Involved preschools, groups of children, and objects of learning.

Preschool	Age of Children	Number of Children	Object of Learning	Experimental Activity
Preschool I	3–5	5	Air resistance	Free fall of different balls
Preschool II	4–6	6	Changes of state	Melting of ice and boiling of water

The teachers followed the teaching sequence described above and the first three steps have been collapsed in the analysis for both preschools, see Table 2. The reason for the three steps being described under one heading in the table is that they occurred as one event. The introductory step was intertwined with the experiment and the documentation by a timelapse or slow-motion movie, followed by a discussion about the content in the movie.

Table 2. Descriptors of the teaching and learning sequence in the two preschools.

Preschool	1–3. Intro, Activity and Discussion	4. Slowmation Production	5. Retell
Preschool I	Air resistance, experiment recorded in slow-motion	Production of a slowmation	One child retelling the experiment, while showing the slowmation to a teacher
Preschool II	Water boiling, documented by timelapse photography	Production of a slowmation	Two children retelling the experiment, while showing the slowmation to a teacher

The analysis leading to the result presented below has focused on answering the two formulated research questions through detailed temporal analysis. The analysis pursued a progression over time for the children's experiences of the object of learning during the steps of the science teaching sequence. The analysis is from a temporal perspective, with the scaffolding of the children's video productions by tablets, and the abstract nature of the objects of learning in focus. To follow the teaching and learning process concerning the object of learning during the different contexts of the teaching sequence, the analysis was carried out in the following steps. The video recordings of the enacted objects of learning were transcribed, including descriptions of nonverbal communicative actions. A qualitative analysis focusing on teacher–child communication during the enacted object of learning was performed. Transcripts of videos were read by the authors independently, and critical incidents from the different contexts were selected. It was a verbatim analysis with a focus on the children's explanations and uses of concepts from the theoretical models related to the objects of learning. The researchers compared their results and a coherent selection of excerpts evolved. Examples from the temporal analysis of the two analysed cases (air resistance of balls in free fall and phases of water during heating of ice) are presented below.

Ethical considerations for this research in cooperation with preschools in a school district adhere to recommendations by the Swedish Research Council [39]. This includes the researchers informing about voluntary participation, that participants had the right to cancel their participation if they wish, and that participants and preschools are given pseudonyms in the data when the study is reported. Trust, virtue, and confidentiality have been keywords. Specific attention was given to informed consent from parents and collaborative consent from the participating children (see [40] for a more in-depth discussion). This is particularly important with young children who may not have ability to express resistance or discomfort with a recording situation.

3. Results

Results related to the two research questions are presented intertwined in the following. We have selected to focus on the second (experiment documented by timelapse or slow-motion movies), and the two final steps (slowmation production and retelling) of the teaching sequence, see above.

3.1. Case 1. Balls in Free Fall

Teacher 1 in preschool 1 introduces an experiment about air resistance. An intermediary object of learning is discovered when the children question whether there is air inside, in the room or not [13].

Teacher 1:	Good morning! Today we will do an experiment. We will talk about something called air resistance.
Erland:	What is that?
Teacher 1:	It is when the air is a resistance for something that is moving.
Mattis:	How could you know that then?
Teacher 1:	Well . . . by the way, do you know if there is any air here, in this room?
Erland:	Yes.
Mattis:	No.
Teacher 1:	Do you think there is Mattis?
Mattis:	No.
Teacher 1:	No.
Erland:	I think there is in there.
Teacher 1:	Where?
Erland:	In the cabinet.
Teacher 1:	In the drying cabinet? You think there is air there.
Erland:	Yes.
Mattis:	It is very hot in there.
Erik:	Me too.
Teacher 1:	When you start it there will be warm air going around in there. Yes, it will.
Erland:	I knew that.
Erik:	Me too.
Teacher 1:	There is air in this room too.
Erik:	I knew also that.
Mattis:	Where?
Erland:	There!
Teacher 1:	You don't see the air, but it is here. We are breathing in the air too, so the air is everywhere. In the air and in the room there are many small molecules that are moving around in the room all the time.
Mattis:	Yes, you do like this [inhales].
Teacher 2:	Yes, we breathe.
Teacher 1:	Yes, there is air coming out of your mouth. Correct, so now we will see when something is moving if we can see any air resistance.

