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Teachers' Considerations for a Digitalised Learning Context of Preschool Science

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Abstract
This study investigates preschool teachers' considerations for including digital tools inscience teaching to develop children's learning of science content. Due to the ongoing digitalisation and demands in society, the utilisation of digital tools has increased significantly in educational settings. Recent research about digital tools in early childhood education focuses on various aspects of technology implementation. However, there is a research gap in which considerations underpin preschool teachers' choices of what, why and how they integrate digital tools into science teaching. The data generation was conducted by different methods. The reflection tool Content Representations (CoRe) is used to make the preschool teachers' considerations explicit when reflecting on planning science teaching regarding specific science content formulated as Big Ideas. Further, video stimulated recall interviews capture the preschool teachers' considerations on their interactions with children in science activities and using digital tools. The Refined Consensus Model (RCM) of Pedagogical Content Knowledge (PCK) was employed as a theoretical framework for analysing and interpreting data around an entire teaching cycle. Some of the teachers' considerations for including digital tools involve accessing children's learning, making the abstract concrete and stimulating children's engagement and learning. Further, the findings indicate that the considerations concerned knowledge about teachers' personal PCK (pPCK) and enacted PCK (ePCK) aspects.

Keywords Preschool Science · Science Education · Digital Tools · Pedagogical Considerations · Refined Consensus Model · Content Representations

Introduction

Preschools should encourage children's understanding of various phenomena and relationships in nature and society and how people, nature and society influence each other. Young children explore, wonder, discuss and collaborate with their peers regarding the surrounding world and use diverse resources and artefacts to construct and make representations about their understanding

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of engaging with phenomena and concepts (Fragkiadaki et al., 2019; Siry, 2013). Children's perspectives and experiences are crucial for forming and conceptualising science concepts (Fleer, 2009; Fragkiadiaki et al., 2019; Larsson, 2013; Siry, 2013; Siry & Max, 2013). Preschool teachers' collective knowledge, including aspects such as children's learning science content and how to use digital artefacts in the learning context, is beneficial as part of this complex process. Fleer (2018) noted that digital technologies affect and comprise new conditions for children's development. Since science knowledge is crucial for understanding today's different societal challenges (Roberts & Bybee, 2014), it could be assumed that understanding the rationale behind using digital artefacts to promote children's learning of science content is of pedagogical value. Since digital literacy is a desirable competence in our lives, educational settings provide potential opportunities for learners to become digitally literate. As children should learn about science and use digital tools in preschool (Swedish National Agency for Education, 2018), children's learning about science content depends on whether preschool teachers use digital tools as a means or an end for science teaching.

Undheim (2022) states that digital technologies include screen-based, not-screen-based, exploratory, and Internet of Toys. Computers (Otterborn et al., 2020), tablets (Fridberg et al., 2018; Nilsen et al., 2021; Otterborn et al., 2019), still cameras and mobile phones (Fleer & Hoban, 2012) are used in preschool settings, for different educational purposes. Digital technologies are used to develop learning about different content and social skills such as cooperation or to enhance confidence, curiosity and reflection (Jack & Higgins, 2019; Otterborn et al., 2019). Regarding preschool science, preschool teachers use digital tools to promote communication about scientific phenomena, search for information about subject content, document children's activities for showing (to others) and stimulate or identify children's learning (Fridberg et al., 2018; Walan & Enochsson, 2022). Digital tools complement other educational tools and create stimulating environments to enhance children's critical reflection and their development of a critical and responsible attitude to technology (Walan & Enochsson, 2022). However, Otterborn et al. (2023) reveal that the boundaries of multidimensional science teaching are pushed, and, at the same time, important values for the Swedish preschool curriculum are preserved through the use of digital tools. For example, multidimensional science teaching involves excursion, emergent systematic inquiry through investigations of organisms and their habitats, ethics or travel in time and space where the children could re-experience the teaching event by viewing films and photographs. Further, this demonstrates how combined multiple digital and analogue tools offer children multimodal science content experiences, such as the narrow environment and related organisms.

Whether digital tools are included in educational contexts for preschool children may depend on various contextual factors such as policy decisions and material resources (Blackwell et al., 2014) as well as the beliefs of the teachers (Jack & Higgins, 2019; Undheim, 2022). Teachers' attitudes concerning technology for children's learning, followed by confidence and support (Aldhafeeri et al., 2016; Johnston, 2019), positively affect teachers' technology use. Undheim (2022) argued that technology integration depends more on how teachers' pedagogical beliefs and practices interact with their beliefs about technology rather than a lack of knowledge about digital equipment and resources. Kewalramani and Havu-Nuutinen (2019) indicated that preschool teachers had an acceptable approach when using technology to support children's inquiry about everyday scientific concepts in combination with hands-on activities. The preschool teachers' pedagogical beliefs concerned children's creative thinking, communication with parents, and sharing children's science learning experiences. According to Johnston (2019), technologies alongside children's experiences are a critical impetus for children's interest in the scientific content of space and the solar system.

This indicates that preschool teachers' pedagogical considerations, as well as attitudes towards digital tools, impact whether, how and why these are included in teaching. For instance, teachers make pedagogical judgements or reflections about excluding specific tools depending on how children use them or if they are suitable for the play-based pedagogy of early childhood (Aldhafeeri et al., 2016).

To promote children's learning in a science context, preschool teachers' knowledge is crucial. Shulman (1986) described teacher's knowledge as Pedagogical Content Knowledge (PCK) consisting of a combination of different knowledge bases to accommodate various teaching challenges. In this study, we suggest that different knowledge components underpin preschool preschool teachers' pedagogical considerations. As pedagogical considerations might be the starting point of including digital tools in the teaching of science, there is a need to explore these considerations in relation to the preschool teachers' enacted teaching. Therefore, this study investigates and describes preschool teachers' pedagogical considerations for using digital tools in teaching science and how these considerations are grounded in preschool teachers' PCK. The following research questions guide the study:

- What considerations do preschool teachers make before and during teaching when digital tools are included to develop children's learning about science content?
- What aspects of PCK are made explicit within the preschool teachers' considerations?

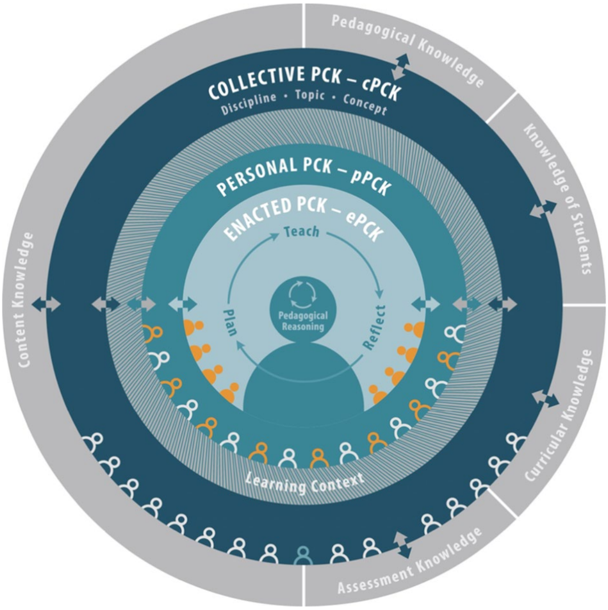
As such, the result of this study will provide useful information on how preschool teachers integrate digital tools in their science teaching and base their activities on pedagogical considerations.

