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The Role of Digital Tools for Teaching and Learning Science Content in Preschool

Maria Papantoni



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The Role of Digital Tools for Teaching and Learning Science Content
in Preschool

Maria Papantoni

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Errata

Page iii: Row 2, add “can” before “support the teaching and learning”.

Page iii: Row 30-31, change “teachers providing opportunities for” to “providing teachers with opportunities to make”.

Pages V, 127: Replace “stödjer undervisning ” with ”kan stödja undervisning”.

Page X: Replace “med Hallstöm och” with ”with Hallström and”.

Page 14: Replace Eshach and Fried (2025) with Eshach and Fried (2005).

Page 17: Add “Thulin (2011)” after “Fleer, 2009a; 2009b”.

Page 18: Add ”et al.” after Hatzigianni.

Page 31: Remove (Yelland, 2018) in the end of the last sentence.

Page 37: Remove Rogoff (1990).

Page 41: Remove Brown et al., 2013.

Pages 50, 57, 89, 109, 119: Add “can” before “support the teaching and learning”.

Page 51: In the caption of Table 2, insert “based on” before the reference to Loughran et al., 2004.

Page 146: Update Bryman & Nilsson (2002) to Bryman, A. (2002). *Samhällsvetenskapliga metoder* (B. Nilsson, Övers.; 1. uppl.). Liber ekonomi.

Page 149: After Forsler et al. (2024) add the following reference: Gabdulnina, K., & Kovrova, M. (2021). The use of a digital microscope for the development of young schoolchildren’s ideas about plants, animals and fungi. *Information Technologies and Learning Tools* 86(6), 19-29.
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Page 147: Replace the full reference entry for Chan and Yung (2015), located after the reference for Chan and Hume (2019).

Page 150: Remove the reference entry: Hoban, G., & Nielsen, W. (2012). Using “slowmation” to enable pre service primary teachers to create multimodal representations of science concepts. *Research in Science Education*, 42(6), 1101-1119 <https://doi.org/10.1007/s11165-011-9236-3>

Page 157: After Skamp (2021), add the following reference: Swedish National Agency for Education. (2025). *SKOLFS 2025:23: Amendments to the preschool curriculum. SKOLFS 2025:23*

TekNaD, Teknik, naturvetenskap och didaktik, är en forskningsmiljö vid Institutionen för beteendevetenskap och lärande (IBL), Campus Norrköping, Linköpings universitet. TekNaD omfattar ett trettiotal seniora forskare, postdoktorer och doktorander i naturvetenskapernas och teknikens didaktik, och är även värd för FontD, Nationella forskarskolan i naturvetenskapernas och teknikens didaktik. Forskningen vid TekNaD fokuserar exempelvis skolämnenas historia; undervisningens innehåll; begreppslig förståelse; analogier, modeller och representationer; multimodalitet; digitala redskap; lärares och elevers attityder; genusfrågor och bedömning.

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The Role of Digital Tools for Teaching and Learning Science Content in Preschool

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Abstract

The overarching aim of this thesis is to provide knowledge about how digital tools support the teaching and learning of science content in a preschool context. The thesis empirically explores the following research question: “How does the use of digital tools support the teaching and learning of science content in the preschool context?”

The thesis draws on a sociocultural perspective on learning, and on the theoretical framework of Pedagogical Content Knowledge (PCK) and its Refined Consensus Model. The results are based on four papers focusing on teachers’ considerations on using digital tools, their experiences of implementing slowmations, children’s and teachers’ engagement with science content and – finally – children’s conceptions of science content when constructing slowmations.

Data were collected using the reflection tool Content Representation (CoRe), video recordings, stimulated recall interviews and the construction of a digital artefact: a slowmation. The overall results show that preschool teachers use digital tools, such as tablets, digital microscopes and projectors, to create an environment, visualise the content, recreate engagement with the content and facilitate communication about the content. The teachers’ considerations on using digital tools reflect different aspects of teachers’ PCK, such as knowledge about children’s learning needs and processes. Additionally, constructing a slowmation provided children with repeated opportunities to revisit and represent the content, and made children’s conceptions about the content explicit. The thesis contributes to thick descriptions of how teaching and learning of science content supported by digital tools is intended, enacted and reflected. The synthesised findings from the individual papers demonstrate that digital tools play versatile but interrelated roles in shaping environments, practices and processes, acting in catalytic, reinforcing and transformative ways. The results of the thesis highlight the importance of teachers providing opportunities for informed consideration of the purpose, methods and selection of digital tools in science education. Reflective tools, like Content Representation, are valuable artefacts for teachers to develop their science teaching, based on purposeful considerations. Digital

tools can be used to support child-centred and content-focused teaching. It is vital that the digital tools used to support science teaching and learning in preschools are thoughtfully integrated, based on their contribution to the teaching process and their relevance to the specific content being taught.

Keywords: science content, digital tools, preschool, pedagogical considerations, Content Representation, RCM of PCK, sociocultural perspective, slowmation

Populärvetenskaplig sammanfattning

Det övergripande syftet med denna avhandling är att ge kunskap om hur digitala verktyg stödjer undervisning och lärande av naturvetenskapligt innehåll i en förskolekontext. Avhandlingen undersöker empiriskt följande forskningsfråga: Hur stödjer användningen av digitala verktyg undervisningen och lärandet av naturvetenskapligt innehåll i förskolan?

Avhandlingen utgår från ett sociokulturellt perspektiv på lärande samt det konceptuella ramverket Pedagogical Content Knowledge (PCK) och dess Refined Consensus Model.

Resultaten baseras på fyra studier som fokuserar på lärares överväganden om att använda digitala verktyg, deras erfarenheter av att implementera slowmation, barns och lärares engagemang i naturvetenskapligt innehåll, och slutligen barns uppfattningar om naturvetenskapligt innehåll när de konstruerar slowmations. Data samlades in med hjälp av reflektionsverktyget Content Representation (CoRe), videoinspelningar, videostimulerade intervjuer och konstruktion av en digital artefakt, en slowmation. De övergripande resultaten visar att förskollärare använder digitala verktyg, såsom surfplattor, digitala mikroskop och projektorer, för att visualisera innehållet, återskapa engagemanget i innehållet och underlätta kommunikationen om innehållet. Lärarnas överväganden kring användningen av digitala verktyg speglar olika aspekter av deras PCK, såsom kunskap om barns lärandebehov och lärprocesser. Att konstruera en slowmation gav dessutom barnen upprepade möjligheter att återvända till och återge innehållet, vilket gjorde barnens föreställningar om innehållet explicita.

Avhandlingen bidrar till täta beskrivningar av hur undervisning och lärande av naturvetenskapligt innehåll med stöd av digitala verktyg planeras, genomförs och reflekteras. Avhandlingens resultat belyser vikten av att lärare ges möjlighet att, individuellt eller kollegialt, göra välgrundade överväganden om syfte, metoder och val av digitala verktyg i naturvetenskapsundervisningen. Reflektionsverktyg, som Content Representation (CoRe), utgör en värdefull artefakt för

reflektion för lärare för att utveckla sin naturvetenskapliga undervisning baserat på genomtänkta överväganden. Digitala verktyg kan användas för att stödja barncentrerad och innehållsfokuserad undervisning. Det är viktigt att digitala verktyg som används för att stödja undervisning och lärande i naturvetenskap i förskolan integreras på ett genomtänkt sätt, baserat på deras bidrag till undervisningsprocessen och deras relevans för det specifika naturvetenskapliga innehållet som är i fokus.

Acknowledgements

“Πάντες ἄνθρωποι τοῦ εἰδέναι ὀρέγονται φύσει.”-

“All human beings by nature desire to know.”

—Aristoteles, *Metaphysics* (Book A, 980).

The ancient quote by the Greek philosopher Aristotle expresses that humans possess an inherent curiosity and a desire to know more. The image on the cover illustrates two children examining leaves. It can be understood as they, in a curious and emerging way, learn about science. This takes place in a context—in interaction with others and with the support of tools—where teachers’ considerations create conditions for such inquiry.

This inherent need to seek knowledge is something I can relate to myself. It has been a driving force behind my choices to seek out contexts where knowledge and interaction with others are central, for example, working as preschool teacher or being part of Font D Graduate School.

Being a doctoral student has meant tentatively learning a new craft—to seek knowledge about phenomena and to articulate that knowledge to others. In this process, the knowledge of others has been invaluable.

A sincere and heartfelt thank you to my flexible principal supervisor, Pernilla Nilsson, who has supported and guided me into the world of research throughout my doctoral studies. Thank you for your sharp questions and for sharing your knowledge of core research issues in such a warm and personal way. I also want to thank you for taking care of matters that fall outside a doctoral student’s writing process.

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I could not have wished for a better combination of supervisors, and I will always be grateful to you.

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Last but not least, I would like to thank my colleagues, both past and present, for reminding me that there is a life beyond the text and the screen.

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Halmstad, April 2026

List of papers

This thesis is based on the following appended papers, referred to throughout the text by their corresponding Roman numerals.

- I. Papantonis Stajcic, M., & Nilsson, P. (2024). Teachers' considerations for a digitalised learning context of preschool science. *Research in Science Education*, 54, 499–521. <https://doi.org/10.1007/s11165-023-10150-5>
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- II. Papantoni, M., & Nilsson, P. (2026). Teachers' and children's engagement with science content through digital tools in preschool settings. *Research in Science and Technological Education*.1–25. <https://doi.org/10.1080/02635143.2026.2657604>
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- III. Papantoni, M., Nilsson, P., & Cederqvist, A.-M. (2025). When science content becomes animated: preschool teachers' experiences of slowmation implementation. *Research in Science & Technological Education*, 1–23. <https://doi.org/10.1080/02635143.2025.2545369>
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- IV. Papantoni, M., Nilsson, P., & Cederqvist, A.-M. Using slowmation to visualise preschool children's conceptions of science content. (Submitted manuscript)

Supporting work

The following publications are not included in the thesis, but have supported the development of the papers on which the thesis is based.

1. Papantonis Stajcic, M., & Nilsson, P. (2023). *Digital tools in preschool science: To be or not to be*. Paper presented at the 15th Conference of the European Science Education Research Association (ESERA 2023), Cappadocia, Türkiye, 28 August–1 September.
2. Papantonis Stajcic, M. (2024). *Engaging with the science content: Children’s and teachers’ interaction through digital tools in preschool science*. Paper presented at the Conference of the Nordic Education Research Association (NERA), Malmö, Sweden, 6–8 March.
3. Papantonis Stajcic, M., Nilsson, P., & Cederqvist, A.-M. (2024). *Aspekter av naturvetenskapligt innehåll: En fallstudie med slowmation som representationsform för att synliggöra förskolebarns förståelse*. Paper presented at the conference on Forskning i Naturvetenskapernas Didaktik (FND) [Research in Science Education], Halmstad, Sweden, 12–14 November.
4. Papantonis Stajcic, M. (2025). *Preschool teachers’ experiences of using Slowmations to teach and learn science*. Paper presented at the Conference of the Nordic Education Research Association (NERA), Helsinki, Finland, 5-7 March.

Contributions

Maria Papantoni carried out the initial background description and study design for all four papers. In addition, Pernilla Nilsson contributed to the background description and study design of all papers through supervision, co-authoring and ongoing feedback. Anne-Marie Cederqvist provided feedback on the interview questions applied to Paper III.

Maria Papantoni established contact with participating preschools, teachers and children, and was responsible for and conducted material preparation, data collection, transcription, and analysis for all papers.

Pernilla Nilsson contributed to the analysis, and reviewed, commented on and participated in the revision of the analyses for Papers I – IV, and Anne-Marie Cederqvist contributed to the analysis and reviewed, commented on and participated in the revision of the analyses for Papers III and IV.

Maria Papantoni authored the first full draft of each paper and further developed the content of all papers. Pernilla Nilsson reviewed and revised subsequent drafts for Papers I–IV, and Anne-Marie Cederqvist reviewed and revised subsequent drafts for Papers III and IV.

Maria Papantoni co-authored the final versions, together with Pernilla Nilsson for Papers I and II, and with Pernilla Nilsson and Anne-Marie Cederqvist for Papers III and IV.

All authors have reviewed and approved the final versions of the respective papers they co-authored before submission.

Regarding Paper I, Maria Papantonis Stajcic is Maria Papantoni's former name.

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Chapter 1

Introduction

TEACHER: Look here! (Pointing at the screen on the wall depicting a leaf and its 'structure'.)

Cloe: Is there a small hole? (Stretches out her hand towards the screen.)

TEACHER: Look at the leaves we have collected. Some of you called these 'paths', and some called them 'patterns'. Can you see clearly on this leaf the paths that we have seen before? (Points at the screen.)

Chris: Yes!

Carl: No! (Shakes his head.)

TEACHER: Chris thinks so, and you [Carl] do not. What do you think, Casper? Can you see the pattern [on the leaf] clearly? (Waves with the digital microscope in a circular motion on the leaf to make it visible to the children.)

Casper: I think it looks like a dinosaur. (Smiles.)

TEACHER: You think it looks like a dinosaur? Oh, and now the colour has changed! It was brown and a little dry there [on this spot]. (Touches the leaf with her finger.)

Cloe: It's a little bit dark there, and there are patterns!

Carl: (Looks at the screen and then at the leaf on the table.)

TEACHER: Is your leaf fresh or is it a wilted leaf? (Asks the question to Carl.)

Carl: I don't know what it is. (Looks up at the screen.)

Chris: Fresh!

TEACHER: It's OK to say that you don't know!

The excerpt above captures an activity at Rainfall Preschool, where children and their teacher actively engage with science content. Building on previous discussions about the water cycle, they examine fresh and wilted leaves using a digital microscope to explore potential connections between leaf structure and water. Images of the examined leaves are projected onto a screen, enhancing inquiry and eliciting discussion. The activity can also be viewed as an example of emergent science (Larsson, 2016a; 2016b), where teachers and children collaboratively investigate and explore science content, and use digital tools to visualise the presence of water in the leaves.