The discussion leads to an agreement that there is air in the room, at least that is what teacher 1 concludes. However, the issue of air will come back as can be seen below. This is an example of illusory intersubjectivity [12], where the teachers appear to believe sufficient intersubjectivity has been established. Teacher 1 also starts to introduce a microscopic model of the air, but that is not pursued or taken up by the children. The introduction continues with the discussion of the two balls (equal size) that will be dropped in the free-fall experiment, see excerpt below.

Teacher 1:	We have a white and an orange. This white is a table tennis ball and this orange is a golf ball. Do you want to feel one Mattis? Hold them in one hand each. Do you feel any difference between them?
Erland:	Yes.
Erland:	This one is hard and this one is a little hard. This one is of stone and this one almost of plastic.
Teacher 1:	You mean the golf ball is hard and the table tennis ball soft?
Erland:	mm.
Erik:	Yes.
Erland:	It is very hard, but that is a little hard.
Teacher 1:	You think the table tennis ball is a little hard too?
Erland:	Mm.
Mattis:	I can, you can juggle . . .
Teacher 1:	Ok, then you have felt that they feel different.
Mattis:	Hard.
Teacher 1:	Can I hold them? This one [golf ball] Erland thought felt hardest and this one [table tennis ball] was less hard.
All children:	Mm.
Teacher 1:	Here, inside [table tennis ball] there is not very much.
Erland:	That is plastic and that is stone or metal.
Erik:	Mm.
Teacher 1:	This one [golf ball] has higher density, that is more, very many things inside. It is very compact. Here [table tennis ball] there is mostly air.
Erland:	So that this is soft and this is hard.
Teacher 1:	It is more that this one is emptier inside. It is called density, this compactness. Now let's watch the experiment on air resistance.

The children struggle here, lacking appropriate wording for comparing the two balls. Erland compares and describes the balls as hard and less hard. However, the balls are both 'hard' as in not soft. They differ in weight due to difference in density, but the children talk about them as made of stone and plastic. The excerpt ends with the teacher trying to introduce the concept of density. However, it is not picked up by the children. We believe that is because it is a so-called intensive quantity, an abstract and difficult concept to appropriate [38].

Next, the experiment is performed with the teacher dropping the two balls, first standing on the floor, then on a ladder. When the teacher is dropping the balls from the top of ladder the children observe a difference between the falling balls. The table tennis ball is accidently dropped a little time before the golf ball, thus getting a head start. Then, the golf ball, falling more rapidly through the air due to its larger mass, 'overtakes' the table tennis ball and hits the floor first. The process is quite fast and details are difficult to observe for the children. So, the experiment is repeated and this time videorecorded (jointly by the children and teacher 2) and then played back in slow motion, making it possible for the children to follow the paths of the two falling balls in detail. An excerpt from the discussion following from the children watching the slow-motion video is below.

Teacher 1:	Which fell to the ground first?
Erland:	It [table tennis ball] though the [golf ball] first came down on the floor. The [table tennis ball] came first because it had a lot of air but the [golf ball] came down to the floor first.
Teacher 1:	You mean first this [table tennis ball] was, but then it [the golf ball] went . . .
Erland:	. . . faster. That's how it was. This [table tennis ball] was faster first, but then that one [golf ball] came faster . . .
Erik:	I can also.
Teacher 1:	Yes, how do you mean?
Erik:	[shows how the golf ball overtakes the table tennis ball on its way towards the floor.]
Teacher 1:	So why do you think this one [golf ball] . . . ?
Erland:	This one [the white golf ball] was heavier and that one [the yellow table tennis ball] only had air.
Teacher 1:	So, because this one [golf ball] is heavier you think it is faster?
Erland:	And this [table tennis ball] has air.
Teacher 1:	And this [table tennis ball] has air in itself.