Theoretical Framework

PCK comprises a blending of varying knowledge teachers need to enhance learners' understanding: subject matter content knowledge, pedagogical content knowledge and curricular knowledge (Shulman, 1986;1987). Subsequently, it guides teachers' understanding of what can be difficult or easy for the learner and an awareness of learners' pre-understanding, experiences, misconceptions, etc. Magnusson et al. (1999) defined five different components of PCK: (i) orientations towards science teaching, (ii) knowledge and beliefs about curriculum, (iii) knowledge and beliefs about students' understanding of specific science topics, (iv) knowledge and beliefs about assessment in science and (v) knowledge and beliefs about instructional strategies for teaching science. These knowledge components represent a further unpacking of the knowledge domains of PCK initially introduced by Shulman (1986).

Since Shulman introduced the concept of PCK, it has been interpreted and used by various researchers (Chan & Yung, 2015; Loughran et al., 2004; Nilsson & Loughran, 2012; Van Driel & Berry, 2012). Researchers and practitioners from different contexts have converged and revised the model of PCK "to withstand scrutiny in different countries, be relevant across different policy environments, be useful for different research paradigms, and inform a wide range of teacher preparation and professional learning programmes" (Carlson et al., 2019, p 92). The Refined Consensus Model (RCM) of Pedagogical Content Knowledge (PCK) (Carlson et al., 2019, see Fig. 1) constitutes the theoretical framework for this study. The RCM described the complex layers of knowledge and experiences that shape and inform teacher practice and mediate student outcomes. Its three complex layers consist of different realms of PCK: collective PCK (cPCK), personal PCK (pPCK) and enacted PCK (ePCK), which interact with each other. The cPCK comprises the combined

Fig. 1 The Refined Consensus Model of PCK



Note: From Carlson et al. (2019, p 83). Used with permission.

professional knowledge of different educators/ teachers. It implies that this knowledge is collective and public. pPCK is the teacher's cumulative PCK that has been shaped and developed through various teaching and learning experiences acquired in different contexts. Finally, ePCK encompasses teachers' specific skills and knowledge expressed and utilised within a particular teaching situation, with specific objectives for the learner(s) (Alonzo et al., 2019). This realm includes not only the direct reasoning (reflection in action) the teacher makes in situ but also reasoning for the teaching (reflection on action), such as planning and making considerations (Carlson et al., 2019). This makes ePCK based on dynamic reasoning, which reflects the learning context where the teacher makes different considerations to meet the learners' needs.

The learning context refers to a broader science education context, the learners, and a specific learning environment. The learning context is situated as a layer between teachers' own knowledge and practice and the knowledge of others. Technology is given a high status in relation to other contextual influences on PCK, and in the Learning Context layer in the RCM (Carlson et al., 2019), technology is regarded as one of many influences on and contributors to a teacher's PCK. As such, technology is a crucial contextual factor and/or a filter in the learning context of preschool science for enabling powerful representations and ways of making the content clear (Nilsson, 2022).

RCM is described as a "meaningful theoretical lens" as it links PCK with teaching practice by describing the cycle of planning-teaching-reflection and pedagogical reasoning as central to PCK (Mientus et al., 2022). Teachers make considerations based on experience and knowledge of different aspects of teaching, for example, how to introduce content to a group of children or how to use digital tools to make the content understandable to the children. As such, the RCM framework functions well as a theoretical lens in this study.

Preschool teachers' considerations before and during teaching are implemented in the planning, teaching and reflection cycle. Therefore, the RCM functions as a meaningful theoretical lens (Mientus et al., 2022) for capturing and analysing the components of PCK that underpin the preschool teacher's pedagogical considerations.

Based on Shulman's ideas of PCK, Mishra and Koehler (2006) introduced TPACK as a conceptual framework in the context of educational technology. TPACK emphasises the complex interplay between content, pedagogy and technology regarding affordances, connections, interconnections and limitations. Further, TPACK has been criticised for having focused too little on the context (Koehler et al., 2014). Based on RCM, Yeh et al. (2021) argued for a collaboration-enriched framework that highlights teachers' TPACK knowledge as an exchange between collective, personal and enacted TPACK. Nilsson (2022) called for further research in TPACK as a whole and argued that the "TPACK framework needs to be unpacked in terms of technology as a contextual influence of teachers' development of PCK for teaching science in a way that promotes students' understandings" (p 17). Therefore, the RCM is used to address how teachers' pedagogical considerations are implemented in the plan-teach-reflect-cycle and what aspect of PCK underpins these considerations. Thus, the study describes preschool teachers' knowledge of an actual science teaching practice underpinned by digital artefacts.

Methods

Qualitative research relates to a desire to describe and represent experiences as they are experienced by the people involved (Polkinghorne, 2005; Silverman, 2021). This study uses a qualitative case study approach to capture and understand preschool teachers' considerations for including digital tools in their science teaching. The preschool teachers' considerations constitute a basis for the learning context.

Research Methods

Mik-Meyer (2021) emphasises that various methods within the same epistemological perspective can positively impact the quality of research and highlight "angles and nuances" (p 360) of the research object. Using different methods to generate data (triangulation) strengthens the study's validity (Larsson, 2005). Several methods were used to ensure capturing various aspects of preschool teachers' considerations connected to the teaching cycle of the RCM (Carlsson et al.).:

A) Reflection tool, content representation, CoRe
B) Group discussion (when completing the CoRe)
C) Video recordings of teaching activities
D) Video-stimulated recall (VSR) interviews

The reflection tool, content representation (CoRe), initially developed by Loughran et al. (2004), required the teachers to formulate Big Ideas and reflect on eight different prompts concerning the identified Big Ideas (Hume & Berry, 2013; Loughran et al., 2004; Mazibe et al., 2020; Nilsson & Elm, 2017). As such, the CoRe formed the starting point for teaching regarding content, objectives, methods, prerequisites and educational challenges. To adapt to the preschool context and address considerations associated with the preschool teachers' use of digital tools, a revised version of the CoRe was developed based on Nilsson & Elm (2017) and Loughran et al. (2004). Prompts six and seven were revised to capture preschool teachers' reflections on using digital tools. Even though the initial CoRe (Loughran et al., 2004) had been revised, the abbreviation CoRe was used in the following sections when addressing the revised version. Table 1 below presents the revised CoRe with the different prompts (left column). The preschool teachers' pPCK components for each prompt are illustrated in the right column. These components are used to analyse and discuss the knowledge that underpin the teachers' pedagogical considerations for using digital tools for teaching science.

Group Discussion

To capture considerations not expressed in the preschool teachers' CoRe, data was generated when the teachers discussed and completed the CoRe.

Video Recording of Teaching Activities

The preschool teachers' interaction with children about science content based on the CoRe was video recorded to enable further analysis. Video observations supported the documentation of the multimodal interactions, which would otherwise have been lost by taking notes (Danby, 2021). Interesting film sequences were played repeatedly for processing and analysis.