Similarly, science education in preschools around the world provides the youngest learners in our society with opportunities to encounter and learn about various science content, and to develop knowledge and skills that are desirable for the needs of today and the future. Scientific knowledge and literacy are vital for understanding our world and addressing various societal challenges. These competencies enable individuals to explain natural phenomena scientifically, understand scientific inquiry and analyse scientific information in order to draw informed conclusions (Roberts & Bybee, 2014; Roy et al., 2025). Early experiences are therefore crucial for children's understanding of science content (Eshach & Fried, 2005; Fleer, 2009a; Larsson, 2013a), as they challenge potential alternative conceptions (Skamp, 2021), nurture future science knowledge (Eshach & Fried, 2005; Siry et al., 2023) and support the development of scientific literacy (Larimore, 2020).

Recognising the significance of early science experiences, it is relevant to consider how these experiences are enabled. One way this occurs is the growing presence of digital tools in educational settings. In recent decades, digital tools have become increasingly integrated into various fields of society and, subsequently, into educational settings. Promoting science learning and digital literacy are emphasised in early childhood education (European Education and Culture Executive Agency, 2011; Swedish National Agency for Education, 2018). The curriculum for the Swedish preschool context (Swedish National Agency for Education, 2018; 2025) highlights science as a central content area, with a goal that children should develop knowledge about plants and animals, as well as simple chemical processes and physical phenomena. Furthermore, the curriculum emphasises the importance of providing every child with opportunities to develop the ability to explore, describe using various forms of expression, and ask questions about and engage in conversations concerning science and technology (p. 15).

Within this curricular and societal context, it is also important to recognise that science education per se entails challenges. Teaching and learning science involves complex phenomena and concepts about the natural world (Skamp, 2021). It also includes complex

processes that are difficult to explain or observe with the naked eye, such as the moon's phases or why an ice cube melts. In their practice, teachers may use different methods and tools to help children learn about these complex phenomena. Digital tools have, in this regard, invaluable potential to pinpoint and make the abstract visible, compared to analogue tools. The tools' technological capabilities facilitate the storage and manipulation of digital information (Selwyn, 2022). Thus, digital tools enable the segmentation, enlargement, simulation, projection and display of representations and details of various objects or phenomena across multiple modalities. These technological functions are particularly relevant in preschool settings, where younger learners can encounter concrete, multimodal representations through time-lapse photography (Myrvold & Holter, 2026; Fridberg et al., 2018), stop-motion animation (Fridberg et al., 2018) or digital microscopes (Gabdulinova & Kovrova, 2021). Digital tools can therefore be said to provide a means of visualising abstract relations and processes (Eilam & Gilbert, 2014; Hoban & Nielsen, 2010). Visualising abstract and even complex content can be particularly important for younger learners in developing their knowledge about – and in – science. Early experiences are essential for constructing scientific knowledge, and digital tools can enrich these experiences by visualising what is challenging to grasp. As such, digital tools provide distinct opportunities to visualise science phenomena, thereby offering pedagogical potential for the teaching and learning of science content.

While digital tools can support children's science learning, their use also aligns with educational objectives related to digital literacy. As digital literacy becomes increasingly valued in our society, preschool science settings serve as potential contexts for children to develop digital competence. Digital competence encompasses, for instance, knowledge to use digital devices and develop a responsible and critical approach to managing technology and valuing information (EU, 2019; Swedish National Agency for Education, 2018). Research highlights the need to critically evaluate how children interact with these tools in the home and preschool environments (Holloway, Green, & Livingstone, 2013), and to produce knowledge in the field of children and media that bridges child development, children's rights

and children's digital experiences in different contexts (Livingstone & Sylwander, 2025).

At the same time, in the Swedish context, a social debate has intensified around using digital tools in educational settings. Concerns have been raised about young children's excessive screen time being harmful to their cognitive development and well-being. These concerns reflect the World Health Organization's recommendations that children under two should not be exposed to digital screens, and that screen use should be limited to one hour for children aged two to five (WHO, 2019). It is important to point out that these recommendations refer to passive and sedentary screen use and cannot be equated with the pedagogical use of screens in preschool. In the debate, digital tools are, on the one hand, considered inadequate for supporting younger children's relational abilities, attention and concentration, or for developing their ability to read, write and count. Instead, analogue learning tools are recommended in early childhood settings (Utbildningsdepartementet, 2023). On the other hand, additional concerns reflect the educational losses of not using digital tools in preschool settings (Pramling Samuelsson et al., 2024). This 'screen-free preschool' debate brings renewed attention to the discussion of digital tools as a potential risk for children or pedagogical opportunities (Nilsen, 2018; Nilsen & Säljö, 2025; Otterborn, 2023).

Until 1 July 2025, the use of digital tools was a prioritised area of learning, emphasising the importance of fostering children's digital competence and encouraging active use of digital tools (Swedish National Agency for Education, 2018). As a result of the updated curriculum (Swedish National Agency for Education, 2025), there has been a significant shift regarding the use of digital tools. The changes in the revised curriculum emphasise that there are no requirements for using digital tools and that learning tools in preschool education should primarily be analogue (Swedish National Agency for Education, 2025). At the same time, preschool teachers' responsibility for ensuring that teaching and learning rest on a scientific basis and proven experience, as well as for the choice of working methods and learning tools, is also emphasised (Swedish National Agency for Education, 2025). These ambivalent curriculum changes challenge teachers'

professional and practice knowledge as a critical ground to determine appropriate tools for teaching and learning (Söderberg, 2025), and devalue the pedagogical potential of digital tools in early childhood education. Nilsen and Kjällander (2023) emphasise that preschools provide a unique environment where children can become producers rather than consumers of digital content, thanks to the guidance of teachers and the collaboration and exchange of ideas with peers. In the same vein, drawing on the report from the Norwegian Screen Use Committee, Nilsen and Säljö (2025) emphasise the importance of content for digital engagement and argue that the use of digital tools should not be appraised based on the amount of time spent, but rather on how they are integrated into pedagogical practices.

Within this debated context, the role of preschool teachers is pivotal in providing support, guidance and reflective practice regarding when, how and why digital tools are used with children to foster engagement and promote meaningful interactions with educational content (Gibbons, 2010; Selwyn, 2022). Digital technology has developed rapidly, which may be challenging for teachers. Whether teachers include digital tools in their practice may rely on various contextual factors such as policy decisions and material resources (Blackwell et al., 2014; Nilsen, 2018). However, previous research also shows that children's learning is subject to using digital tools in teaching (Aldhafeeri et al., 2016; Blackwell et al., 2014; Bittner, 2019).

For example, teachers use digital tools for different purposes, such as learning about various content and enhancing collaborative skills (Jack & Higgins, 2019; Otterborn et al., 2019; Undheim, 2022; Walan & Enochsson, 2024). Further, teachers may exclude digital tools based on how children use them (Nilsen, 2018) or because they consider them unsuitable for the play-based pedagogy of early childhood (Aldhafeeri et al., 2016; Bird & Edwards, 2015). In summary, the abovementioned findings demonstrate that teachers have pedagogical intentions for the use of digital tools.

Given that teachers have pedagogical intentions for implementing digital tools, it must also be acknowledged that teaching and learning do not occur in a vacuum, but in a context where individuals interact and (re)create knowledge using diverse artefacts (Säljö, 2000;

Vygotsky, 1978; Wertsch, 1985). Preschool science constitutes such a learning context. It is defined as a complex process where children – in interaction with peers and teachers – explore, communicate and collaborate in connection with science phenomena and concepts, and construct representations about them by using diverse resources and artefacts (Fragkiadaki et al., 2019; Siry, 2013; Siry & Max, 2013). Furthermore, they review their understandings (Fragkiadaki et al., 2019). Children’s perspectives, experiences and anchorage in everyday life (Fleer, 2009a; Larsson, 2013a) are crucial for forming and conceptualising science phenomena and concepts.

The increasing use of digital tools in preschools in recent years has been recognised in educational research. For instance, some of the research body focuses on children’s digital play (Edwards & Bird, 2017; Fleer, 2018), how technologies constitute mediating contexts for connecting experience and everyday concepts with scientific concepts (Fleer & Hoban, 2012) or how they are used to scaffold children’s reasoning about phenomena (Fridberg et al., 2018). Incorporating digital tools alongside other resources can enhance children’s exploration and promote collaborative learning between teachers and children (Bittner, 2019), as co-learners engage, converse and thoughtfully challenge each other’s ideas. Digital tools can therefore serve as significant artefacts to cultivate knowledge for children and teachers (Bittner, 2019). This indicates that teachers’ pedagogical considerations are crucial in implementing digital tools for stimulating and developing children’s learning. Further, capturing teachers’ pedagogical considerations for using digital tools when engaging with science content in such teaching and learning contexts is vital for understanding the complex processes of preschool science. Studying teachers’ pedagogical considerations is crucial because they reflect on the knowledge of science content, their students’ learning needs and understanding, the role of technology and the specific learning context. Understanding how these aspects influence the use of digital tools in preschools is essential, particularly in science education and early childhood education.

This thesis explores the use of various digital tools and technology-promoted artefacts based on teachers’ intended, enacted and

reflected teaching of science content in preschool. It builds further on the existing knowledge within preschool science education concerning how teachers pedagogically consider using diverse digital tools for teaching and learning science content in interaction with children in preschool settings. Previous research emphasises the importance of studying the use of digital tools within authentic teaching and learning contexts (Nilsen, 2018; Ollinen, 2019; Otterborn, 2023). Specifically, Selwyn (2010) advocates for a critical view of digital tools used in education, examining beyond the state-of-the-art, such as the most effective use of digital technology for predetermined educational goals, but rather focusing on the state-of-the-actual, including what technology use in education actually looks like, why it takes the forms it does and what consequences result from these practices.

There is still limited knowledge about how digital tools, anchored in preschool teachers' pedagogical considerations, are used in authentic science teaching and learning contexts in preschool, and how they support children's engagement, understanding and meaning making of science content. Moreover, this limited knowledge also includes empirical insights into how digital tools and technology-promoted artefacts are intentionally used in preschool, based on teachers' experiences and in relation to making children's conceptions of science content explicit. This thesis responds to this gap by exploring why and how using digital tools supports the teaching and learning of science content. As experienced and interpreted by both teachers and children, this research provides thick descriptions (Geertz, 2000) of such contexts.

Furthermore, by drawing on empirical findings and rich descriptions, this research provides knowledge and addresses the research gap concerning the digitalised learning context of preschool science from various perspectives:

- Teachers' intended teaching about science content when integrating and using digital tools and technology-promoted artefacts (Paper I)
- Teachers' enacted teaching regarding the use of digital tools and engagements with the science content in interaction with children (Paper II)

- Teachers' reflected teaching exploring their experiences of using and implementing digital tools and technology-promoted artefacts to teach and represent science content (Papers I and III)
- Children's engagement and learning of science content, as visualised through the process of the construction of a technology-promoted artefact, such as slowmation (Paper IV)

This research highlights the potential of digital tools in science education, particularly in terms of how they can meaningfully support the teaching and learning of science content in preschool settings. Its insights underscore the relevance of investigating the role of digital tools in preschool contexts, especially amid the ongoing debate about screen-free preschools.

Aim and research questions

The aim of this thesis is to provide knowledge about how digital tools can support the teaching and learning of science content in a preschool context. The point of departure is teachers' articulated pedagogical considerations for integrating digital tools in their science teaching. Additionally, it builds on enacted science activities, where teachers and children – *in situ* – engage with science content with the support of digital tools. The following overarching research question guides the thesis:

“How does the use of digital tools support the teaching and learning of science content in the preschool context?”

Figure 1 below provides an overview of the thesis.

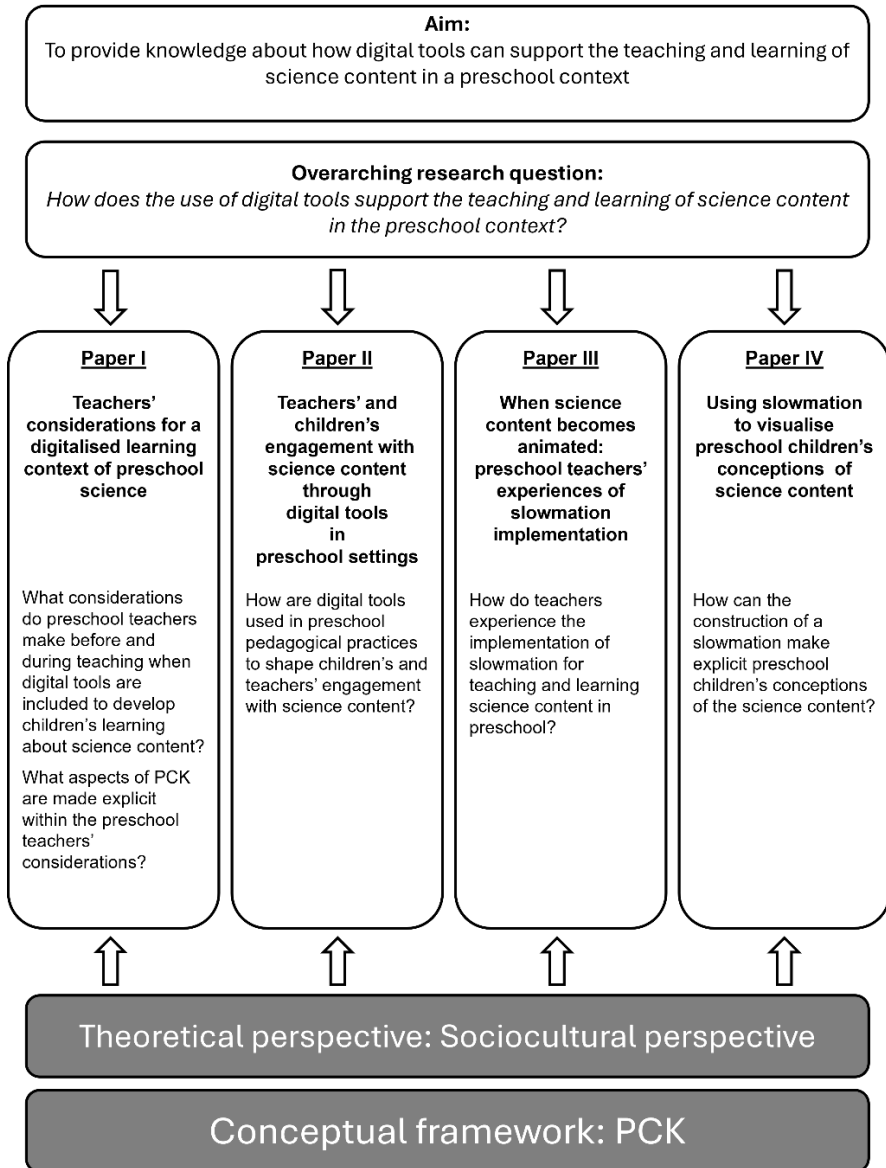


Figure 1. Overview of the thesis

Outline of the thesis

This thesis comprises seven chapters. The introductory chapter outlines the problem area and presents the overall purpose and research questions. Chapter 2 reviews relevant literature on the teaching and learning of science as well as the use of digital tools in the preschool context. The theoretical framework guiding the analysis and interpretation of data is introduced in Chapter 3, while methods and methodological choices are described in Chapter 4. Chapter 5 presents the key findings from each study and offers a synthesis of the findings in relation to the overarching research question. Chapter 6 discusses the results in connection with previous research and the theoretical framework. It presents the thesis's methodological and conceptual contributions, implications and suggestions for future research. Finally, Chapter 7 contains a Swedish summary of the thesis.