The children introduce explanations in this excerpt in answering the question from the teacher, who continues to drive the communication forward by follow-up questions. The children seem to adopt the notion—more mass gives more speed through the air—supported by the stimulated recall with the slow-motion video.

During the discussion activity, when viewing the video, they get back to the issue of air in the room. The children claim that there will be air if the window is opened, and from there they finally conclude that breathing requires air, and end up seeming to accept that there is air also inside a room. The existence of air in the room was apparently an intermediary object of learning [13], something the children needed to experience, and that emerged during the teaching. However, intersubjectivity concerning air in the room appears to have been established towards the end of the discussion.

The children are given a shoebox, compressed paper balls (one white and one yellow) and various types of string, scissors, and adhesive tape to use in producing their slowmation. They go about it and towards the end of the session it becomes clear that the children have concluded that the air "under the ball" hinders the table tennis ball from falling as fast as the golf ball. So, the ways the children are thinking about the experiment are elucidated to the preschool teachers during the work with the slowmation animation.

Teacher 1:	Viktoria, why did the table tennis ball fall slower to the ground? What was it that stopped it?
Viktoria:	It was the air.
Teacher 1:	The air, what about the air?
Viktoria:	That it was under.
Teacher 1:	Was the air under? Under, what do you mean?
Viktoria:	Under the ball.

In the excerpt, Viktoria explains the difference in movement by the air under the ball. They rig the shoebox scene with strings, one for the golf ball used to lower the ball between shots, but two for the table tennis ball, one for lowering it and one (representing the air) to counteract the fall, see Figure 2.

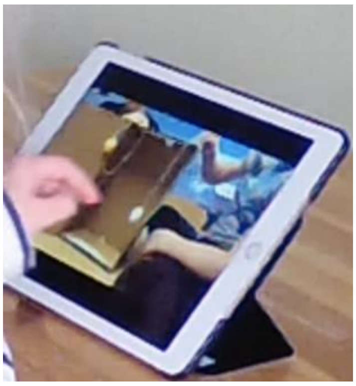

Figure 2. The child Viktoria pointing at the screen while running the slowmation in the retell activity.

The produced slowmation is demonstrated by one child to a teacher that had not been part of the teaching sequence before.

Viktoria:	We tried to do what we did before with a shoebox like this.
Teacher 3:	The other balls you used before and now you tried with this instead?
Viktoria:	Mm.
Teacher 3:	Yes, click one more time so that I can see. Which one is falling fastest downwards.
Viktoria:	First it is this one [table tennis ball], then this [golf ball].
Teacher 3:	Why does it fall? How come that it happens like this?
Viktoria:	This [table tennis ball] comes first, that one [golf ball] then. And then that one [golf ball] passes further down.
Teacher 3:	And which one won?
Viktoria:	That one [golf ball] did.
Teacher 3:	Why did it win?
Viktoria:	Because it does not go on the air. Don't you see?

The excerpt shows that Viktoria has appropriated an explanation where the air resistance is the cause of the differing speed of the falling balls. It becomes quite clear that Viktoria and the other children have added the second string to the table tennis ball in order to represent the opposing air "under the ball". She points to the extra string and accentuates "don't you see". The slowmation thus helps to establish the way that children are thinking about the experiment. The children do not pick up on the concept of density. It could be because it is an abstract and difficult concept, but also because it does not really come into play in the experiment since the balls have the same geometrical form and size. The concept of more mass and thus more speed through the air works fine to explain the result of the experiment.

3.2. Case 2. Heating of Ice

The next case is from preschool 2 and their activities on the phase changes of water from ice to vapour. The preschool teachers have reached consensus in using a theoretical model based on the movement of water molecules as the background for the teaching sequence.