Table 1 Revised version of the reflection tool CoRe including associated components of pPCK for each prompt (1–8)

Prompts	*Components of pPCK*
1. What do you intend the children to learn about this idea?	Knowledge of content, knowledge of curriculum
2. Why is it important that children learn about this?	Knowledge of content, knowledge of curriculum, knowledge of children's learning processes
3. What else do you know about this idea (which you don't think the children need to participate in now)?	Knowledge of content, knowledge of children's learning processes, knowledge of how to meet children's learning needs
4. How do you make use of children's experiences/knowledge/questions to teach this idea?	Knowledge of children's learning processes, knowledge of how to meet children's learning needs, knowledge of content, knowledge of context
5. What perceptions/misconceptions might the children have about this idea, and how do these affect the teaching of the idea?	Knowledge of children's learning processes, knowledge of how to meet children's learning needs, knowledge of content
6. What teaching methods will you use? What tools (analogue/digital) will you use? Motivate why these are appropriate to use in teaching this idea.	Knowledge of children's learning processes, knowledge of how to meet children's learning needs, knowledge of technology, knowledge of context
7. What possibilities and limitations do you see with using analogue/digital tools in teaching this idea?	Knowledge of children's learning process, knowledge of how to meet children's learning needs, knowledge of content, knowledge of technology, knowledge of context
8. How do you ensure the children have learnt what you intended them to learn?	Knowledge of children's learning processes, knowledge of assessment, knowledge of content

The prompts are inspired by Loughran et al. (2004); Nilsson & Elm (2017). The associated components of PCK are inspired by Nilsson & Elm (2017)

Video-Stimulated Recall Interviews (VSR)

Qualitative research interviews give access to subjective experiences and permit researchers to describe the participants' real world (i.e. preschool teachers' considerations). In this study, sequences from video recordings were used as video-stimulated recall (VSR) (Lyle, 2003) after the completed teaching activities. The purpose is to provide reflective discussions, where the video sequences stimulated preschool teachers' reflections on their considerations and arguments made before and during the performed teaching activities.

Research Context

The study involved 16 preschool teachers (from now mentioned as teachers) working in three different preschools in southern Sweden. The teachers' teaching experience varied from almost 2 years to 46 years. Overall, 20 children participated (aged 3–6). Preschool one (P1) consisted of three departments, of which two participated in the study. Cooperation between the departments was usual, and children from both departments were mixed during the teaching activities. Preschools two (P2) and three (P3) had one department each. The teachers planned activities focusing on science content such as water phases, water circulation and friction. The teachers themselves determined the science content as part of their long-term work and grounded on children's interests, wonderings or needs. (see the Appendix) summarises the number of participants in the different preschools distributed across the phases for data collection.

Ethical Guidelines

Ethical guidelines for research (Swedish Research Council, 2017) regarding consent, participation, trust and confidentiality were followed throughout the study. Detailed information about the study's aim and methods, consent, data storage and access was provided verbally and in writing to the participants. The participating children (aged 3–6 years) were informed in a child-friendly way, and children's reactions to participation during the video recording were carefully taken into account (Larsson et al., 2021). The children's guardians gave their consent for the children's participation. The reflection tool was introduced to the teachers a short time before the completion of the CoRe. Concerning group discussion and the interviews, the teachers were offered to take part in the transcriptions.

Data Collection

The teachers ($n = 16$) completed the reflection tool within their current working team during an audio-recorded planning session (1.5 h). Appendix 2 presents the CoRe from P2 to illustrate an example of the teachers' considerations on the various prompts.

The first researcher was present as a facilitator but avoided involvement in the teachers' conversation except for clarifying questions and summarising the discussions, if necessary.

After completing the reflection tool, the teachers planned different activities. The planning sessions for the activities have not been part of the data collection. The activities differ since the preschools, by choice, work with different topics and Big Ideas, such as the water cycle, the water phases and friction. After the planning sessions, the teachers performed the activities with children with a focus on the specific content. The first researcher attended and video recorded activities that included digital technologies. During the teaching activities ($n = 6$), children ($n = 20$) and teachers ($n = 8$) interacted with the specific science content with the support of digital tools. The activities took place on different occasions and lasted about half an hour. (see the Appendix) provides an overview of the teaching activities in the three preschools. Information about the science content and the related Big Ideas the preschools worked with and a description of the activities are specified. The table also details which digital tools and how they were used in the activities and the participating teachers and children. Pseudonyms have been used to ensure the children's and the teachers' confidentiality. The number after the children's name indicates the children's age.

Finally, interviews ($n = 6$) were conducted, audio-recorded and lasted approximately 1.5 h. The teachers (= 8) who participated in the teaching activities were interviewed individually or in pairs, depending on the teachers' attendance during the teaching activity. Some of the teachers (Preschools 2 and 3) participated in more than one activity and, consequently, in more than one interview. In the interviews, film equences from the video recordings during the activities served as VSR.

The selected film sequences represented different moments of the teaching activity and were chosen by the first researcher to form a holistic view of the activity. The selection of sequences depended on how the digital tools were related to the teaching content and happened in the teaching activities. At Preschool 1, the films were shown in their entirety, while at the other preschools, various sequences from the teaching sessions were shown. Overall, the film sequences ranged from about 10 to 27 min. The sequences were used as a starting point for the teachers to remember and relate to their teaching. Another reason was to establish a common ground for the teachers and researcher about the topics discussed during the interview. Initially, the teachers were asked to describe what happened in the teaching activity. The first researcher who performed the interviews used open, semi-structured questions (Morse, 2012) to engage teachers in their pedagogical considerations and supplied them with follow-up questions.

Data Analysis

The data were analysed through thematic analysis (Braun & Clarke, 2006). As the study intended to capture preschool teachers' considerations before and during teaching when digital tools are included to promote children's learning of science content, the data were analysed in two parts:

An analysis where codes from CoRe and Group discussion were merged to considerations before teaching. Subsequently, a separate analysis where codes from the interviews refer to considerations during teaching. Due to the study's aim to investigate the preschool teachers' considerations, there was no coding on the video-recorded activities per se. In the interviews, the teachers were asked for instance to describe the teaching activity and clarify their consideration for why and how the digital tools were used. The teachers' expressed considerations in the interviews refer to their considerations during teaching. The video-recorded teaching activities were used to elucidate the teachers' considerations during the interviews.

An iterative thematic analysis (Braun & Clarke, 2006) with an open approach to the data was used to capture the teachers' considerations. Analysis of the data can be summarised as follows:

(1) Familiarising with the teachers' considerations, which includes reading several times the CoRes and transcripts from group discussions and interviews to obtain an overview.
(2) Preliminary coding after meaning condensation (Brinkmann & Kvale, 2018) relevant data sections.
(3) The codes were coloured and clustered in groups concerning digital tools, science content and pedagogical issues or in the intersection between those groups.
(4) After reviewing the codes, various categories were identified and were, if necessary, revised, checking that they did not fit in another category. There was a "back and forth" process for steps 2–4, and different methods were used, such as taking notes and colour coding.
(5) Categories were compiled and classified into various aspects of the teacher's considerations, forming a distinct theme. The themes were finally compared with each other to exclude that they addressed similar considerations.
(6) Finally, themes were described with illustrative quotes to exemplify teachers' considerations.

Throughout the analysis process, the authors checked that there were distinct boundaries between the themes. To guarantee the validity of the thematic analysis, the identified themes and illustrative quotes were discussed between the researchers to promote interrater validity.

The different themes were then discussed based on RCM as well as the different components of pPCK (see Table 1). Concerning validity, the implementation of the methods, analysis of data and documentation of results have been discussed and reflected on by both researchers, which, according to Newton and Burgess (2008), ensures process and outcome validity. The results and sections from the entire data material have also been discussed and, as such peer validated within two different seminars. As part of the validation process, the teachers were offered access to the transcripts.

Figure 2, below, illustrates an example for steps 1–5 from the analysis for considerations during teaching.