Science education in the preschool context

The preschool context

This thesis is based on empirical research conducted in a Swedish preschool context. Preschool is defined as a part of the Swedish education system (SFS 2010:800). Since 1998, the Swedish preschool has been governed by a national curriculum, marking its formal integration into the education system (SFS 1985:1100). Additionally, since 2011, preschool has been defined as a separate school form within the Swedish school system, with its mission being regulated by the School Act (SFS 2010:800) and the Curriculum for the preschool, Lpfö 18 (Swedish National Agency for Education, 2025). At the time when this thesis project was conducted, an earlier version of Lpfö 18 (Swedish National Agency for Education, 2018) was in effect. This curriculum will be referenced when describing the studies' context. Where appropriate, for example, in the discussion, the current curriculum will also be considered. The Education Act (SFS 2010:800) stipulates that preschool education should aim to enable children to acquire and develop knowledge and values. It must promote the development and learning of all children and a lifelong desire to learn. Preschool education is based on a holistic view, recognising the care, development and learning of children as being intertwined. Therefore, according to the Curriculum for the preschool, Lpfö18 (Swedish National Agency for Education, 2018), education in preschool should stimulate children to develop an understanding of themselves and their environment. This development should be grounded on exploration, curiosity and play, and on children's needs, experiences and interests (Swedish National Agency for Education, 2018).

Science content is central in this thesis. The Swedish Curriculum (Swedish National Agency for Education, 2018) highlights science as one of the focus areas for teaching and learning. The learning of science is framed within the learning goals for preschool education, which emphasise science knowledge as crucial for children (up to 6 years). The following objectives are aimed explicitly at learning in and about science:

- an understanding of relationships in nature and different cycles in nature, and how people, nature and society affect each other,
- an understanding of how different choices people make in everyday life can contribute to sustainable development,
- an understanding of natural sciences, knowledge of plants and animals, and simple chemical processes and physical phenomena, and
- an ability to explore, describe with different forms of expression, ask questions and discuss science and technology (Swedish National Agency for Education, 2018, p. 15)

In concrete terms, teaching science may involve working with content such as sorting and categorising species, investigating physical phenomena and chemical processes such as friction and decomposition, or reasoning on and formulating hypotheses about scientific issues.

In the preschool context, the role of the teacher encompasses stimulating children's development and learning through both planned and spontaneous engagement with content. The planning and implementation of teaching activities should be based on the goals in the curriculum and children's earlier experiences and knowledge. Through both planned and spontaneous activities, teachers should encourage children's curiosity, creativity and interest. Although the composition of professions may differ between Swedish preschools, preschool teachers have an overarching pedagogical responsibility – together in work teams with childcare workers and sometimes other professions – to meet the requirements of preschool education as regulated in the Curriculum for the preschool (Swedish National Agency for Education, 2018). This means that teachers work

together to plan, teach and evaluate the pedagogical work concerning different contents.

In an audit conducted by the Swedish Schools Inspectorate (2017), the quality of how preschools stimulate and develop children's learning in science was examined. Twenty-two preschools were reviewed, focusing on how science is integrated into the preschool's educational mission, how concept development is supported and what factors influence the effectiveness of teaching. According to the Swedish Schools Inspectorate (2017), most of the audited preschools' work with science has a focus on 'animals and nature'. When teaching physical phenomena and chemical processes, the work stops at isolated experiments, without a well-considered and clear purpose or with no connection to science phenomena that children can observe in their everyday lives. The audit also stresses that such experiments become 'just a doing' and do not necessarily enhance children's learning. Regarding communication about the science content, it was noted that teachers do not commonly use scientific concepts in their interactions with children. Additionally, children were rarely allowed to engage in conversations and ask questions about science, such as about diverse cycles. The audit emphasises the significance of acknowledging children's questions in educational practices in order to avoid neglecting children's interests, motivation and experiential world (Swedish Schools Inspectorate, 2017). These findings have implications for children's learning of crucial science content, including the formation of scientific concepts and children's conceptions. Additionally, it highlights the need for teachers' purposeful and directed teaching of science content to stimulate children's learning in science.

Preschool science education – teaching and learning science

Science education was primarily developed to address the need to learn and teach science in secondary and primary education (Ravanis, 2017). Siry et al. (2023) stress that early childhood education has long been a recognised field of study, and during the last 25 years a focus

on science education during the early childhood years has come to the fore.

Larimore (2020) stresses that science education for younger children should embrace the best of both early childhood education and science education. That means a child-centred approach that focuses on children's whole development, emphasising holistic scientific practices regarding how children engage with science over specific process skills (e.g. predicting), promoting experiences with phenomena in children's local contexts, and using sociocultural approaches (e.g. child–teacher interactions) in the planning and teaching of science. Furthermore, Larimore (2020) suggests that the focus in preschool science teaching should be related to content knowledge, the development of skills or practices to use that knowledge, and non-cognitive development.

Children's scientific literacy is acknowledged as a crucial educational asset to overcome the various challenges of our time (European Education and Culture Executive Agency, 2011; National Research Council, 2012), and science is therefore an integral part of curricula worldwide (European Education and Culture Executive Agency, 2011; National Research Council, 2012). The preschool therefore can be understood as a foundational learning venue for the youngest members of society, aged 1–6, acting as a dynamic arena for the development of knowledge and essential skills. It functions as a meeting place where early cognitive, social and emotional growth is nurtured through purposeful interactions and experiences (Swedish National Agency for Education, 2025).

Eshach and Fried (2025) discuss whether science should be taught to preschool children and problematise the notion that 'science is about the real world'. They argue that science is not about the world in a *direct* way, but rather about the ideas, concepts and theories used to interpret the world. They also state that conceptions and ideas are based on what we observe and experience in the world. Siry et al. (2023) emphasise that inquiry-based science classrooms offer children opportunities to engage in different science phenomena and develop process skills such as observing, asking questions, making predictions, offering explanations, recording observations and

communicating. This emphasises that preschools should thus support children in grasping different science phenomena, nurture their curiosity and scientific reasoning, and provide various opportunities that mediate the real world.

According to Eshach and Fried (2005, p. 316), “[a]s a term, ‘science’ is used to describe both a body of knowledge and the activities that give rise to that knowledge”. Subsequently, some of the research bodies in the science education field refer to young children’s learning about phenomena and concepts (Fleer, 2009a; Fragkiadaki et al., 2019; Larsson, 2013a; 2013b; O’Connor et al., 2021). For instance, Siry et al. (2023) stress that one key focus in science education is how children comprehend and engage with science phenomena and related concepts.

Emergent science

According to Larsson (2016a), science in preschool can be described as an essential area of knowledge, which has a prominent place in the education system but is organised differently than a ‘school subject’.

A central concept in teaching and learning science is *emergent science*. It refers to the incipient learning and understanding of science for children through exploration and experimentation in everyday activities (Siraj-Blatchford, 2001). Furthermore, the term refers to children’s opportunities for learning without any requirement that some understanding of either concepts or processes is achieved. Instead, the focus is on the children developing curiosity and interest in science (Larsson, 2013b; Siraj-Blatchford, 2001), promoting their scientific skills, attitudes, understandings and language through shared investigations with their peers and teachers (Otterborn, 2023). Emergent science can integrate planned teaching while focusing on specific content like buoyancy or friction. A key characteristic is a strong emphasis on children’s experiences and their exploration of science content (Otterborn, 2023). In that respect, it is emphasised that children’s emergent science knowledge is an ongoing process (Larsson, 2013a).

Engaging with science content

In this thesis, engagement or engaging with science content refers to an involvement or being involved in a science practice to encounter, experience, explore and investigate the science content. It represents an interactive process where teachers and children, or children with their peers, interact with each other and use diverse (digital) artefacts to develop an understanding of the science content. Accordingly, engaging with science content encompasses exploring diverse science phenomena and concepts, and enrolling in science practices, such as using digital microscopes to compare the structure of leaves.

Engaging with different science content allows children to explore the natural world. For instance, Siry et al. (2023) state that science teaching and learning in early childhood are related to life science, with a few exceptions in the fields of physical, earth and space science (Siry et al., 2023). Similarly, Larimore (2020) specifies that life sciences (42%), earth/space sciences (24%) and physical/energy sciences (31%) are content areas across the science classrooms in the United States. In a literature review, O'Connor et al. (2021) synthesise the empirical research of 57 studies on science concept formation in the early years (from birth to six years). Based on this review, children aged 3–6 years actively develop foundational concepts in science through engagements with different contents within physics, biology and chemistry, such as astronomy, buoyancy, magnetism, the properties of matter, electricity, forces, materials and their properties, the living world and changes of states (e.g. water). These studies indicate the importance of engaging with science content to support learning (O'Connor et al., 2021). They also support the view of children as being capable of learning science (Larimore, 2020).

Children's emotions and motivation play a crucial role in their engagement with and learning of science content. Siry et al. (2023) describe that when children's engagement with science is built on positive emotions in science, science understanding can evolve due to the interplay between science and emotions. Providing children with opportunities to express their understanding through diverse media, such as images and videos, enhances their comprehension while also

promoting positive emotions and motivation (Siry et al., 2023). This has implications for teachers' science practice, in both the planned and enacted phases of teaching, as it considers children's interests, experiences or pre-understandings, or when and how to use artefacts to engage with science content.

As mentioned above, research highlights that young children are capable of grasping abstract scientific ideas, such as friction and changes of state (O'Connor et al., 2021). However, alternative conceptions – which are different from scientific explanations – act as expansions of children's wider knowledge within a particular context to interpret their daily experiences (Skamp, 2021; Vosniadou & Skopeliti, 2017). Providing young children with opportunities to engage with science content lays the foundation for early exploration and helps to counter the development of alternative conceptions.

Teachers' role in providing opportunities to engage with science

Research has shown the pivotal role teachers play in facilitating preschool children's understanding of diverse scientific concepts (Fleer, 2009a; 2009b; Yıldız Taşdemir & Güler Yıldız, 2024). Furthermore, teaching science can be complex, as it involves conveying, clarifying and illustrating abstract concepts to enable children to develop an understanding of various scientific concepts (Eilam & Gilbert, 2014).

Eilam and Gilbert (2014) stress that teachers must cultivate pedagogies for teaching children about visual representations and gradually increase their awareness of children's ability to use, generate and manipulate representations. In addition, the use of animations, being dynamic representations, addresses difficulties such as representing processes for different phenomena, as opposed to showing static images of a process (Eilam & Gilbert, 2014). Moreover, creating and producing digital narratives, such as storytelling and animations, offers valuable learning experiences (Hoban et al., 2013). Representations enabled by technology can facilitate the visualisation of abstract concepts. A notable example of these representations is 'slowmations', which are narrated digital animations created by children to represent

and visualise science content (Hoban & Nielsen, 2010). Engaging in these scientific practices helps children develop their understanding and conceptions of the content, and provides opportunities for teachers to support them.

The integration of digital tools into preschool education

“In this sense, the term ‘technology’ has always referred to the processes and practices of doing things, understanding things and developing knowledge.” (Selwyn, 2022, p. 9)

This thesis aims to provide knowledge of how digital tools support the teaching and learning of science content in a preschool context. Concerning the quotation above, the knowledge provided in this thesis may help unpack the supportive role of digital tools in preschool science teaching and learning. This section describes what is meant by digital tools, and why and how they are used in the preschool context. The description is important in order to understand the relationship with children’s learning about a specific content in the preschool context, where learning occurs through interaction with others. Although the term ‘digital technology(ies)’ may have been used in literature, this thesis uses the term ‘digital tools’. Digital tools pertain to diverse digital artefacts, resources and technology-promoted artefacts that are used purposefully in the teaching and learning of science content.