The children and the teachers watched and discussed the timelapse movie of the experiment where ice cubes were heated in an e-piston on a hob. Then, it was time for the children to start the slowmation production. The teachers let the children draw on paper first. The paper has a grid with six squares to help the children to set the sequence of scenes. Next, it was time to choose materials for the slowmation production. The children were struggling with how to represent the ice. So, the teachers were trying to scaffold the children's process with some suggestions, and by referring to their drawing on paper. However, they received no response from the children at that point in time.

Teacher 1:	Yes, then came the water. But, how are we going to make our movie now? What things do we need to make the movie? Have you been thinking about that?
	Children not responding.
Teacher 1:	What can we use that looks like ice and water? [Points to a drawing made by Nero.]
	Children not responding.
Teacher 2:	Maybe one of these bottles? [Points to an e-piston] Should we use that?

Teacher 1 moved on and suggested using balls of cotton to represent the ice cubes. Nero immediately associated the balls of cotton to something else—marshmallows—and the process was temporarily held up.

Teacher 1:	[Opens a cupboard] Shall we see if we find something fun here! When we did this last time, well it was snow then. Then we had this kind of cotton. [Takes out a box with cotton balls].
Teacher 1:	[Holds up a cotton ball] Look!
Nero:	[Laughing] Maschemellu!
Teacher 1:	[Laughing] Yes! It is this kind of cotton balls, it is. Could they be ice cubes?
Nero:	Yes, they are almost like maschemellu.
Teacher 1:	Yes, it is so.

Finally, they all agreed to use the cotton balls to represent the ice cubes. They put them in the e-piston and the children started taking pictures for the slowmation movie. The preschool teachers tried to get the children to reason about how to represent melting of the ice. Then, Nero adds "It's not for real", pointing to the fact that you cannot get cotton to melt like ice, because it is not "for real". This indicates that it is a difficult abstraction for him to think about, the behaviour of ice in terms of cotton balls. Based on the underlying theoretical model, a possibility here would have been to pull and extend the cotton balls to one continuous piece of cotton. But, this is not picked up by the children. This is possibly because they are not comfortable with the modelling—it is not for real.

Teacher 1:	So, now we have put in all the ice cubes. What happened then?
Teacher 2:	What happened then?
Teacher 2:	Let's look. [Brings Nero's drawing.]
Teacher 1:	[To Farah] Now you also get to watch.
Nero:	[Looks at drawing] Then it has melted to ice, then it came water.
Teachers:	Yes.
Teacher 2:	Mm, when the ice melts, water will come.
Teacher 1:	How should we do then? Now this ice that is in here [points at the cotton balls in the e-piston]. Farah, it should melt now. How should it melt?
Nero:	It's not for real!
Teacher 1:	No, it isn't for real. That is what is a bit tricky.

The children find the transformation between reality and model difficult. We did not observe any utterances from the children referring to the drawing on paper that would indicate that this additional step had scaffolded the process. Nero hesitates in his abstract thinking about the ice melting, but the next excerpt shows that he was getting there when he was looking in the box for something to represent the water, or was he looking for real water?

Nero:	[Looks into the box] Here is no water.
Teacher 1:	No, there is no water in there.
Farah:	[Joins Nero at the box.]
Teacher 1:	What is it you want to have as water then?
Nero:	This one. [A piece of white paper.]
Teacher 1:	Hm, that is probably little big as water.
Nero:	This one then?
Teacher 1:	That is a gauze bandage that you wrap around the arm.
Nero:	[Puts it back in the box.]

The work with the slowmation continued and they finally produced an animation. Later, when Nero was presenting the slowmation and talking about it, he noticed that something was missing—there are no water droplets during the boiling. An interesting thing here is that when he suggests a remedy for this, he is talking about real water, again. This indicates that the abstract nature of the phenomenon makes it difficult for the children to transform between the real world and the artifacts of the model used in the slowmation animation.