Results

Several themes were identified in the thematic analysis (Braun & Clarke, 2006). Table 2 provides an overview of these themes and presents an indication of their characteristics. The findings are presented in two parts: considerations *before* teaching and considerations *during* teaching. Illustrative quotes from the teachers are included to exemplify how the teachers reasoned in relation to the themes.

Considerations Before Teaching

The teachers base their considerations on different components of their PCK. As such, their considerations can be understood as expressions of their pPCK.

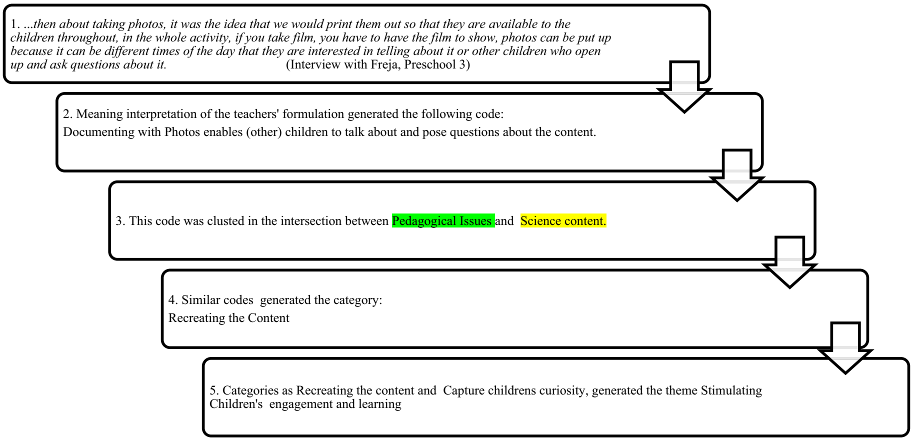


Fig. 2 Example from data analysis for considerations during teaching

Approaching the Content

From the beginning, the teachers found it challenging to articulate what they did not initially intend the children to learn about the Big Ideas (prompt 3). Content such as chemical formulas, acidification, the potential of hydrogen, molecules and atoms, and earthquakes may be perceived as too complex and abstract for children and subsequently challenging to grasp. Edita's words during the group discussion may exemplify the following:

Edita: we found out at the dinner table that water is H_2O
Elena: molecules.
Elsa: molecules, H_2O, and so.
(…)
Elisabeth: chemical formulas.
Edita: so I asked why is that. 'I do not know [they said]' I did not dare to say why, so [I said] 'we will think about it, and then we will talk about it another time'.

Edita's reflections illustrate that teaching abstract concepts such as molecules and chemical formulas may be perceived as too demanding, and the teachers need to carefully reflect on when to use them. Her considerations can be understood in different ways. They may reflect her knowledge of children's learning processes and what might be suitable when meeting the children's learning needs in this context. On the other hand, her considerations of not choosing to use scientific concept(s) may be understood as a lack of knowledge of the content or even how to meet children's learning needs by not challenging children and making them familiar with scientific vocabulary.

Accessing Children's Learning

The teachers continually used digital tools to capture children's experiences and ideas and emphasise the tools as important for their science teaching. One reason was to gain access to children's pre-understanding and how they use concepts as a starting point in their learning processes. By using documentation supported by digital tools, such as video-recorded

Table 2 A summary of the thematic analysis: themes with associated definitions

	Themes	*Definitions*
Considerations before teaching	Approaching the content	Including considerations of how to make the content accessible to the children. These considerations do not include digital tools but are a base for using them
	Accessing children's learning	Considerations based on the importance of participating in children's understanding of the content as a starting point for further learning
	Digital technologies as enablers	Considerations indicating possibilities for creating learning settings regarding the content
	Digital technologies as inhibitors	Considerations involving constraints for a learning context of science
Considerations during teaching	Digital technologies in a contemporary educational context	Consisting of considerations on learning about and with digital tools as up-to-date prerequisites
	Using digital tools to make the abstract concrete	Digital tools reinforce the content and links between different modes/methods in diversified teaching
	Stimulating children's engagement and learning	Digital tools are depicted as means for engagement and learning

children conversations, the teachers become aware of how children understand the content or what concepts they use when talking about the content. Further, the teachers' reflections indicate how their documentation with digital tools (knowledge of technology and assessment) functions as guidance for their further teaching. As such, in their considerations, they use their knowledge of children's learning processes and how to meet children's learning needs when they design teaching activities.

> During the reflection sessions [during planning session], we bring documentation that we have with the children and then analyse it and move on. Weave their previous experiences into what we do and talk about. (Clara, P2).

Digital tools and resources, such as tablets, development plans and learning logs in digital platforms, were used to capture the children's ideas and make them visible to guardians. That enabled the sharing of children's learning processes with guardians and the utilisation of their knowledge about the children's learning processes for continuous planning. Elsa (P1) sums up by saying:

> Then I hope it becomes a big thing outside the preschool so that parents get involved and they will see different things than what we see here.

Sharing children's thoughts would enable the other children to learn by taking part in someone else's experiences and ideas around the content. The teachers in P1 and P3 expressed in their CoRes that children learn from each other and that digital tools play an essential role in affecting other children's learning.

> The children can relive what they have experienced and retell it to other children and educators who have not been involved. The children can put into words what is happening, they can make hypotheses, see connections, understand cause and effect etc. (CoRe, P3)

Digital tools, as stated above, made it possible to access children's experiences and open up to learning about the content. Accessing children's ideas opened different ways of thinking about the science content. This related to the preschool teacher's knowledge of how to meet children's learning needs.

Digital Technologies as Enablers

This theme summarised teachers' considerations for including digital tools in enriching the learning context by creating different settings. In that sense, digital tools contributed to what is lacking in preschool. Projectors, green screens, tablets and phone applications were considered to help children learn about the content and provide opportunities for learning. By using different instructional strategies, such as projecting different water environments (e.g. waterfall) on a screen, the teachers provided the children with a sense of the content "that cannot be explored in the reality of the preschool" (CoRe, P1). Hence, tools are used to augment the children's experiences about the content with virtual ones, indicating the teacher's knowledge of technology, context and how to meet children's learning needs.

Further, the teachers described the digital tools as a substitute for teachers' possible limited knowledge when the children asked questions that the teachers could not respond to. The teachers mentioned the tools served as a platform for teachers to co-investigate with children. Those considerations were based on the teacher's knowledge of children's learning process and the teacher's understanding of how to meet children's learning needs.

Digital Technologies as Inhibitors

Although the teachers expressed few limitations in including digital tools (prompt 7), it is important to demonstrate those few as making explicit teachers' pedagogical knowledge. Firstly, Emilia (P1) highlights that it is difficult to know the limitations of digital tools before using them in interaction with children, indicating her knowledge of how to meet children's learning needs. Further, the teachers (P1) emphasised not being in a hurry to search when children ask for or "Google" an answer. They considered it vital to "stay in the question" with the children and analyse with them. This provided opportunities to think and imagine for themselves. They argue that by immediately seeking answers digitally, many reflexive encounters were wasted. Instead, the teachers said that children should initially contemplate how to find the answer (by themselves). Further, P3 also raised aspects such as "presence loss" around the activity among participants when attention is directed to a screen. This could be counterproductive when digital tools were considered to enable a reflexive environment through sharing children's reflections. Those considerations concerned lost opportunities that otherwise could build up a reflexive learning context about science. Therefore, their considerations elucidated the preschool teacher's knowledge of the context, but also that their knowledge of children's learning processes underpinned the need to meet their learning needs.