As Hatzigianni (2023) states, digital tools encompass a wide range of digital devices, the internet, digital platforms, social media and other technical resources that can be used for education, communication, management, advertising or similar purposes in early childhood settings. Further, digital tools used in early childhood settings comprise many elements, including physical devices as resources. Undheim (2022) describes digital tools in preschool settings as screen-based (e.g. tablets, phones), non-screen-based (e.g. cameras, projectors), exploratory (e.g. digital microscopes), Internet of Toys (e.g. robotics), digital resources (e.g. applications) and media.

Digital tools encompass multifaceted but intercorrelated aspects of technology, divided into material, human and social aspects (Selwyn, 2022). *Artefacts and devices* represent technology, including its design and manufacturing. Furthermore, *activities and practices* illustrate how individuals engage with these technologies, while *context* refers to social, cultural and organisational conditions within which technologies are used (Selwyn, 2022). Digital tools, in this view, are not simple tools (Hatzigianni, 2018) but cultural artefacts, embedded within social contexts and knowledge systems passed down through generations, underscoring the interplay between human and non-human elements in the world of technology (Säljö, 2023).

Digital technologies have given way to new educational resources such as tablets, computers, educational software and applications, which offer new opportunities (Chen & Ding, 2024). The use of digital tools as prevalent artefacts and resources for teaching has created new learning practices as digitalisation continues. For instance, Yelland (2018) studied the potential of tablets and revealed that there were potentially three essential ways in which these digital tools can contribute to new learning:

1. Developing basic literacy (and numeracy) skills: Alongside manipulatives and natural materials, apps can help introduce and practise foundational skills that are essential for later complex learning.
2. Creating imaginative multimodal texts documenting the learning journey, such as representations of children's interests supported by 'open-ended apps'. These texts/artefacts make children's literacy visible in a meaningful way. Artefacts (e.g. eBooks) can be characterised as a dynamic and permanent record of children's daily experiences, and can be retrieved by themselves or others.
3. Rethinking teaching methods to use tablets to document learning, provide support, incorporate actual tasks and share ideas with authentic audiences (Yelland, 2018).

It is also significant that emerging digital practices constitute an ecology, making digital tools integral to preschool practice and part of children's lives (Arnott et al., 2018). Yelland (2018) emphasises that digital tools enhance other resources, and that developing literacy in

diverse multimodal contexts is essential for acquiring 21st-century skills comprising creativity, critical thinking, collaboration and communication. These skills are valued as being more vital than knowing many facts.

Furthermore, Chen and Ding (2024) emphasise the crucial role of digital tools in fostering children's creative development. This means nurturing their ability to think figuratively, explore, solve problems and express themselves in unique ways. Creative development is closely linked to aspects of creative thinking, artistic self-expression and the ability to generate ideas. It also stimulates the development of self-confidence and self-expression, allowing children to explore their thoughts, feelings and experiences. These statements underscore that the use of digital tools can be intentionally used to both create an educational environment and stimulate children's learning, as well as building up their engagement.

Digital tools redefining teaching and learning

Nowadays, according to the digitalisation of our society, digital tools constitute integral resources and embedded parts of contemporary education (Arnott et al., 2018; Selwyn, 2022). This has come to redefine education, since technologies cannot be seen as only 'peripheral' to the main activity in educational settings (Hatzigianni, 2018). The use of digital tools is linked to processes and practices of doing and understanding things and developing knowledge (Selwyn, 2022; Säljö, 2021; 2023). Bittner (2019) remarks that, when viewing digital tools' role as cultural artefacts, it is important to develop conceptualisations of technology that connects to children's everyday experiences. Moreover, Bittner (2019) argues that this perspective positions technology as a complementary and supplementary artefact alongside other artefacts of children's play, investigations and previous experiences.

There has been considerable discussion in the literature regarding whether digital tools facilitate or hinder learning (Chen & Ding, 2024; Nilsen, 2018). According to Selwyn (2022), digital technologies and digital practices are considered to yield more control and

flexibility to the individuals who use them. Digital technologies are therefore associated with significantly enhanced and improved ways of doing things.

When focusing on learning processes, digital technologies can transform pedagogies in early childhood education (Hatzigianni, 2018). In a meta-ethnographic study, Samuelsson (2025) examined the use of digital tools across three case studies conducted between 2015 and 2022. This time span covers the period before the introduction of the Swedish curriculum's emphasis on digital skills, through the early phases of the reform, and into the stage when the curriculum had become more established. The use of digital tools shifted from being perceived as foreign objects and a form of childcare, to being recognised as tools for play and learning, and eventually complementing traditional methods in preschool practice, such as drawing circles with the help of a robot. Digital technologies signify a substantial change in how we learn, remember or understand, due to the way we retrieve, handle and employ information and knowledge. This contributes to a different way of interacting with knowledge (Säljö, 2023). Furthermore, digital tools can be part of integrative educational processes, which are constantly changing and should not be taken for granted (Hatzigianni, 2018). Substantial research shows that these tools create new learning methods in various ways, particularly due to their ability to simulate real-life situations while processing information at a scale, speed and complexity that was previously impossible (Selwyn, 2022).

In preschool settings, combined with other approaches, resources and materials, digital technologies contribute to reinforcing learning experiences of the content (Otterborn et al., 2024) and the development of basic literacy skills (Yelland, 2018). Wilmes and Siry (2024) described how engaging with science content (e.g. worms) through digital microscopes allowed interactions with classmates and the teacher, responding to questions in a hands-on, physical way. The open-ended learning environment encourages collaborative exploration and supports learning through direct, sensory experiences. Bittner (2019) highlights another aspect of teaching and learning, namely that teachers and children become co-educators and co-

learners when using digital tools. This means that teachers are not only facilitators, but also active participants in the exploration of science content. Consequently, children take on an engaged role, and science learning becomes dynamic and interactive. The educational potential of digital tools is better understood when teachers are given space for critical reflection on the theoretical premises and the value of using them in teaching (Bittner, 2019; Palaiologou, 2016).

Teachers' considerations for integrating digital tools

In a literature review, Undheim (2022) emphasises that teachers' integration of technology depends more on how teachers' pedagogical beliefs and practices interact with their beliefs about technology and children rather than their knowledge about digital equipment and resources. According to Kewalramani and Havu-Nuutinen (2019), teachers' intentions of using technology can be understood as their technological and pedagogical beliefs. For instance, teachers had an acceptable approach to using technology to support children's inquiries about everyday scientific concepts in combination with hands-on activities. The teachers' pedagogical beliefs concerned children's creative thinking, communication with parents and sharing of children's science learning experiences.

In this thesis, beliefs, attitudes, knowledge, experiences and intentions are understood to underpin preschool teachers' pedagogical considerations for using digital tools and shaping the provided teaching in a meaningful way to facilitate children's learning of science content.

Digital tools have been shown to offer the potential to enhance children's learning in science. Fleer and Hoban (2012) used digital animation to stimulate children's language in relation to science content such as forces and dinosaurs. The activity resulted in children developing science concepts in the context of creating animations. It also showed that when animations were played, children asked questions, which contributed to their conceptual progress. Fridberg et al. (2018) studied how tablets were used to promote children's collaborative

learning of phenomena, by using time-lapse photography and slow-motion production in different learning contexts (i.e. group discussion, stimulated recall in a group, production of slowmotion and experimentation). There was enhanced and focused reasoning about the water phases when timelapse movies were used to stimulate recall. Further, when the children were active in experimentation or producing slowmotion, the children's communication was promoted and they focused on problem-solving. This finding shows that collaborative learning supported by digital tools enhances children's conceptual development, communication and reasoning.

The inclusion of digital tools in preschool settings can vary due to various factors. Blackwell et al. (2014) point to contextual factors such as policy and available resources. Teachers' beliefs can also influence whether or why digital tools are included (Jack & Higgins, 2019; Undheim, 2022). Jack and Higgins (2019) emphasise that teachers' knowledge of digital tools impacted how the digital tools were integrated into their teaching. Teachers are more likely to use digital tools when their pedagogical beliefs and practices align with their views on technology, rather than due to a lack of knowledge about digital tools and resources (Undheim, 2022; Vidal-Hall et al., 2020). In the same vein, Aldhafeeri et al. (2016) and Bittner (2019) state that teachers' positive attitudes concerning the digital tools' role in children's learning, followed by confidence and support, enhance teachers' use of digital tools. When stimulating children's exploration of science concepts, preschool teachers had an 'acceptable approach' to using digital tools alongside hands-on activities concerning children's creative thinking, as well as sharing children's learning experiences (Kewalramani & Havu-Nuutinen, 2019). Moreover, previous research highlights that teachers acknowledge the potential of digital tools to extend learning by further engagement (Bittner, 2019; Otterborn et al., 2024; Walan & Enochsson, 2024). Bittner (2019) also highlights the benefit of technology in positioning educators as co-learners and constructors of knowledge, actively engaging in the learning process alongside children. This implies that the combination of both digital tools and practical, interactive activities is appropriate and supports children's exploration of science concepts.

In the Swedish context, there has been a recent change regarding the role of digital tools as learning tools to address such issues. On 1 July 2025, a regulation came into force stating that there is no requirement to use digital tools in preschools (SKOLFS 2025:23), which was the case at the time of data collection for the various studies in this thesis project. According to Chen and Ding (2024), children's preparedness for a digital future is a critical need, and early familiarity with digital tools helps them to adopt and develop skills that are essential in a digitalised everyday life. Using digital tools in preschool education presents both opportunities and challenges, such as the opportunity of fostering children's creative and cognitive development (Chen & Ding, 2024), and the challenge of teachers not knowing how to use digital tools to teach science (Walan & Enochsson, 2024). It is imperative that educational contexts make reasoned and considered decisions when developing and implementing digital tools (Chen & Ding, 2024).

Against this background of how pedagogical considerations might be the starting point for including digital tools in science education, there is a need to explore these considerations concerning preschool teachers' enacted teaching. Further, it is relevant to explore how digital tools influence the interaction between preschool teachers and children, and how they might contribute to children's understanding of science content.

How are digital tools used in preschool?

Previous research has shed light on how digital tools are used in a preschool context. Teachers use various kinds of digital tools in educational settings to enhance children's learning. Computers (Otterborn et al., 2020), tablets (Fridberg et al., 2018; Nilsen, 2018; Otterborn et al., 2019), still cameras and mobile phones (Fleer & Hoban, 2012) are used in preschool settings worldwide for different educational purposes. Digital tools are used to develop learning in other subjects and social skills such as cooperation (Jack & Higgins, 2018; Otterborn et al., 2019), or to enhance confidence, curiosity, reflection, etc. (Jack & Higgins, 2018). Additionally, according to Bittner (2019), technologies are a critical impetus for children's interest in science content like

space and the solar system. Further, the integration of digital tools in combination with other resources supports children's inquiry and establishes co-learning between educators and children. This involves seeking information and images together on the internet and establishing a shared sense of wonder and discovery with the children as they explore new information about science content (Bittner, 2019). In that way they interact, discuss, and challenge their own and others' thinking (ideas). According to Bittner (2019), "[t]echnology was identified as a tool to foster knowledge and understanding for both educators and children" (p. 314).

Regarding preschool science, teachers use digital tools to promote communication about science 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, 2024). Digital tools are also used for close observation and investigation (Wilmes & Siry, 2024). Additionally, digital tools complement other educational tools (Otterborn et al., 2024) and create stimulating environments to enhance children's critical reflection and their development of a critical and responsible attitude to technology (Walan & Enochsson, 2024).

Chen and Ding (2024) emphasise the importance of adopting a blended approach for effective integration into preschool settings. A blended approach fluidly combines digital and traditional teaching methods, supports interactive, child-centred learning and fosters greater engagement among children.

Using digital tools to visualise science content

Science teaching and learning involve complex and abstract phenomena, requiring teachers to make deliberate pedagogical considerations and decisions regarding what methods and tools to use to support children's learning. Previous research highlights diverse ways to use digital tools to support children's learning by visualising such content (Otterborn et al., 2024; Patron et al., 2024; Walan & Enochsson, 2024). For example, digital tools have been used in combination with

analogue tools, allowing versatile engagement with the content (Otterborn et al., 2024; Walan & Enochsson, 2024). Otterborn et al. (2024) describe the use of digital tools as pushing the boundaries of multidimensional science teaching, referring for example to emergent systematic inquiry, aesthetics, embodiment and sensory experiences, etc., by adding the dimension of ‘travelling in space and time’. Such an aspect enabled children, for instance, to relive a visit to a forest, travelling in space and time, by viewing video and photographed sequences, including enlarged images of the sowbugs they had encountered and studied during the forest visit. This approach also invites other children to engage in a shared experience (Otterborn et al., 2024). Similarly, beyond staging environments as backgrounds, teachers also use projected images and videos (e.g. photons) to visualise how something is and to prompt children’s exploration of abstract science concepts (e.g. light) in play-responsive teaching (Lund et al., 2024). This use of digital tools reveals that science content becomes mediated through projected images and videos, offering opportunities for re-engagement and deepened understanding.

Moreover, digital tools allowed children and teachers to further explore the science content, such as studying and counting details of crustaceans on projected images or adding features to a digital picture of a sowbug retrieved from the internet (Otterborn et al., 2024). Likewise, previous research emphasises that teachers use digital tools to support and complement analogue tools to visualise science content and provide different experiences of it (Otterborn et al., 2024; Walan & Enochsson, 2024).

Representations are significant artefacts in science teaching and learning, particularly in visualising science content. Constructing representations plays a crucial role in supporting children to refine and articulate their understanding of science content (Ainsworth, 1999; Carolan et al., 2008; Prain & Tytler, 2012). Children’s ability to visualise abstract phenomena – for example, celestial objects and their movement from different perspectives – is essential for promoting knowledge and understanding (Plummer, 2014). Furthermore, representations convey an understanding of an object or phenomenon, and are interpreted in conjunction with other signs (Waldrup et al., 2010).