Nero:	[Puts his hand to the forehead] There were no waterdrops!
Teacher 2:	Did we forget them??
Nero:	Yes!
Teacher 2:	How could you make them then?
	. . .
Nero:	Yes, I know! If it rains [showing with his hand in the air, Farah joins in] then there are water drops.
Teacher 1:	Yes, it is, but how would we have made the waterdrops here?
Nero:	Hmm, waterdrop in there [points to the e-piston]. And on water [points to the sink].
Teacher 1:	Real water?
Nero:	I get. [He leaves the chair and goes to the sink].
Teacher 1:	Do you want to make waterdrops now at the end? OK.

As can be seen in the excerpt above, it is not clear if the children have succeeded in transforming their reasoning between reality and the produced model. Nero seemed to retain the idea that real water was needed in the animation. Again, the slowmation production has helped to elucidate the children's explanatory models, i.e., their way of thinking about the investigated phenomenon, for the teacher.

4. Discussion

We have previously reported that the process of group discussion, documented experimentation, stimulated recall and slowmation production is a fruitful teaching arrangement when working with preschool children and a science phenomenon [27]. That teaching model was also utilized in this study, with the addition of a fifth step to elucidate the lived object of learning. It takes its departure in the participating children's experiences focusing a specific object of learning adhering to variation theory and developmental pedagogy [31,32], and synthesizes the specific (content and theoretical models) and general (investigations, questions) domain knowledge [21]. For the work teams in the preschools, the task was to jointly choose and use theoretical models on the 'right' level, explanations that are accurate in the sense that they do not contradict more sophisticated theoretical models, but at the same time not too abstract for the children. This process, supported by us, concurs with earlier results [7,14,16], and was found to be appreciated by the work teams. In the words of a preschool teacher from a previous study we made on science teaching, 'It's a balancing act all the time, really tricky' [29].

In the present study, it becomes clear that children's reflections and understanding of theoretical models take time to develop and that the different steps in the teaching model and the use of children's video productions by tablets support the ongoing reflections, and the discovery of emerging intermediary objects of learning [13], such as the issue of air in the room. Documenting a slow natural process such as ice melting with timelapse photography, or a faster natural process such as items falling by slow-motion video, makes it possible to capture natural processes that otherwise would be difficult to observe in detail. In line with [28], we have seen that the recreation of the natural process when producing a slowmation movie has the possibility to aid the teacher in observing and experiencing the children's explanatory model of the investigated phenomenon. A previous study by us also showed enhanced reflections about the science phenomenon among the children when creating and re-watching videos on the tablet [27]. Another benefit with the videos in steps 2 and 4 of the teaching sequence is the children's joy of having been part of producing them. Although it could be argued that work with the material (balls, cotton, etc.) in itself supports children's reflections about a physics phenomenon, the feedback we have got from in-service preschool teachers and student preschool teachers trying out the teaching sequence is that the video productions frame the activity and constitute a motivation factor for the children. When the material has been removed from the table, they still have the movies to look at and to show friends and parents, something they do with pride. But as the result in this study points out, creating a representation of a natural process in different materials may also constitute a pitfall. The children's transfer of their understanding from the documentation (e.g., timelapse or slow-motion video) to abstractions such as cotton balls representing ice cubes, could potentially complicate the discussion about the content. We have previously elaborated on this in an article about intermediary objects of learning, i.e., that 'stumble blocks' for the children can emerge when contextualized language or metaphors are used by the teacher [13,41]. Furthermore, we would like to emphasize that technology and digital tools can indeed be used to scaffold learning of specific content for groups of children in preschool rather than being used disconnectedly by single children [7,26,27]. Teaching physics in preschool is a rather unexplored area. We have experienced that it requires both pedagogical content knowledge and updated skills about children's learning [12,13,27]. We report that the teachers were supported in recognising the children's views of the objects of learning by the children's video production, especially the slowmation. This is also an important experience we have taken with us as teacher educators. Student preschool teachers are now in their courses working with the explicit formulation and discussion of theoretical models and slowmation production. This in order to help them prepare for future challenges in connection to the renewed national curriculum and the requirements therein related to the teaching of science content and digital tools [1].