Considerations During Teaching

Based on the interviews performed after the teaching activities, explicit teachers' pedagogical considerations are given for using digital tools during the teaching activities. These are described in the light of teachers' ePCK.

Digital Technologies in a Contemporary Learning Context

Considerations revolved around digital tools in education as contemporary prerequisites, requirements and possibilities. The teachers stated that they used digital tools to make children learn to handle the tools (P1, P2). They also referred to the use of technology as required in education due to its contemporaneity and because digital tools constitute part of children's daily lives:

> …that it is their world too, it is their world of experience, they work with the iPad, they work with these things and film on YouTube and all that, and then you can use their experiences to build on further… (Cornelia, P2)

Further, the teachers considered using digital tools to promote compensatory learning concerning the children's existing use of digital tools outside preschool. The way they designed their teaching around the digital tool made explicit their knowledge of technology:

> And I am also going to show that you can use the iPad for other things than, for example, playing games and things that they might have in their world at home … (Clara, P2).

The above statements implied teachers' knowledge of the curriculum since digital competence and challenging children's learning are grounded in curricular objectives. It also shows a contextual knowledge since the teachers utilise children's experiences and needs.

Using Digital Tools to Make the Abstract Concrete

Considerations within this theme showed how science content transforms from an "abstract" phenomenon to a more concrete understanding. The teachers specified that digital tools are used as part of a diversified teaching. They also provide an additional way to approach the understanding of the specific content in combination with other methods and materials due to children's various learning needs. The teachers highlighted that using digital tools in combination with physical objects strengthened the understanding of the content. For instance, during an activity in P1, besides concretely investigating liquid water and ice, children also experience the stages of water through images and sound by seeing a film about the different forms of aggregation. Therefore, the various encounters with the specific content in different modes, such as physical, visual (images), and auditive, reinforced the understanding of the content through links between content and modes. Elisabeth (P1) explains:

> …then they can relate to what happened on the table … and look the same on the film.

In the example above, different components of knowledge were intertwined in the teachers' considerations. For instance, choosing appropriate film content (digital resource) concerning children's understanding of the content indicates knowledge of content, technology and how to meet children's learning needs. Diverse teaching per se is an indication of knowledge of how to meet children's learning needs when teachers unfold abstract science content and make it more concrete for the children.

Stimulating Children's Engagement and Learning

This theme can be described as educational benefits for enhancing children's engagement and learning when utilising digital tools in science teaching. Here, digital tools enable children to come close to science content. The tools create anticipation and an atmosphere about the content, and according to Emilia (P1), a "wow" feeling. The use of digital tools can provide motivational strategy to engage children with specific content. In that sense, the teachers make explicit their knowledge of how to meet children's learning needs.

In addition to engaging children, digital tools were also used to access the children's learning processes, for example, to learn about their experiences and ideas and what they learnt (or not) about the content. Using digital tools becomes a way to look back and "discern the progression", according to Freja (P3). Here, digital tools underpin the teachers' knowledge of assessment in science.

In all three preschools, the teachers emphasised the children's engagement in the documentation. Elin (P1) highlighted that the children observed different aspects than the teachers and took "ownership of their learning" to become active participants in the learning context implying knowledge of assessment. The importance of stimulating children's engagement is exemplified by the teachers who demonstrate their knowledge of children's learning processes and how to meet children's learning needs when describing how they provide opportunities for children to produce their own material.

> it is probably about participation, I think, both that you, that you let them take responsibility for the documentation, responsibility for feeling important to take the photo and that this is linked to showing it, 'I have taken this photo' that, yes, the

> whole process that they also get to be in all the parts, not only being a consumer, but also producing the material for it, they are, they are competent. (Freja, P3)

Another aspect of this theme responds to recreating the activity with the children, for example, by projecting video recordings from a teaching session. It refers to the tools' potential to access the science content on another occasion. Therefore, the digital tool contributes to extending possible learning beyond a specific time and space. It enables the children to reflect on the content and their experiences with other participants in the science learning context. Learning about the content is not fixed in a particular occasion but provides multiple encounters with the content, even for the children who did not participate in the original teaching session.

> …photos can be set up because there may be different times of the day that they are interested in talking about it or other children opening up and asking questions about it. (Freja, P3)
> just the fact that we have set up the cycle [pictures] in there, we talk about it every dinner there, when they tell us that it goes up and down and back and forth, we have to, you have to make use of it. (Cornelia, P2)

Thus, it implies the teachers' awareness of how the children experience and use concepts (knowledge of assessment, knowledge of children's learning processes) and how to revive teaching about the specific content (knowledge of how to meet children's learning needs).

Discussion

This study investigated preschool teachers' pedagogical considerations for including digital tools before and during science teaching. The teachers' considerations before teaching are summarised as preconditions for teaching and learning science. They involve content, learners and digital artefacts, all crucial parts of the learning context. Considerations during teaching concern the teaching activity, the interaction between content, learners and digital tools, and how learning is promoted. Regardless of the kind of considerations above, digital tools are crucial for the learning context of science in preschool. As the learning context refers to a broader science education context, the learners, and the preschool's specific learning environment, technology is attributed as an important contextual factor (Carlson et al. 2019; Nilsson, 2022) for enabling learning about the content (Nilsson, 2022). The learning context is situated as a layer between teachers' own knowledge and practice and the knowledge of others. The findings of this study make explicit components of PCK, underpinning the teachers' pedagogical considerations for using digital tools in their science teaching. During the group discussions, teachers reflect together with their colleagues. Their personal knowledge (pPCK), derived from previous teaching, combines with their general knowledge about teaching and digital tools (cPCK). Considerations made by the teachers during the enacted teaching activities, expressed during the interviews, demonstrate their knowledge of the current teaching situation, including aspects related to the children, science content and digital tools (ePCK). Technology is considered for strengthening the understanding of the content by making the content concrete. The teachers in this study highlighted that using digital tools contributes, when combined with other methods, to augment the understanding of science content, as in the theme of using digital tools to make the abstract concrete. For example, one consideration is that showing a film about water phases should strengthen and support children's learning of the specific content. In that sense, digital tools are an amplifying filter in the understanding of the content. As such, it might be asserted that the integration of teachers' knowledge of how to meet children's learning needs, knowledge of technology and knowledge of context within the teaching activity indicates the teachers' ePCK for teaching science.

Furthermore, digital tools contribute as a resource for creating a dynamic and reflexive learning science context. It is possible to develop occurring encounters with the science content through technological functions. Digital tools contribute to an "extended" learning context beyond a specific time and space, where the science content is recreated. Activities or materials, such as reflection, making an iMovie or photos (see in the Appendix), supported by digital tools, offer repeated opportunities to encounter the science content once again, where children and teachers reflect and discuss. Similar findings are reported by Otterborn et al. (2023), where digital tools enable the re-experience of science content in multidimensional science education. Previous research (Fragkiadaki et al., 2019; Siry, 2013) point out that children construct an understanding of phenomena and science concepts through various processes, such as discussions. In that sense, digital tools contribute to opportunities for children to conceptualise different phenomena and concepts. Further, children's perspectives and experiences are crucial for conceptualising science concepts (Fleer, 2009; Fragkiadaki et al., 2019; Larsson, 2013, Siry, 2013; Siry & Max, 2013), which is enabled by the digital tools in the above activities.