Previous research emphasises that children's representations may differ from scientific explanations, which can have consequences in future education (Saçkes, 2015; Skamp, 2021; Vosniadou & Skopeliti, 2017). Vosniadou and Skopeliti (2017) propose that alternative conceptions should be viewed as 'hybrid' constructs, blending initial ideas with scientific explanations, rather than simply incorrect beliefs. Although these conceptions may be deeply embedded and challenging to shift, Skamp (2021) emphasises that children acquire scientific knowledge gradually and in fragmented ways. Recognising children's existing understandings and potential alternative perceptions about science content is crucial for creating meaningful science learning opportunities (Ampartzaki & Kalogiannakis, 2016). This also applies to teachers being aware of how children perceive the intended teaching content when encouraging them in their further learning.

The process of constructing a representation initiates a learning journey related to the concept or object represented, thereby making children's understanding explicit and accessible. Yelland (2018) underscores that multimodal artefacts created by using tablets and through open-ended digital applications provide imaginative ways to document children's learning journeys. These artefacts capture children's development by representing their interests and experiences in a meaningful, visible format. They can be revisited by both the children themselves and others, adding continuity to their learning process (Yelland, 2018).

Besides documenting children's learning, technology-promoted artefacts can be used to support the visualisation of abstract phenomena. Although Undheim and Jernes (2020) emphasise that technology does not automatically improve pedagogical practice, they stress the importance of teachers' involvement in providing learning opportunities through digital storytelling, collaboration and sharing views (Undheim & Jernes, 2020). Plummer and Cho (2024) highlighted that storybooks about moon phases and magnetism, for example, can play an important role in how teachers and children can co-construct explanations about science content. This is enabled since children's storybooks initially inspire, contextualise and conceptualise diverse science content that children observe and develop emerging

explanations for. These findings position stories and narratives as significant for science learning, both for children's engagement and for eliciting scientific processes.

The significance of developing and producing digital narratives, like storytelling and animations, has also been emphasised in previous research as a meaningful educational tool (Fleer & Hoban, 2012; Hoban et al., 2013; Patron et al., 2024). The construction of technology-enhanced artefacts, which provide multimodal representations of scientific phenomena, can enhance children's science learning (Ainsworth, 1999; Prain & Tytler, 2012). In another study, Adbo and Vidal Carulla (2020) investigated children's understanding of the concept 'small', with a focus on chemistry. By deconstructing familiar objects for the children and using magnifying glasses, microscopes and visual computer animations, experiences were offered to the children, enabling them to move from a broad understanding to envisioning the molecular and atomic levels of the objects. Moreover, the children were able to distinguish between macro and micro perspectives of 'small'.

Within purposeful science teaching, digital tools can serve as valuable artefacts for visualising science content in ways that make it more tangible and concrete for preschool children.

Using slowmation to represent science content

Slowmation, an abbreviation for 'slow animation', is defined as a simplified approach to creating short, animated films that are narrated and played at a rate of two frames per second (Hoban & Nielsen, 2010). Slowmation is based on the stop-motion animation technique, whereby objects are manually adjusted as images are captured and edited digitally. This method enables animation to be used practically in scientific contexts (Hoban & Nielsen, 2010).

A slowmation consists of five key representations: Background, Storyboard, Models, Digital Photographs, and The Animation (Hoban & Nielsen, 2010). These five multimodal components serve as cumulative representations, since they build on each other. Their sequential structure encourages learners of various ages and in diverse settings

to engage with science content in multiple ways, allowing them to express their understanding differently through each representation (Hoban & Nielsen, 2010; Nielsen & Hoban, 2015; Fler & Hoban, 2012; Mou et al., 2021; Yıldız Taşdemir & Güler Yıldız, 2024). The different representations can be described as follows:

Background: This initial representation involves key information and knowledge that are essential for understanding the content represented in the slowmation. In this stage, children may look for facts, or educators can offer insights related to the specific content.

Storyboard: Once the background information has been obtained, learners construct a storyboard. This involves breaking down the content into chunks or scenes, explaining how these can be staged in terms of resources, and explaining in what order.

Models: Here, children create models to show the different parts/scenes that will be represented in the slowmation. The models can be in 2D or 3D format, and using existing models from the preschool setting is applicable. This representation necessitates that children consider each element in a tangible way to depict the content, particularly regarding distinct features.

Digital Photographs: These refer to the representation involving children taking digital photographs and manipulating the models for the appropriate sequence and movements to be visible.

The Animation: The digital images are uploaded into software (computer or tablet applications) and can be edited for the final step of sound recording. This representation synthesises previous representations, coordinating the models displayed in digital photographs, narratives and resources like written text or music.

Mou et al. (2021) highlight that animations, featured in slowmations, have emerged as a powerful educational tool that stimulates children's opportunities for reflection, enhancing their story comprehension skills and increasing enjoyment in the learning process. Fridberg et al. (2019) investigated children's verbal communication across different learning contexts. The construction of slowmations was found to be a beneficial and effective tool in synthesising the specific (i.e. content, concepts, theories and theoretical models) and domain knowledge, and investigations (i.e. hypotheses, problematising and

questions) for young children's science learning. For example, when using slowmotion and timelapse, the children demonstrated enhanced and focused reasoning about the science phenomenon 'phase changes of water'. Slowmotion construction prompts children to reflect deeply on scientific explanations and how to express them visually. By creating narrated animations, children transform their ideas into tangible representations, fostering purposeful explorations of science concepts. According to Fridberg et al. (2018, p. 1024), when children create narrated animations, "their actions and ideas are turned into a concrete and visible product, through new meaning making of objects in an imaginary way that they are familiar with through play." This description acknowledges the construction of slowmotions as a process and a product that blends playful imagination with concrete meaning making based on children's experiences (Fridberg et al., 2018).

Additionally, animations can support exploration, reasoning and decision-making (Fleer, 2018; Mou et al., 2021), since children intentionally select objects for the animations, as they have negotiated choices during play (Fleer, 2018). When digital animations are integrated during roleplay, storyboards help with thinking, primarily through 'what if' scenarios (Fleer, 2018). Digital storytelling with animations engages children in meaningful cognitive challenges, promoting self-regulation through sequencing and scene capture (Fleer, 2018). In science-focused activities, such as representing water molecules, digital animation fosters collaboration, turn-taking and peer learning among young children (Patron et al., 2024). However, effective use of digital tools requires teacher support and intentional scaffolding to ensure that children focus on representing content representation, rather than technical issues (Patron et al., 2024).

Teachers play a vital role in enriching this process, not least by co-directing, co-animating, co-acting and crafting real-world environments (Fleer, 2020). Prior assessment of children's digital competencies helps educators plan and implement appropriate support, ensuring that animation becomes a purposeful medium for scientific exploration and creative expression (Patron et al., 2024).

As stated above, slowmation can serve as an effective tool for capturing children's understanding of science content, since it provides repeated and multimodal opportunities to revisit content (Hoban & Nielsen, 2010; Fleer & Hoban, 2012). Although slowmations have primarily been used with older learners, they can offer valuable insights into younger children's perceptions. As Yelland (2018) notes, digital artefacts can be considered as a dynamic and permanent record of children's everyday experiences, which is accessible to both the children themselves and others (Yelland, 2018).

Theoretical framework

In this chapter, I present and clarify the theoretical and conceptual framework that underpins this thesis. It consists of a sociocultural perspective and Pedagogical Content Knowledge (PCK). These two frameworks serve as guiding lenses for understanding the distinct aims of the individual papers and the thesis as a whole, both ontologically and methodologically. First, I introduce each framework, highlighting the essential premises that are most relevant to this thesis. I then clarify how combining these frameworks provides a deeper understanding of the role of digital tools in science teaching and learning in preschool settings.

A sociocultural perspective on teaching and learning science

“The most significant moment in the course of intellectual development, which gives birth to the purely human forms of practical and abstract intelligence, occurs when speech and practical activity, two previously completely independent lines of development, converge.” (Vygotsky, 1978, p. 24)

This quotation can serve as a metaphor for what occurs in a preschool context when teachers and children engage with science content. The practical activities involved in engaging with science content can be supported by digital tools, through which children and teachers collaboratively discuss and exchange experiences related to the content.

The sociocultural perspective that forms part of the theoretical framework of this thesis is based on Lev Vygotsky’s (1978; 1986) ideas about learning and development. This perspective has been elaborated on by later interpretations (Lave & Wenger, 1991; Säljö, 2000; Wertsch, 1985; 1998). According to this perspective, all higher functions of human activities (e.g. communication, learning) emerge as actual interactions or social practices between individuals. These

social practices are situated in the cultural context in which they emerge (Lave & Wenger, 1991; Säljö, 2021; Vygotsky, 1978).

From this perspective, understanding how science teaching and learning are supported by digital tools means examining the social practices that emerge when teachers and children engage with science content. Furthermore, it involves analysing how knowledge and meaning of science content are constructed in these practices through interactions between teachers and children and through their use of digital tools.

According to Vygotsky (1978), learning and development are interrelated processes. Every function in a child's development first takes place at a social level (between people – interpsychological) and then at an individual level (within the child – intrapsychological) (Vygotsky, 1978). This signifies that processes and actions central to science education, such as communicating, explaining, using scientific concepts or representing science content, unfold in interaction with others and are situated in the cultural context of science.

In this thesis, this means analysing the communicative and collaborative activities through which teachers and children in preschool jointly construct meaning about science content, situated within the cultural and institutional context and informed by their use of digital tools.

Cultural tools as mediators in science practices

Another central premise of a sociocultural perspective, which informs how learning is conceptualised, is that human abilities and actions are shaped by the ways individuals develop different kinds of tools or artefacts (Säljö, 2022; Vygotsky, 1978). Within social practices, people use different kinds of tools, including physical tools (such as microscopes) and intellectual tools (such as written language and scientific models). From this viewpoint, individuals draw on their experiences and knowledge to create cultural tools, or signs, which represent outcomes of cultural and historical evolution and can be characterised as forms of a culture's collective memory (Säljö, 2000; 2021, 2023). These cultural tools or signs (e.g. scientific concepts and models)

function as mental tools that individuals use to think, just as physical tools (e.g. a microscope) help us act on the physical world (Vygotsky, 1978).

Building on this, Wertsch (1998) argues that cultural tools serve as means for individuals to manage the challenges they face. Among these tools, language is considered “the tool of the tools,” since it enables interaction within social practices (Vygotsky, 1986). Accordingly, the limitations of what individuals can know and do are not restricted within the body itself (Säljö, 2022), but are stretched out through their capacity “to collaborate with a range of cognitive amplifiers” (Säljö, 2021, p. 71). In this thesis, this view is used to understand how digital tools support engagement with science content and help visualise what is not immediately observable, sufficiently clear, or concrete.

Given the central role of cultural tools in shaping human action and learning, digital tools can be understood as contemporary cultural tools within pedagogical practices. In this context, digital tools play a significant dual role in social practices, like science teaching and learning activities. On the one hand, digital tools are, per se, viewed as cultural tools that are shared across generations within social contexts and integrated with valuable knowledge (Hatzigianni, 2018; Selwyn, 2022; Säljö, 2021; 2022). On the other hand, digital tools (e.g. digital media) make other cultural tools accessible and can facilitate learning through interactions between adults and children (Barron & Levinsson, 2019; Murphy, 2022).

Appropriation serves as a valuable metaphor to explain learning within a sociocultural perspective. According to Säljö (2000), appropriation is a gradual process through which learners familiarise themselves with cultural tools, learn to use them, and gain experience of using them productively within the social practices they engage in. Actions, ways of thinking or knowledge are *appropriated* through interaction with other participants and through different artefacts (Säljö, 2000). Appropriation should therefore not be seen as internalisation, copying or transmission of knowledge (Säljö, 2000). In preschool science practices, appropriation could involve children familiarising

themselves with scientific inquiry or scientific concepts by using digital tools.

Similarly, *mediation* (Vygotsky, 1978; Wertsch, 1985; Säljö, 2000) constitutes another crucial symbolic process in learning. In situations where human beings are not in direct contact with the world, various physical tools – as well as intellectual or cultural tools – mediate their understanding of it. Mediation implies a ‘pre-interpretation’ of the surrounding world and is carried out in interaction with others when cultural tools are used (Säljö, 2000). In this process, meaning and significance are transferred between the user and the cultural tool used (Säljö, 2000).

Wertsch (1998) suggests that mediation plays a role in almost every human action. He also emphasises that cultural tools, as mediational means, are material in nature, can serve multiple simultaneous purposes, and can both constrain and enable mediated action (Wertsch, 1998). Artefacts are therefore an integral part of the social practices we engage in. Artefacts of different kinds, such as linguistic, intellectual or digital artefacts, mediate reality for people in social practices. In science activities, for example, digital tools such as digital microscopes can be used to mediate the structure of leaves, and projectors can be used to augment the sense of a waterfall. Accordingly, teachers’ pedagogical content knowledge is mediated by the pedagogical considerations and big ideas articulated in reflection tools (see Content Representation, CoRe, p. 49).

Children’s learning and development are dynamic and can be described in terms of the *zone of proximal development* (ZPD). This zone refers to the space between what children can do on their own (*actual development*) and what they can do with the help of knowledgeable others (Vygotsky, 1978). Before developing *scientific* concepts, children use *everyday* concepts related to their experiences. It is therefore crucial that the learning situation is appropriate to the child’s development level (Vygotsky, 1978). This underscores the importance of connecting teaching to children’s experiences for meaningful science learning. In this context, digital tools can serve as mediators of children’s experiences and knowledge, as well as for teaching, learning and representing science content.

A shared focus on interaction and communication

Language, “the tool of the tools”, is seen as the central cultural tool enabling interaction within social practice (Vygotsky, 1978). Säljö (2000) argues that there is a continuity in thinking between individuals maintained through linguistic communication. Moreover, Adbo and Vidal Carulla (2020) emphasise that young children’s meaningful understanding of chemistry concepts relies on teachers’ ability to create suitable activities and understand how children interpret these experiences. Sustained and shared discussions between teachers and children are important for children’s understanding and learning (Adbo & Vidal Carulla, 2020).