Abstract phenomena, with invisible processes like the evaporation of water, introduce difficulties, also for older children [37]. Children in this study were seen to struggle in transforming between the real world and the artifacts of the model used in the slowmation animation. This finding concurs with earlier work on students' usage of particle models of matter. It is inherently difficult for students to appropriate this kind of theoretical model. We report on some success for the teaching sequence reported on here, and successful measures have also been reported earlier [35,36]. A basis for the tentative success reported on here is believed to be the use of variation of the critical aspects of the learning objects together with multiple representations made possible by the computer tablet [24,31]. Specific difficulties were also observed in this study for explanations involving 'intensive quantities', i.e., concepts involving quotients [38], in this case the density of falling balls. The density concept was shortly introduced by the teacher, but not picked up by the children. It certainly is a pertinent concept, but not primarily in focus for the object of learning (air resistance) reported on here. However, these latter phenomena, involving intensive quantities, did not induce the same difficulties with 'moving' between the real world and the slowmation model as in the case of the 'invisible processes'.

5. Conclusions and Implications

In conclusion, we state that, for children to pick up and use introduced theoretical models of physics phenomena, preschool teachers benefit from jointly establishing and keeping the selected theoretical model in mind during consecutive teaching situations. Teachers that were able to, at the same time, keep two perspectives in mind, both the children's perspective—what the children express in a specific situation—and the object of learning, were successful. We refer to this as 'mutual simultaneity' [12,13], and with it in place we have seen that a sequence of teaching instances scaffolded by tablets, and with persistent focus on an object of learning, gives children opportunities to develop sophisticated reasoning concerning physics phenomena.

It was seen that abstract phenomena, as discussed above, introduced challenges for the children's experience and the communication during the teaching activities. Specific care seems to be needed for the teachers to use decontextualised generative language and explicitly name concepts, objects, and events during the teaching.

The data in this study from two groups of children in two preschools can be seen as limited. We would say that, even so, the results convey how physics teaching can be implemented and analysed in preschool. The result definitely indicates critical aspects to be considered in early years physics teaching. We would highlight the importance of teachers relating to the children's perspectives and to the object of learning. The use of a teaching sequence like the one presented here has been seen to fruitfully scaffold children's learning in physics.

A professional development programme of several years, as the one reported on here, has been seen to make possible potentially sustainable development of model-based teaching scaffolded by digital tools, in this case iPads™, of content initially viewed as difficult and challenging by the preschool teachers. Particularly positive aspects of the PD program were that it (1) involved all staff members and headmasters, (2) it was extended over several years, and (3) it was in close cooperation with university researchers. The PD program has been completed and a report of the overall program is being finalised and will be reported on elsewhere. Results and experiences from the PD have also been brought to the attention of teacher educators and become useful in pre-service teacher education.

Author Contributions: Conceptualization, A.R., M.F., A.J. and S.T.; Data curation, A.R., M.F., A.J. and S.T.; Formal analysis, A.R., M.F., A.J. and S.T.; Funding acquisition, A.R., M.F., A.J. and S.T.; Investigation, A.R., M.F., A.J. and S.T.; Methodology, A.R., M.F., A.J. and S.T.; Project administration, A.R.; Resources, A.R.; Writing—original draft, A.R., M.F., A.J. and S.T.; Writing—review & editing, A.R., M.F., A.J. and S.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research project is funded by the Research platform Learning in Cooperation, Kristianstad University.

Institutional Review Board Statement: Ethical considerations for this research in cooperation with preschools in a school district adhere to recommendations by the Swedish Research Council and meet the ethics requirements of our institution.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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