The child orientation was visible, for instance, in the themes of accessing children's learning, stimulating engagement and learning and approaching the content. The teacher's considerations consisted of thoughts including digital tools in teaching for documenting children's learning, which is in line with Walan and Enochsson (2022). In this child-oriented learning context, the teachers, based on their knowledge of children's learning needs, saw the children as producers when engaging with digital tools. It was an emphasis, in all preschools, on children's engagement with documentation of the science content. Considerations like "children observing other aspects than the teachers" show a focus on the importance of how the children experience the science content. According to Fragkiadaki et al. (2019), children's perspectives and experiences are essential in conceptualising science. Recent research has shown that digital tools complement other tools of both digital and analogue characters (Walan & Enochsson, 2022). Digital tools can be viewed as a means of teaching to approach scientific content (Johnston, 2019), where technologies next to children's experiences are the critical impetus for children's interest in science content, and digital tools are used for curiosity and reflection (John & Higgins, 2018). Surprisingly, even though the science content is clearly stated in the national curriculum for preschool (Swedish National Agency, 2018), few considerations were linked to teachers' knowledge of curriculum. This might be explained due the child orientation in teachers' considerations.

Though the findings of this study are based on considerations from only 16 teachers in three Swedish preschools, they are still of interest in this field. The study sheds light on teachers' considerations around an entire teaching cycle (plan-teach reflect), which refers to the inner circle of the teaching cycle by the RCM (Carlson et al., 2019). It is also necessary to understand what teachers consider essential when integrating digital tools into their science teaching. The use of CoRe design (Loughran et al., 2004) together with the teachers made explicit preschool teacher's considerations in ways that also captured aspects of their pPCK as well as their ePCK, which shows the importance of unpacking knowledge about how technology is used in an enacted teaching situation (Nilsson, 2022; Yeh et al., 2021). The results indicate how the CoRe helped the teachers to reflect on why different tools are used (or not) to support children's learning in science. Limited research uses the RCM as a theoretical lens focusing on the preschool science context (Chan & Hume, 2019). Therefore, more studies must focus on different aspects of the learning context that preschool teachers and young learners are part of.

Conclusion

The present study was set out to investigate and describe preschool teachers' pedagogical considerations for using digital tools in teaching science and how these considerations are grounded in preschool teachers' PCK. As recent research points out (Kewalramani & Havu-Nuutinen, 2019; Undheim, 2022), this study identifies that pedagogical considerations underpin the use of digital tools for teaching science content in preschool science education. The result of this study showed that teachers make various considerations for including digital tools in preschool science, which can be summarised as considerations before teaching and considerations during teaching. Nearly all considerations intersect with content, children's learning and digital tools. The considerations shape prerequisites for the learning context of preschool science and emphasise a child-oriented learning context.

In conclusion, according to the teachers' considerations, digital tools constitute resources that shape the learning context of preschool science. The digital tools reinforce the understanding of the content in addition to the diversified teaching alongside other materials and modes. Further, digital tools make it possible to recreate the science content repeatedly, opening up new encounters where children and teachers reflect and communicate on the science content. This creates a dynamic, reflective science context.

Despite its exploratory nature and based on a small sample of participants, the present study offers some insight into preschool teachers' PCK. The teachers' considerations revealed different components of PCK and can, as such, provide important insight into how aspects of PCK can be captured within a preschool science context. Following the entire cycle of plan-teach-reflect enables an understanding of the expressed pedagogical considerations for using digital tools in a science learning context.

Hence, this study would make a valuable contribution to the field of preschool science by using RCM for studying, analysing and interpreting preschool teachers' considerations for a digitalised learning context of science. Further studies need to be carried out using RCM as a conceptual framework for studying and analysing science education in preschool. Exploring children's and preschool teachers' interaction in science activities when using digital tools could be potential future research for accessing further insight into preschool science.

Appendix 1

Table 3 Overview of participants in the different data collection methods

Method	*Preschool 1*	*Preschool 2*	*Preschool 3*
CoRe and group discussion	7 t	4 t	Big Idea 1: 4 t[a] Big Idea 2: 4 t[a]
Teaching activities	Activity 1: 2 t, 4 c Activity 2: 2 t, 4 c	Activity 1: 2 t, 5 c Activity 2: 2 t, 8 c	Activity 1: 1 t, 2 c Activity 2: 2 t, 3 c
Stimulated recall interviews	Interview 1: 2 t Interview 2: 2 t	Interview 1[b]: 2 t Interview 2[b]: 2 t	Interview 1: 1 t Interview 2: 2 t

t teacher, *c* child; [a]One teacher participated only on this occasion. [b]Same teachers attended in interviews 1 and 2.

Appendix 2. Reflection tool, Content Representations, CoRe, Preschool 2

Brief information on the reflection tool.

The tool is a variant of Content Representation (CoRe) based on specific knowledge or key ideas that are important for understanding a particular area of work in science. For example, if we are working with the field of water, "The phases of water" and "Water circulates in a cycle" are important specific knowledge known as Big Ideas. For the sake of simplicity, Big Ideas have been translated as idea.

The different questions (in the left column) should be answered in relation to the respective Big Idea and not in general about the teaching. Please give concrete examples in your answers!

	Big Idea/ Idea 1 water exists in 3 phases	Big Idea/ Idea 2 water circulates in a cycle
1. What do you intend the children to learn about this idea?	We want the children to understand that water exists in 3 phases and become familiar with the concepts: solid, gas and liquid	Evaporation-abstract, difficult to explain and understand Importance of water for all of us, nature, humans
2. Why is it important that children learn about this?	Knowing how water works, that it is essential for us humans, to provide prior knowledge, children are curious and want to know, and it is good to know before school and later on	The environment—why we need to take care of water This knowledge is important to have in the future, in school and as a global citizen
3. What else do you know about this idea (which you don't think the children need to participate in now?	Do not make teaching too abstract, make it more concrete through experiments, etc Not at present	Natural disasters, not negative images, but hope for the future The cycle can be at different levels of detail, which we will not go into
4. How do you make use of children's experiences/knowledge/ questions to teach this idea?	Interviews, conversations, and record conversations to see what the children know beforehand. Document what the children are interested in so we can see what we can do next. Divide the children into smaller mixed groups so that everyone is heard. We observe the younger children	Interviews, conversations, and record conversations to see what the children know beforehand. Document what the children are interested in so we can see what we can do next. Divide the children into smaller mixed groups so that everyone is heard. We observe the younger children
5. What perceptions/misconceptions might the children have about this idea, and how do these affect the teaching of the idea?	Water vapour is difficult for children to understand. Abstract, they do not know that it is water. Some children have previous experience with the different forms, and then we have to adapt our teaching to that by: going further and challenging what they know, challenging what they don't know, and changing the group constellations so that the older ones teach the younger ones, those who have more knowledge we challenge more	That water cannot run out, that it is difficult to understand the cycle, that it is connected We must have varied teaching, repeated and adapted to all children to give them an understanding of the cycle