When interacting with other participants in a social context, the concept of *intersubjectivity* (Rogoff, 1990; Rommetveit, 1974; Wertsch, 1985) is useful for understanding how participants coordinate perspectives and construct meaning. Intersubjectivity refers to the process of dialogue and co-listening, in which participants share perspectives, including those that differ from one’s own (Linell, 2009, 2014). Intersubjectivity refers to a partial and temporary shared understanding of an issue between people when they communicate and interact (Linell, 2009; 2014; Säljö, 2000). Importantly, intersubjectivity is not about two communicating parties agreeing, but rather involves a communicative process of meaning-making.

In preschool science practices, intersubjectivity can support interaction between teachers and children when engaging with science content. Fleer (2010) explains that “when teachers are conceptually and contextually in tune with the child, they are able to frame the learning activities the children participate in so that they generate a motive for expanding their play and learning” (p. 96). Likewise, research shows that teachers demonstrate contextual intersubjectivity through their use of the material involved (Henriksson et al., 2026; Larsson, 2013a) and how they use their knowledge about children’s previous experiences and interests (Larsson, 2013a). Fridberg et al. (2019) argue that teachers need to establish a mutual simultaneity, a form of intersubjectivity in the teaching situation. A foundational step to achieving this mutual simultaneity is to incorporate children’s

perspectives into the learning objectives. Fridberg et al. (2019) further emphasise that this is accomplished when the teacher simultaneously considers what the children already understand and the intended learning objective, aiming to connect the two in a way that extends and deepens the children's experiences. Larsson (2013a) further describes examples of conceptual intersubjectivity, such as how a teacher directs children's attention to a specific aspect of a science phenomenon, supporting the children's focus and reflection by asking questions and also by sharing the same focus as the children in an activity exploring sound.

In this thesis, intersubjectivity serves as an interpretive concept for comparing and synthesising results across the different papers. It helps with understanding how the use of digital tools supports attention, participation and collaborative discussion when teachers and children jointly construct meaning about science content.

Building on intersubjectivity, projected images and videos function as an externalised form of memory (Samuelsson, 2019). They may direct attention to teaching content (Lund et al., 2024), link to children's prior experiences (Samuelsson, 2019; Otterborn et al., 2023), and stimulate exploration of concepts through embodied interactions (Samuelsson, 2019) and play-responsive teaching (Lund et al., 2024). A pertinent issue in digitalised preschool science contexts, therefore, is how digital tools facilitate interaction between teachers and children as they engage with science content. The abovementioned findings underline the teacher's role in orchestrating activities, artefacts, and children's perspectives and experiences in ways that support and sustain communication and interactions in science teaching and learning situations.

In this thesis, preschool is regarded as an arena in which children and teachers exchange perspectives and knowledge about science content through interaction within situated science activities involving digital tools. Various cultural tools, such as scientific concepts, models and digital tools, act as mediators. Through these, teachers and children interact, (re)create and (re)share knowledge. When teachers make pedagogical considerations for digitalised science learning contexts, such as which artefacts to use in interaction with

children, how the artefacts will mediate the science content, and how to promote sustained shared discussions between teachers and children, conditions are created to support the development of higher mental functions and scientific thinking. Thus, to understand learning, we need to study it in its context and how the different tools are used (Säljö, 2000). If digitally enhanced preschool science teaching and learning constitutes the research object, it is necessary to study the emergent learning context *in situ*; for instance, how teachers and children use digital tools to engage with and represent science content.

In this thesis, it is relevant to consider digital tools as significant cultural artefacts in the interaction between teachers and children regarding science content. This includes exploring and understanding how different tools are used to mediate science content.

This has implications for the teaching of science content and the conditions created for children's learning. When using digital tools, it is important that the teacher keeps the intended science content in focus, draws attention to it or guides children to notice it. It is also important to provide opportunities for children to make explicit what they perceive of the intended science content when using digital tools.

Grounding this thesis in the sociocultural perspective helps us to understand how the use of cultural tools, here as digital artefacts, mediates higher mental functions (Säljö, 2021), particularly in communicative and interactive learning situations, such as understanding or reasoning about science content. The sociocultural perspective is explicitly used in Paper II to analyse and discuss how digital tools are used across different activities and how engagement with the content unfolds. Additionally, the sociocultural perspective is used to discuss the thesis's overall findings.

Pedagogical Content Knowledge

Shulman (1986) introduced the concept of Pedagogical Content Knowledge (PCK) to acknowledge a teacher's professional knowledge as a specialised form. Initially, Shulman emphasised subject matter, curriculum and pedagogical content knowledge (Shulman 1986). This

specialised knowledge base included – as a minimum – content knowledge, curriculum knowledge, general pedagogical knowledge, pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, and knowledge of educational ends, purposes and values and their philosophical and historical grounds (Shulman, 1987). As such, PCK comprises a blending of different knowledge bases that teachers need in order to enhance students’ understanding. Through their PCK, described as the amalgam of content and pedagogical knowledge, teachers use their knowledge to promote students’ learning effectively. For instance, besides subject matter and curricular knowledge, it requires teachers to understand what may be difficult or easy for the student. Therefore, an awareness of students’ pre-understanding, experiences and alternative conceptions is necessary when teaching a content (Shulman, 1986; 1987).

Different models of PCK (Magnusson et al., 1999; Park & Oliver, 2008) have subsequently been developed to explain the nature of PCK. For instance, Magnusson et al. (1999, p. 97) defined five connected components of PCK, summarised in Table 1 below. This model is widely cited by researchers (Buldu & Buldu, 2021; Chan & Hume, 2019; Sannert et al., 2026), and was also used as an analytical lens for the first study in this thesis.

Table 1. Components of PCK for science teaching (Magnusson et al., 1999).

Components of PCK	Including
Orientations toward teaching science	Goals of teaching science and characteristics of instruction regarding orientations, e.g.: process, academic rigor, didactic, conceptual change, activity-driven, discovery, project-based science, inquiry, guided inquiry

Knowledge of science curriculum	Knowledge of goals and objectives Knowledge of specific curricular programme
Knowledge of students' understanding of science	Knowledge of requirements for learning Knowledge of areas of student difficulty
Knowledge of assessment in science	Knowledge of dimensions of science learning to assess Knowledge of methods of assessment
Knowledge of instructional strategies	Knowledge of subject-specific strategies Knowledge of topic-specific strategies (representations and activities)

The Refined Consensus Model

Since Shulman introduced the concept of PCK, it has been interpreted and used by various researchers (Abell, 2007; Alonzo & Kim, 2016; Brown et al., 2013; Chan & Yung, 2015; Kutluca & Mercan, 2022; Loughran et al., 2004; Nilsson & Loughran, 2012; Rollnick & Mavhunga 2017; Van Driel & Berry, 2012). Due to the different interpretations and inconsistent use of PCK highlighted in various forms of reviews (Abell, 2007; Chan & Hume, 2019), several researchers expressed a desire to reach a consensus about how the concept was defined and interpreted in research. Therefore, in 2016, researchers from various international contexts gathered for a summit to reach a consensus on the different interpretations of the model of PCK. The aim was to revise the PCK model “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).

Three aspects of PCK

The Refined Consensus Model (RCM) of PCK (Carlson et al., 2019) – see Figure 2 – was developed to describe the knowledge and experiences that shape and inform teacher practice and mediate student learning 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.

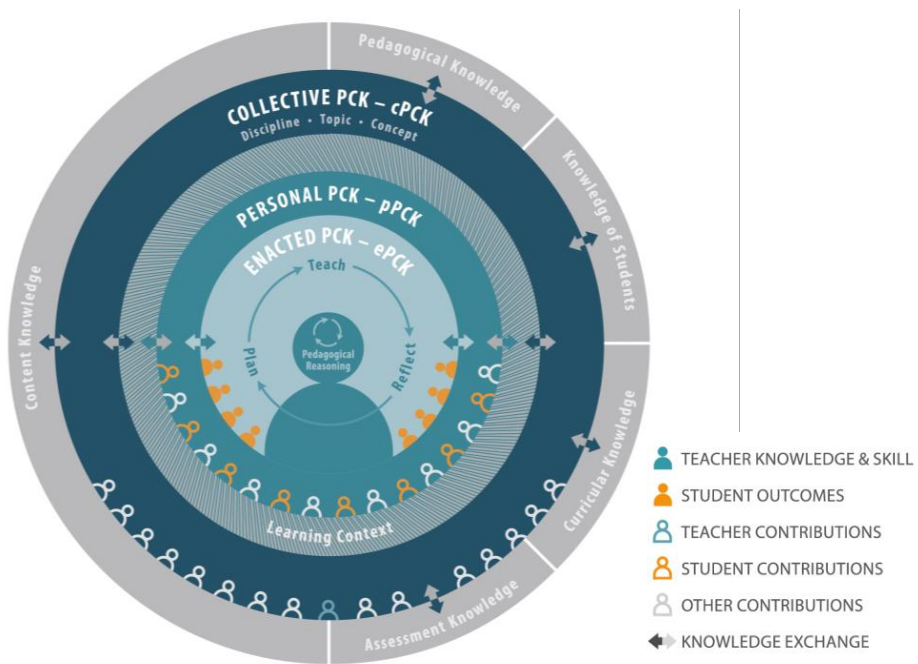


Figure 2. The Refined Consensus Model (RCM) of PCK by Carlson et al. (2019, p. 84). Reproduced with permission from Springer Nature.

The cPCK comprises the combined professional knowledge of different educators or teachers. It implies that this knowledge is collective and public. The pPCK is the teacher’s cumulative PCK that has been shaped and developed through different teaching and learning experiences acquired in different contexts (i.e. interaction with others, students and colleagues), or through different contexts and

interaction with others (i.e. teaching or professional sharing). In the preschool context, teachers use their pPCK and cPCK when they collectively plan and evaluate their teaching in their work teams.

The ePCK encompasses teachers' specific skills and knowledge expressed and used within a particular teaching situation, with clear objectives for the teaching situation for the typical student(s). This realm includes not only the direct reasoning (reflection in action) the teacher carries out *in situ*, but also their reasoning for the teaching (reflection on action), such as planning and making considerations (Carlson et al., 2019). RCM recognises the pedagogical cycle of teaching as a dynamic process (illustrated at the centre of the model), where pedagogical reasoning unfolds uniquely for each teacher and in every teaching situation. Teachers reflect on the learning context and make different considerations to meet the students' needs in relation to the content, curricular objectives, instruction strategies or representations. Previous research also emphasises the need for further investigations of teachers' pPCK and ePCK, and how they interact (Mazibe et al., 2020; Nilsson & Cederqvist, 2025).

Learning context

In the RCM model, the learning context is situated as a ring between teachers' personal knowledge and practice (pPCK) and the broader PCK representing the knowledge and practice of others (cPCK).

The learning context signifies the space and time in which a specific science learning takes place. Various factors, such as the broader educational climate (e.g. policies and national standards), individual student attributes (e.g. experiences, age and language skills) and a specific learning environment (e.g. preschool), identify and mediate the learning context (Carlson et al., 2019). The actual classroom environment, which can be formal or informal, is another important factor that influences teachers' actions and affects students' learning. The choice of artefacts used by a teacher influences the learning context and creates opportunities for children to engage with content, particularly through their mediating functions.

Students' attributes are emphasised as perhaps the most important aspect of the learning context. Having knowledge about

students' attributes informs teachers' considerations and decisions. This thesis emphasises children's attributes, such as prior experiences and pre-understandings of science content, within a reflection tool called Content Representation (CoRe), which is described in a subsequent section, used to examine teachers' pedagogical considerations for teaching science with digital tools.

As digital tools are an integral part of today's society, they have also become important artefacts for teaching in different learning contexts. According to Nilsson (2024), digital tools are one of many contextual factors in the learning context layer that influence teachers' PCK. The pedagogical considerations that guide the use of digital tools and the way the tools are used in a specific learning context for teaching a specific science content are based on teachers' experiences and knowledge of, among other things, the content, the children, the tools and the learning context as a whole. In this thesis, teachers' pedagogical considerations are central and form the basis for all the studies and the empirical findings in the papers. Specifically, Paper I examines which aspects of PCK are made explicit within teachers' pedagogical considerations for using digital tools in intended and enacted teaching.

Paper II provides thick descriptions (Geertz, 2000) of how enacted teaching with digital tools shapes the learning context and the involved science practices enabled by the digital tools, as well as how the engagement with the content between children and teachers unfolds *in situ* when using digital tools.

Paper III focuses on teachers' experiences of using a specific digital artefact, slowmations, to represent and visualise science content, and demonstrates teachers' reflected teaching with digital tools.

Paper IV shows how the construction of a digital artefact (e.g. slowmation), including interactions between teachers and children, environments and materials (e.g. models, manuscripts and multi-modal teaching), sheds light on children's outcomes, such as their conceptions of the science content. This paper demonstrates that constructing digital artefacts shapes learning contexts, which offer recurring interactions with the content and mediate children's learning. In

digitalised learning contexts, digital tools are valuable artefacts, enabling teachers to scaffold children in learning science content.

Thus, the findings in this thesis can be said to provide knowledge about how the use of digital tools shapes the preschool science learning context.

Professional knowledge bases

The outer layer of the model consists of teachers' professional knowledge bases. Content knowledge encompasses the academic content of a given discipline, as well as discipline-specific knowledge and skills, to provide explanations and understand the nature of science. In this layer, there is also generic educational knowledge such as curriculum knowledge, pedagogical knowledge, knowledge of students and assessment knowledge (Carlson et al., 2019). The diverse knowledge teachers possess informs their choices regarding which digital tools to use and the rationale for employing these tools to foster intersubjectivity between teachers and children.

Using RCM for educational research

“With a focus on empirical findings from classroom-based research, the RCM as an interpretive tool may contribute to the understanding of the connections between PCK and teachers' practice. Here, it does not matter whether PCK is regarded as an integrative or a transformative construct because both are legitimate and possible. [...] Furthermore, the RCM presents as a model that is suitable for a wide range of research foci. The RCM as a theoretical scaffold offers a robust baseline for communicating empirical findings within the community as well as beyond.” (Mientus et al., 2022, p. 13)

In a systematic review, RCM is described as a “meaningful theoretical lens” since 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). Pedagogical reasoning can be seen as a prerequisite for developing PCK in the context of science teaching practice. In this thesis (Paper I), teachers – as part of their

pedagogical reasoning – consider what and how to teach science content using digital tools (Papantonis Stajcic & Nilsson, 2024). Based on their considerations, the teachers enact their pedagogical content knowledge to meet children and their understandings and learning needs, and decide how to use the digital tools in that context.

RCM has previously been used in research for various purposes, focusing on different realms of teachers' PCK at various educational levels. Some of the recent research in the Swedish context was conducted by Forsler (2024), who – in a thesis based on four interconnected studies – focused on different aspects of teachers' PCK when teaching sustainable development (SD) in science education. For instance, in one of the studies, Forsler et al. (2024) used CoRe, individual interviews, video recordings of lessons and video-stimulated recall to elicit 11 upper-secondary science teachers' ePCK and pPCK. The findings revealed the capture and articulation of the teachers' pPCK, the plan–teach–reflect cycle when the teachers enacted the teaching (ePCK) and the potential development of pPCK from that specific cycle. Overall, Forsler et al. (2024) stated that the combination of the reflection tool CoRe and video-based reflection supported the teachers' pedagogical reasoning when teaching SD.

RCM has also been used in research within the context of higher education. Kiliç (2024) used RCM as a theoretical framework to examine 18 preservice teachers' pPCK (i.e. declarative PCK) and ePCK (i.e. dynamic PCK) about the science phenomenon of seasons. The preservice teachers' pPCK was studied through individual interviews based on vignettes, whereas their ePCK was examined through classroom observations and video recordings of their teaching. The findings showed that the preservice teachers had a limited level of pPCK on the topic of seasons. The preservice teachers demonstrated limited knowledge in all aspects of topic-specific pPCK and showed mostly limited competencies in all elements of topic-specific ePCK during their teaching practice. The qualitative findings of this study showed a notable difference between preservice teachers' pPCK about seasons as expressed in the interviews and the competencies related to their ePCK that they demonstrated when teaching in the classroom. These findings support the connection between pPCK and ePCK, which is

also specified in the RCM (Carlson et al., 2019). In the context of this thesis, and particularly for Paper I, the findings lend support to using different settings (i.e. CoRe, group discussions, interviews and science activities) to investigate teachers' considerations for and use of digital tools based on their PCK (pPCK and ePCK).

Different realms of PCK and elements in the RCM model have been further researched. For instance, by combining elements of RCM with the five components of PCK listed by Magnusson et al. (1999), Vergara et al. (2024) describe the pPCK development of a group of biology teachers in the context of teaching evolution, using cPCK as a reference. Behling et al. (2022) focused on the potential filters that moderate the transformation between the different realms of PCK. RCM has also been used to research teachers' PCK in other fields, such as mathematics (van der Jagt & Nielsen, 2024).

Alonzo et al. (2019) argue that when looking at teachers' enacted PCK of RCM, planning–teaching–reflection occurs in two distinct cycles: a macrocycle focusing on the process of planning–teaching–reflection and a microcycle that focuses instead on reflections and decisions that take place at the time of teaching. A strength of RCM is that it links PCK with teaching practice by describing the cycle (planning–teaching–reflection) and pedagogical reasoning as central to PCK.

The abovementioned research includes a few examples of the research field where RCM has been used as a theoretical or an analytical framework to investigate, capture and describe teachers' PCK or different aspects of it. These examples show that RCM is suitable for qualitative studies (and quantitative analyses, as in Vergara et al., 2024), and that different instruments can be combined to investigate teachers' PCK. They also show that RCM as a theoretical framework is applicable for researching teachers' PCK in different educational levels and settings.

A teacher's PCK in the context of digitalisation

As mentioned previously, digital tools are an integral part of contemporary society and educational contexts. Why and how teachers use digital tools can be linked to teachers' PCK. A framework that is often

used in contrast to PCK is Mishra and Koehler's (2006) concept of Technological Pedagogical Content Knowledge (TPACK). Based on Shulman's ideas of PCK, Mishra and Koehler (2006) introduced TPACK as a conceptual framework in the context of educational technology. TPACK describes the complex interplay between content, pedagogy and technology, emphasising affordances, connections, interconnections and limitations. Further, Koehler et al. (2014) argue that TPACK is a competence at the intersection of subject content, technology and pedagogy, and requires the coordination of competencies from all three areas of knowledge.

TPACK emphasises the integration of technological knowledge into content and pedagogy (Mishra & Koehler, 2006; Nilsson, 2024). With its focus on the reflective use of technology for promoting children's understanding of the science content, TPACK could assist as a suitable framework to use in this thesis, particularly in Paper I. However, Koehler et al. (2014) state that TPACK has been criticised for having focused too little on the teaching context that technologies are part of. Additionally, Nilsson (2024) calls for further research on the TPACK framework as a whole, and not only on the different components of TPACK separately. Nilsson (2024) further claims 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). Further, Yeh et al. (2021) argue for a collaboration-enriched framework that highlights teachers' TPACK knowledge as an exchange between collective, personal and enacted TPACK, and underline that RCM can be applicable for this purpose. In Paper II, TPACK is addressed by citing literature that uses the framework to explore how digital tools are employed in various science contexts. Furthermore, it is used to discuss the role of teachers in integrating digital tools into their science classrooms. Instead, in Paper I, the RCM model is used to address the teachers' considerations, captured, articulated or reflected in different phases during the plan-teach-reflect cycle of their teaching. As such, the teachers' considerations represent "actual teaching practice" (Nilsson, 2024, p. 18). The digital tools are understood as embedded artefacts in the learning context to address their contextual impact on

teaching. This thesis describes teachers' knowledge of an actual learning situation in science underpinned by digital artefacts.

Content Representation (CoRe) for capturing teachers' PCK

In 1999, Veal and MaKinster highlighted the difficulties in capturing the complexity of a teacher's PCK. To address this criticism, Loughran et al. (2004) introduced Content Representation (CoRe) as a tool to stimulate teachers' reflection when planning for different essential teaching aspects of a specific science topic. CoRe captures and represents science teachers' PCK, and has been used in different contexts since its introduction in 2004 (Hume & Berry, 2013; Nilsson & Elm, 2017; Nilsson & Loughran, 2012). The CoRe tool intends to make teachers' knowledge visible by making them formulate Big Ideas and responding to the different prompts about their intentions for teaching. By making explicit their knowledge and experiences about specific content using CoRe, teachers focus on what is vital about a particular content area (framed through Big Ideas) and how they can develop the conceptualisation and understanding of this through their teaching (Loughran et al., 2004).

Content representations can be described as a detailed summary of the pedagogical considerations the teacher makes about specific Big Ideas. The CoRe tool focuses on different prompts (see Table 2) in relation to each particular idea, and addresses what the children are expected to learn and why it is important. Furthermore, in CoRe, teachers are prompted to reflect on what experiences the children have and what difficulties they may encounter when engaging with the specific Big Ideas (e.g. probing for children's alternative conceptions). The CoRe tool also prompts teachers' considerations about which methods and tools to use, and what possibilities or limitations might influence the teaching of the specific ideas. Finally, teachers are prompted to consider how they will ascertain children's understanding of the specific science Big Ideas. Since this thesis was carried out in a Swedish preschool context, some prompts were adapted to better suit the preschool context, such as considering children's experiences

(Swedish National Agency for Education, 2018). Within this thesis, children's attributes are specifically emphasised in Content Representation (CoRe) where teachers articulate their pedagogical considerations regarding the children's prior experiences and their understandings of the science content (conceptions and misconceptions) (see prompts 4 and 5 in Table 2).

Taking into account the thesis's focus on digital tools, the seventh prompt deals with the teacher's considerations about the opportunities and limitations of teaching with digital tools. Similarly, Nilsson (2024) modified the original CoRe with two additional prompts, resulting in a T-CoRe. The T-CoRe comprised the two prompts "What digital teaching procedures will you use and what are the particular reasons for using these to engage with this idea?" and "What opportunities and challenges might the use of digital technologies provide for your teaching and students' learning of this idea?" in order to stimulate student teachers to focus on how and why to use digital technologies in their teaching practice.

This thesis aims to provide knowledge about how digital tools support the teaching and learning of science content in a preschool context. The teachers' considerations on how digital tools are used to engage with science content with children are the core points of departure for this digital tools-based science teaching and learning. In summary, the reflection tool CoRe, as used in this thesis, clarifies and ties together the teachers' considerations about science content, children's learning and how to teach specific ideas. CoRe is illustrated in Table 2 below.

Table 2. The revised version of the reflection tool CoRe (Loughran et al.,2004).

	Big Idea 1	Big Idea 2, etc.
1. What do you intend the children to learn about this idea?		
2. Why is it essential that children learn about this idea?		
3. What else do you know about this idea (which you don't think the children need to participate in now)?		
4. How do you use the children's experiences/knowledge/questions to teach this idea?		
5. What perceptions/misconceptions might the children have about this idea, and how do these affect the teaching of the idea?		
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.		
7. What possibilities and limitations do you see with using analogue/digital tools in teaching this idea?		
8. How do you ensure the children have learnt what you intended them to learn?		

Several studies using CoRe to reveal teachers' PCK have been conducted in science education for both school pupils (Adadan & Oner, 2014; Barendsen & Henze, 2019; Mazibe et al., 2020) and younger children (Buldu & Buldu, 2021; Nilsson & Elm, 2017). In a Swedish preschool context, Nilsson and Elm (2017) found that CoRe elicited the teachers to focus on and establish the fundamental ideas of the

topic for their teaching. The reflection based on the eight prompts identified in CoRe also led the teachers to consider children's needs and experiences. To accomplish that, the teachers needed to synthesise content knowledge, knowledge of children's preconceptions and different learning strategies. The teachers also experienced that their content knowledge affects the focus, purpose and direction of teaching. Further, Nilsson and Elm (2017) discuss that it is beneficial for early childhood researchers to use additional research methods, such as interviews with teachers and children, to provide extensive aspects of teachers' PCK and children's learning needs. The reflection tool CoRe has previously been used in combination with video to capture teachers' reflections about their teaching (Forsler et al., 2024; Nilsson & Karlsson, 2019).

In this thesis, in Studies I and III, video recordings of science activities and interviews with teachers were used in addition to CoRe. Video sequences from the recorded activities were used as stimulated recall during the interviews to elicit the teachers' reflections (Lyle, 2003; Malva et al., 2023).

Digital tools in preschool science through the lens of a sociocultural perspective and Pedagogical Content Knowledge

While various perspectives and frameworks could be applied to explore the context and key concepts of this thesis, the chosen theoretical framework is used to analyse digitally enhanced preschool science teaching and learning in terms of the interaction between teachers, children, digital tools and science content. A sociocultural perspective (Säljö, 2000; Vygotsky, 1978) is used to describe the teaching and learning of science in preschool as a science practice, while teachers' considerations and knowledge about using digital tools are described within the framework of Pedagogical Content Knowledge (Shulman, 1986; 1987).

A sociocultural perspective, with an emphasis on context, social interaction, situated learning and cultural artefacts (Vygotsky, 1978),

provides an adequate theoretical lens for understanding how digital tools can serve as mediating artefacts within educational contexts, such as preschool science practices. Preschool, as a practice in itself, is situated in a societal context that defines its mission through various laws, ordinances and guiding documents, such as school acts (SFS 2010:800) and curricula (Swedish National Agency for Education, 2018; 2025). Learning in preschool emerges through interactions and engagements within the cultural contexts in which they are embedded. These social practices are fundamental in preschool, such as between teachers and children or between children in different learning activities. Interaction between teachers during planning sessions to shape learning experiences for children or when teacher teams collectively reflect on and evaluate their practice, for instance, is an example of such social interactions.

Science teaching and learning include the use of policy documents, teachers' personal and collective knowledge of science, the desired knowledge of science, and the materials and artefacts available for exploring science phenomena. In a sense, science teaching and learning are therefore shaped by this cultural context. The way science activities are arranged, and the opportunities children are provided with to interact with others, and to reflect on and exchange ideas and perspectives, also inform their engagement with and understanding of science content. Similarly, the artefacts that teachers choose to use in science teaching can mediate science content and support the appropriation of important scientific competencies, such as observing, formulating hypotheses, predicting and making scientific explanations.

A sociocultural perspective therefore supports the understanding of how digital tools in science activities shape the way teachers and children engage with the content, engage with each other and make meaning of their experiences. As such, the sociocultural perspective provides tools with which to conceptualise preschool science teaching and learning as a science practice.

In relation to the sociocultural perspective, the RCM of PCK addresses both the individual and collective perspectives of teacher

knowledge and skills. Based on their knowledge and skills, teachers shape the prerequisites that enable science practices to emerge.