	Big Idea/ Idea 1 water exists in 3 phases	Big Idea/ Idea 2 water circulates in a cycle
6. What teaching methods will you use? Which tools (analogue/digital) will you use? Motivate why these are appropriate to use in teaching this idea.	Experiments, theatre, film, writing and reading language, and discovering the outdoor and local environments. Through dialogue with children, children/children Tools—projector, computer, tablet, stove, freezer, pencil and paper, paint, Tiggy tests Motivate- they learn more by using digital tools, they see it in front of them visually Analogue—it becomes more concrete when they do experiments, they remember more when they can feel and use more of their senses It provides variety in teaching so we can meet all children at their level We want to arouse the children's curiosity and interest them in the project	Experiments, film, creating in 3D, mind maps, dividing children into small groups, Tools—projector, computer, tablet, pencil and paper, paint. Motivational- they learn more by using digital tools, they see it in front of them visually Analogue—it becomes more concrete when they do experiments. Remember more when you can feel and use more of your senses It provides variety in teaching so we can meet all children at their level We want to arouse the children's curiosity and interest them in the project
7. What possibilities and limitations do you see with the use of analogue/digital tools in teaching this idea	Easier to capture children's attention with different digital tools. It is faster to find and search for information together with the children. Aesthetic forms of expression, multimodal Limitations—weather, staff,	Possibilities—capturing children according to their interests and knowledge. Use digital tools to attract children; It is their world of experience There are limited digital tools, a lack of time, and ignorance When using digital tools, you reach more children at the same time, and they can exchange ideas with each other Analogue—limitations that you can't be so many children at the same time. It can also be a possibility that you can do it several times
8. How do you ensure if children have learnt what you intended them to learn?	Interview the children, and document through films and dialogue. Mindmap, reflection on our planning sessions, the children can express themselves by, for example, drawing and observing the children in free play	Let the children tell each other —film and reflect on it. Try doing experiments yourself. Draw and verbalise what they do

Table 4 Overview of teaching activities

Preschool	Science content	Big ideas	Teaching activities	Digital tools used	Teacher	Children and age in years
1	Water	Water is among us	1. Float and sink with different materials in sweet and salty water	Cellphone: take pictures and record (under the water) Projector: show an environment	Elin and Elena	Eskil, 5 Erik, 5 Ella, 4 Ebba, 5 Elliot, 4
		Water appears in three forms	2. Watch a film about the water phases and conduct experiment with ice and liquid water	Tablet: take pictures Projector: show film Film: about the water phases	Emilia and Elisabeth	Eskil, 5 Erik, 5 Enzo, 5 Ellen, 4
2	Water circulation	Water is part of a cycle	3. Examining dry and fresh leaves with "web egg."	Digital microscope "Webb egg": investigate leaves and take pictures Projector: projecting pictures from "webb egg." Computer: connecting webb egg and projector	Cornelia and Clara	Christian, 3 Carl, 3 Cloe, 4 Chris, 4 Casper, 3
		Water appears in three phases	4. Making an iMovie Children look at pictures and talk about water circulation	Tablet: watch an iMovie, choosing pictures iMovie: use the application for designing a film	Cornelia and Clara	Cindy, 5 Cesar, 5 Conrad, 5 Charlotte, 5
3	Friction	A force is needed to generate friction. It takes force to create friction	5. Testing different "shoes" and detecting friction	Tablet: take pictures	Freja	Fiona, 5 Flora, 4
		It takes two surfaces to establish friction	6. Reflection: watching afilm of children moving a box	Projector: showing a (self-recorded) film	Freja and Fanny	Fiona, 5 Felix, 4 Fenja, 4

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Data Availability The anonymous data supporting this study's findings are available from the corresponding author upon reasonable request.

Declarations

Ethics Approval and Consent to Participate The study is compliant with ethical standards. Approval was obtained by the Swedish Ethical Review Authority (nr: 2022–02782-01). The participants were informed about the study, participation was voluntary, and their consent was obtained.

Competing Interests The authors declare no competing interests.

References

Aldhafeeri, F., Palaiologou, I., & Folorunsho, A. (2016). Integrating digital technologies into play-based pedagogy in Kuwaiti early childhood education: Preschool teachers' views, attitudes and aptitudes. *International Journal of Early Years Education, 24*(3), 342–360. https://doi.org/10.1080/09669760.2016.1172477

Alonzo, A., Berry, A., & Nilsson, P. (2019). Unpacking the complexity of Science Teachers' PCK in action. In A. Hume, R. Cooper & A. Borowski (Eds.), *Repositioning pedagogical content knowledge in teachers' professional knowledge* (pp. 271–286). Springer. https://doi.org/10.1007/978-981-13-5898-2_12

Blackwell, C., Lauricella, A., & Wartella, E. (2014). Factors influencing digital technology use in early childhood education. *Computers and Education, 77*, 82–90. https://doi.org/10.1016/j.compedu.2014.04.013

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brinkmann, S., & Kvale, S. (2018). *Doing Interviews* (Second ed., Vol. 2, Qualitative Research Kit). SAGE Publications, Limited. https://doi.org/10.4135/9781529716665

Carlson, J., Daehler, K.R., Alonzo, A.C., Barendsen, E., Berry, A., Borowski, A., Carpendale, J., Chan, K.K.H., Cooper, R., Friedrichsen, P., Gess-Newsome, J., Henze-Rietveld, I., Hume, A., Kirschner, S., Liepertz, S., Loughran, J., Mavhunga, E., Neumann, K., Nilsson, P., ... & Wilson, C.D. (2019). The Refined Consensus Model of Pedagogical Content Knowledge in Science Education. In A. Hume, R. Cooper, A. Borowski (Eds.), *Repositioning Pedagogical Content Knowledge in Teachers' Knowledge for Teaching Science* (pp. 77–94). Springer. https://doi.org/10.1007/978-981-13-5898-2

Chan, K. K. H., & Yung, B. H. W. (2015). On-site pedagogical content knowledge development. *International Journal of Science Education, 37*(8), 1246–1278. https://doi.org/10.1080/09500693.2015.1033777

Danby, S. (2021). Ways of working with video and online data: From fieldwork to analysis. In D. Silverman. (Eds.), *Qualitative research* (5th ed., pp. 283–298). SAGE.

Driel, V., & Berry, A. (2012). Preschool teacher professional development focusing on pedagogical content knowledge. *Educational Researcher, 41*(1), 26–28. https://doi.org/10.3102/0013189X11431010

Fleer, M. (2009). Understanding the dialectical relations between everyday concepts and scientific concepts within play-based programs. *Research in Science Education (australasian Science Education Research Association), 39*(2), 281–306. https://doi.org/10.1007/s11165-008-9085-x
Fleer, M. (2018). Digital animation: New conditions for children's development in play-based setting. *British Journal of Educational Technology, 49*(5), 943–958. https://doi.org/10.1111/bjet.12637
Fleer, M., & Hoban, G. (2012). Using 'Slowmation' for intentional teaching in early childhood centres: Possibilities and imaginings. *Australasian Journal of Early Childhood, 37*(3), 61–70. https://doi.org/10.1177/183693911203700309
Fragkiadaki, G., Fleer, M., & Ravanis, K. (2019). A cultural-historical study of the development of children's scientific thinking about clouds in everyday life. *Research in Science Education (australasian Science Education Research Association), 49*(6), 1523–1545. https://doi.org/10.1007/s11165-017-9665-8
Fridberg, M., Thulin, S., & Redfors, A. (2018). Preschool children's collaborative science learning scaffolded by tablets. *Research in Science Education (australasian Science Education Research Association), 48*(5), 1007–1026. https://doi.org/10.1007/s11165-016-9596-9
Hume, A., & Berry, A. (2013). Enhancing the practicum experience for pre-service chemistry preschool teachers through collaborative CoRe design with mentor preschool teachers. *Research in Science Education (australasian Science Education Research Association), 43*(5), 2107–2136. https://doi.org/10.1007/s11165-012-9346-6
Jack, C., & Higgins, S. (2019). What is educational technology and how is it being used to support teaching and learning in the early years? *International Journal of Early Years Education, 27*(3), 222–237. https://doi.org/10.1080/09669760.2018.1504754
Johnston, K. (2019). Digital technology as a tool to support children and educators as co-learners. *Global Studies of Childhood, 9*(4), 306–317. https://doi.org/10.1177/2043610619871571
Kewalramani, S., & Havu-Nuutinen, S. (2019). Preschool preschool teachers' beliefs and pedagogical practices in the ıntegration of technology: A case for engaging young children in scientific ınquiry. *Eurasia, 15*(12). https://doi.org/10.29333/ejmste/109949
Koehler M.J., Mishra P., Kereluik K., Shin, T.S., Graham, C.R. (2014). The technological pedagogical content knowledge framework. In J. M. Spector., M. D. Merrill, J. Elen., & M. Bishop. (Eds.), *Handbook of Research on Educational Communications and Technology*. (pp. 101–111). Springer. https://doi.org/10.1007/978-1-4614-3185-5_9
Larsson, J. (2013) Children's encounters with friction as understood as a phenomenon of emerging science and as "opportunities for learning", *Journal of Research in Childhood Education, 27*(3), 377–392.https://doi.org/10.1080/02568543.2013.796335
Larsson, J., Williams, P., & Zetterqvist, A. (2021). The challenge of conducting ethical research in preschool. *Early Child Development and Care, 191*(4), 511–519. https://doi.org/10.1080/03004430.2019.1625897
Larsson, S. (2005). On quality of qualitative studies. *Nordisk Pedagogik, 25*(1), 16–35. https://doi.org/10.18261/ISSN1891-5949-2005-01-03
Loughran, J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching, 41*(4), 370–391. https://doi.org/10.1002/tea.20007
Lyle, J. (2003). Stimulated recall: A report on its use in naturalistic research. *British Educational Research Journal, 29*(6), 861–878. https://doi.org/10.1080/0141192032000137349
Mazibe, E. N., Coetzee, C., & Gaigher, E. (2020). A comparison between reported and enacted pedagogical content knowledge (PCK) about graphs of motion. *Research in Science Education (australasian Science Education Research Association), 50*(3), 941–964. https://doi.org/10.1007/s11165-018-9718-7
Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & G.N. Lederman (Eds.) *Examining Pedagogical Content Knowledge* (vol 6, pp. 95–132). Springer. https://doi.org/10.1007/0-306-47217-1_4
Mientus, L., Hume, A., Wulff, P., Meiners, A., & Borowski, A. (2022). Modelling STEM preschool teachers' pedagogical content knowledge in the framework of the refined consensus model: A systematic literature review. *Education Sciences, 12*(6), 385. https://doi.org/10.3390/educsci12060385
Mik- Meyer, M. (2021). Multimethod qualitative research. In D. Silverman. (Eds.), *Qualitative research* (5th edn., pp. 357–374). SAGE.
Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for preschool teacher knowledge. *Preschool Teachers College Record, 108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Morse, J. (2012). The ımplications of ınterview type and structure in mixed-method designs. In J. F. Gubrium, J.A. Holstein, A. Marvasti & K.D. McKinney (Eds.) *The SAGE Handbook of Interview Research: The complexity of the craft* (2nd ed., pp. 193–204). Uni SAGE Publications, Incorporated.

Newton, P., & Burgess, D. (2008). Exploring types of educational action research: Implications for research validity. *International Journal of Qualitative Methods, 7*(4), 18–30.

Nilsen, M., Lundin, M., Wallerstedt, C., & Pramling, N. (2021). Evolving and re-mediated activities when preschool children play analogue and digital memory games. *Early Years, 41*(2–3), 232–247. https://doi.org/10.1080/09575146.2018.1460803

Nilsson, P. (2022). *From PCK to TPACK - Supporting student teachers' reflections and use of digital technologies in science teaching*. Research in Science & Technological Education. https://doi.org/10.1080/02635143.2022.2131759

Nilsson, P., & Elm, A. (2017). Capturing and Developing Early Childhood Teachers' Science Pedagogical Content Knowledge Through CoRes. *Journal of Science Teacher Education, 28*(5), 406–424. https://doi.org/10.1080/1046560X.2017.1347980

Nilsson, P., & Loughran, J. (2012). Exploring the Development of Pre-Service Science Elementary Teachers' Pedagogical Content Knowledge. *Journal of Science Teacher Education, 23*(7), 699–721. https://doi.org/10.1007/s10972-011-9239-y

Otterborn, A., Schönborn, K., & Hultén, M. (2019). Surveying preschool teachers' use of digital tablets: General and technology education related findings. *International Journal of Technology and Design Education, 29*(4), 717–737. https://doi.org/10.1007/s10798-018-9469-9

Otterborn, A., Schönborn, K., & Hultén, M. (2020). Investigating preschool educators' implementation of computer programming in their teaching practice. *Early Childhood Education Journal, 48*(3), 253–262. https://doi.org/10.1007/s10643-019-00976-y

Otterborn, A., Sundberg, B., & Schönborn, K. (2023). The impact of digital and analog approaches on a multidimensional preschool science education. *Research in Science Education (Australasian Science Education Research Association)*. https://doi.org/10.1007/s11165-023-10133-6

Polkinghorne, D. E. (2005). Language and meaning. Data collection in qualitative research. *Journal of Counseling Psychology, 52*(2), 137–145. https://doi.org/10.1037/0022-0167.52.2.137

Roberts, D.A., Bybee, R. W. (2014). Scientific literacy, science literacy and science education. In *Handbook of Research on Science*. (Vol 2, pp. 545–558). https://doi-org.ezproxy.ub.gu.se/https://doi.org/10.4324/9780203097267

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14. https://doi.org/10.3102/0013189X015002004

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–22. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Silverman, D. (2021). Introducing qualitative research. In D. Silverman. (Eds.), *Qualitative research* (5th edn., pp. 3–16). SAGE.

Siry, C. (2013). Exploring the complexities of children's inquiries in science : Knowledge production through participatory practices. *Research in Science Education (australasian Science Education Research Association), 43*(6), 2407–2430. https://doi.org/10.1007/s11165-013-9364-z

Siry, C., & Max, C. (2013). The collective construction of a science unit: Framing curricula as emergent from kindergarteners' wonderings. *Science Education, 97*, 878–902. https://doi.org/10.1002/sce.21076

Swedish National Agency for Education. (2018). *Curriculum for the Preschool, Lpfö 18*.

Swedish Research Council. (2017). *Good research practice*. https://www.vr.se/download/18.5639980c162791bbfe697882/1555334908942/Good-Research-Practice_VR_2017.pdf

Undheim, M. (2022). Children and preschool teachers engaging together with digital technology in early childhood education and care institutions: A literature review. *European Early Childhood Education Research Journal, 30*(3), 472–489. https://doi.org/10.1080/1350293X.2021.1971730

Walan, S., & Enochsson, A. (2022). Affordances and obstacles when integrating digital tools into science teaching in preschools. *Research in Science & Technological Education,* 1–20. https://doi.org/10.1080/02635143.2022.2116423

Yeh, Y., Chan, K. K. H., & Hsu, Y. (2021). Toward a framework that connects individual TPACK and collective TPACK: A systematic review of TPACK studies investigating preschool teacher collaborative discourse in the learning by design process. *Computers and Education, 171*, 104238. https://doi.org/10.1016/j.compedu.2021.104238