The double arrows in between the realms (cPCK, pPCK and ePCK) and the collective nature of cPCK indicate the importance of interactions between teachers and teachers (cPCK), and between teachers and children. Through these interactions, ideas are exchanged, and science knowledge is both constructed and reconstructed. Further, as described by Alonzo et al. (2019), working with CoRe as a reflective tool has the potential to transform science teachers' tacit pPCK into explicit pPCK. When implemented into teaching practice, it can also inform teachers' ePCK for planning, teaching and reflecting. In this study, CoRe was used in teacher groups to stimulate preschool teachers' collective reflections and to capture their pedagogical considerations and their PCK for teaching a specific topic. In this context, CoRe can be understood as an artefact (Säljö, 2021) for stimulating reflection and contributing to preschool teachers' collective PCK (cPCK). As such, the use of CoRe is supported by the sociocultural perspective, in that it serves as both an artefact and a foundation through which teachers (re)construct knowledge, partly in collaboration with colleagues during reflective practice, and partly through interactions with children. In addition, CoRe can illustrate teachers' pPCK in that it captures the what, the how and the why of teachers' intentional use of digital tools.

In sociocultural terms, artefacts play a crucial role in enabling interaction and sharing knowledge and experiences within practices (Vygotsky, 1978; 1986). Likewise, teachers play a crucial role in designing suitable science activities that enable children to interpret their experiences in a meaningful way (Adbo & Vidal Carulla, 2020).

Additionally, when teachers and children engage in ongoing, meaningful conversations together, where ideas are exchanged and explored, children's ability to understand concepts and learn effectively is significantly supported. Such sustained and shared discussions (Adbo & Vidal Carulla, 2020) are facilitated by projected images (Lund et al., 2024) and can contribute to intersubjectivity (Linell, 2009) between teachers and children regarding science content.

Since digital artefacts impact the way we retrieve, manage and use information and knowledge (Hatzigianni, 2018), it is necessary to ground the exploration of digital tools in science practices based on teachers' PCK.

The sociocultural perspective and the RCM of PCK, as an integrated lens, offers valuable insights for studying, interpreting and describing how digital tools support the teaching and learning of science content in preschool.

Combining a sociocultural perspective with RCM provides an understanding of how digital tools can mediate fruitful interactions between teachers and children and stimulate meaningful science learning practices in preschool. It also provides a theoretical lens through which to analyse how these science practices, as intended, enacted and reflected science practices, are grounded in teachers' PCK.

Methodology

Robson and McCartan (2016) state that adopting a scientific attitude is highly valuable when conducting real-world research, as it involves being *systematic* (e.g. thinking carefully and deliberately about the research process), *sceptical* (e.g. being open to having one's ideas challenged and considering alternatives) and *ethical* (e.g. ensuring the research respects and protects the rights and well-being of participants and those affected by it). Investigating the use of digital tools for teaching and learning science content in a preschool context involved approaching the real world from different angles and perspectives, and through various methods. This chapter outlines the choices, considerations, and challenges regarding research design, data collection, analysis procedures, methodological aspects and ethics, to illustrate the systematic, sceptical, and ethical aspects of this thesis.

Researching the context of digitalised preschool science

A qualitative approach (Silverman, 2021) is used to investigate how the use of digital tools supports the teaching and learning of science content in the preschool context. The reasons for this choice are grounded in the nature of the research object, as qualitative approaches are needed to capture the complexities of people's lives and experiences (Brinkmann & Kvale, 2018). The aim of this thesis is to provide knowledge about how digital tools support the teaching and learning of science content in a preschool context. The four papers of the thesis shed light on preschool teachers' pedagogical considerations (Paper I) and experiences (Paper III) regarding integrating digital tools, and teachers' and children's engagement with the science content supported by digital tools (Paper II), as well as children's perceptions of the science content during the construction of a technology-based artefact, slowmation (Paper IV). Overall, the thesis investigates and describes how individuals (*teachers* and/or *children*) act

(*consider, use, experience and conceive*) upon science content through the use of digital tools. In other words, it draws on a qualitative approach that emphasises the perspectives of the participants involved.

The thesis does not intend to quantify or generalise findings, but rather to provide thick and detailed descriptions (Geertz, 2000; Lincoln & Guba, 1985) of specific contexts and participants' use of digital tools to engage with science content. Through a planned and considered design, the digitalised context of preschool science is inductively and flexibly explored (Robson & McCartan, 2016). Like other qualitative research, the thesis takes – or at least, intends to take – a holistic perspective on the research object, meaning examining the research object from various angles, focusing on teachers' considerations and experiences, children's perceptions, the artefacts used and their relevance for the teaching and learning of a specific science content.

Research context and participants

This section provides insight into the participants and the research context which formed the empirical data for the thesis.

A total of 21 preschool teachers and 37 children (aged 3–6) from four preschools in southern Sweden participated. To guarantee anonymity, the preschools are named here as Rainfall, Waterfall, Windfall and Wingfall. The preschools varied in size: Waterfall and Wingfall were larger, with several departments, while Rainfall and Windfall were smaller with one department each. Waterfall, Rainfall and Windfall were located on the outskirts of a smaller town, whereas Wingfall was situated in a smaller village.

The preschools were chosen on the premise of voluntariness, with the assumption that the participating preschool teachers intended to work with science content and were interested in using digital tools in their teaching. The science projects described in the empirical papers were part of the preschools' long-term work based on the Swedish curriculum (Swedish National Agency for Education, 2018). The teachers planned and organised the activities, and the researcher attended.

The participating teachers had different educational backgrounds; some were preschool teachers and others were childcare workers. The combination of the two professions is common in the Swedish preschool context, and the decision to address them both as teachers and include them in the study is based on the research object's focus. The teachers' teaching experience varied from almost two years to 46 years, and they also had varied experience of using digital tools or had attended technological competence training. During the studies, the teachers worked with science content such as water phases, water circulation, friction, bees and dinosaurs. The content was determined by the teachers as part of their long-term work, grounded in the curriculum, and designed to address children's interests and learning needs.

The preschools had access to digital tools such as mobile phones, tablets with various applications, and projectors. Two preschools also had access to digital microscopes, and the teachers had previous experience using green screens. Many of the teachers had experience of working with movie-making software such as iMovie. Teachers had access to help from the municipality's ICT educator; however, downloading different applications was a cost issue for the preschools in question.

Design of the studies

The thesis consists of four studies presented in four separate papers (I–IV). Different methods and instruments are employed to meet the aims of the studies, and some of them are repeated across the studies. Data generation took place on two separate occasions. Studies I and II were conducted from September 2022 to February 2023, while Studies III and IV were conducted from February to June 2024. The research design and data collection process, including the context and participants, are presented according to these data collection occasions. The methods and instruments used, which may be shared across the four studies, are then presented separately.

Research design and data collection (Studies I – II)

To explore teachers' considerations for including digital tools in their teaching (Study I) and how the use of digital tools is enacted to stimulate children's learning of science content (Study II), a continuum of research steps was carried out, including various actions, is summarised in Figure 3 and further explained in the section below:

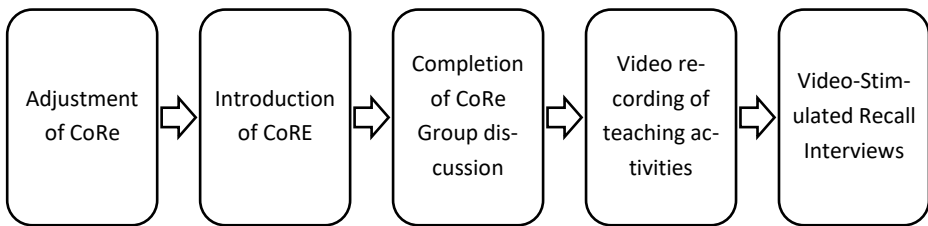


Figure 3. Design for Studies I and II.

The reflection tool Content Representation (CoRe) (Loughran et al., 2004) was initially selected to capture teachers' pedagogical considerations for teaching science with digital tools. However, to better suit a preschool context, the version of CoRe designed by Nilsson and Elm (2017) was found to be more appropriate. This version was further revised, and some adjustments were made based on the feedback from a preschool teacher team from another school that had tested CoRe.

The reflection tool was then introduced to the 15 teachers in their respective preschools and teams. The introduction focused on what a Big Idea could be and the different prompts. In Preschool Windfall, a new teacher attended on a later occasion and a short introduction took place in connection with the completion of CoRe. Written information about CoRe was also provided to the teachers as a summary of the introduction, and in case the teachers wished to deepen their understanding further. The summary included an explanation of the different prompts and what defining Big Ideas involves. It also included

sources of information and strategies concerning the different prompts.

The teachers completed the CoRe tool in their respective teams during a planning session (Study I). The teachers' group discussions during the planning sessions were audio-recorded and lasted almost 1.5 hours for each group. The researcher was present as a facilitator but avoided interfering in the teachers' discussions except for answering any questions asked by the teachers and summarising the discussions when necessary. By audio-recording and attending the planning sessions, I gained a pre-understanding of the teachers' considerations as articulated in CoRe.

Between this step and the previous step, the teachers planned teaching activities in line with the reflections in CoRe. Based on the aim of the study, only activities that included digital tools were thereafter video-recorded in the subsequent teaching activities. Video recordings were selected to capture the interaction between children and teachers about the specific science content with the support of digital tools (Study II). The video recordings were also used to enhance teachers' reflections regarding their considerations during science teaching as material for the upcoming video-stimulated recall interviews. The teachers primarily taught in pairs, but there were also occasions when a teacher performed the activities individually. On average, the teaching activities lasted half an hour, ranging from 25 to 45 minutes. To capture teachers' and children's engagement with the science content, a handheld video camera was used to zoom in when necessary. Additionally, two tablets were positioned to capture 'activity' in the room from different angles and to avoid technical mishaps. When the teachers used projectors, a tablet was positioned to video-record the displayed images and to support the upcoming analysis (Study II).

The last step involved interviews in which selected video sequences functioned as stimulated recall (Lyle, 2003; Malva et al., 2023) for the teachers to reflect upon the teaching activity and the use of digital tools. Video sequences were used to show different parts of the activity to support teachers in recalling the activity and to reflect on their pedagogical considerations. The teachers also had the

opportunity to stop or replay the film if necessary, to be able to talk in depth about what had happened in the classroom and their pedagogical considerations before and during teaching. Overall, the video sequences served as a point of departure for what was said during the interviews, and brought the teachers and the researcher closer to the subject of conversation. CoRe was also available during the interviews if the teachers needed to refresh their memory on their various pedagogical considerations articulated.

Research design and data collection (Studies III– IV)

Studies III and IV focus on slowmation (Fleer & Hoban, 2012; Hoban & Nielsen, 2010) and its role as a digital tool for teaching and representing science content. Study III focused on teachers’ experiences of implementing slowmation for teaching and learning science content. Study IV focused on children’s perceptions of the science content during the construction of the slowmations. Figure 4 below illustrates the design of Studies III and IV.

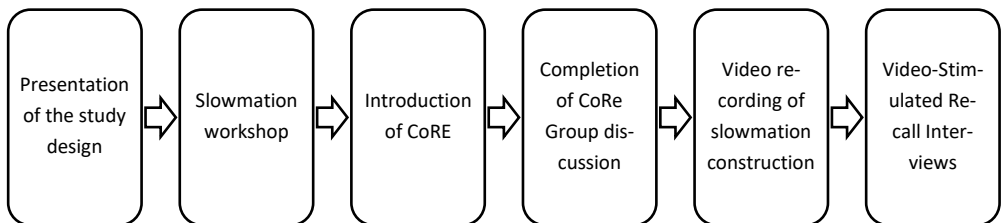


Figure 4. Research design for Studies III and IV.

The design of Studies III and IV has some phases in common with the design of Studies I and II, as described in the previous section, such as the introduction of CoRe, the completion of CoRe during group discussions and the stimulated recall interviews. This design is based on the same methodological assumptions and decisions for the collection of qualitative data as for Studies I and II.

A first meeting with teachers from the department who worked with children aged 4–6 years and the principal was held to present the purpose and design of the study before deciding to participate in the

study. Teachers were informed about the characteristics of representations and the design of slowmations, including different representations. The presentation also included a demonstration of a slowmation¹. Teachers were given a short presentation on CoRe. The choice to focus more on the slowmation was due to the study's focus, and in order not to overload the teachers with information. The teachers had the opportunity to ask questions during this meeting.

A workshop on slowmation followed. The idea of the workshop was to prepare the teachers for the different steps of slowmation construction in order to be able to implement the slowmations in science teaching, as well as to guide the children in this process. Teachers were presented with a slowmation to explain the different steps of the process. The slowmation that was presented included the life cycle of butterflies, and was used as material for the teachers to watch and practise. Teachers were provided with the manuscript and models (two-dimensional images), as well as written instructions on how to use the stop motion application to import and transfer digital images into an animated film and how to record narratives. The teachers then worked in groups to practise constructing slowmations.

Afterwards, the reflection tool was introduced to the five participating teachers in their teams. Additional information about CoRe was provided. The introduction focused on Big Ideas and the different prompts in conjunction with the completion of CoRe.

During a planning session, five teachers completed CoRe within their respective teams through group discussion. They articulated Big Ideas and pedagogical considerations for teaching science content. The group discussion lasted almost an hour and was audio-recorded. Teachers were also encouraged to design teaching activities for the Background representation (the first representation) of slowmation, and to create opportunities for children to represent the science content of these activities (e.g. drawings), whenever applicable.

Over a period of two months, the two teams created their slowmations together with the children. The process culminated in

¹ www.slowmation.com

completed slowmations that were viewed by the teachers and the children. All sessions were video-recorded.

The final step involved interviewing teachers about their experiences of implementing slowmation, and refers solely to Study III. This was done using video-stimulated interviews in which video sequences from the construction process served as a platform for reflection. The interviews lasted nearly an hour and were audio-recorded. CoRe was available for reference during the interviews.

Table 3 below illustrates the distribution of participants per preschool, as well as the various methods that were used in the different studies.

Table 3. Overview of the distribution between participants and the methods used to generate data.

Method	Waterfall Preschool	Rainfall Preschool	Windfall Preschool	Wingfall Preschool	
CoRe and group discus- sion	7 teach.	4 teach.	4 teach. ^a	3 teach.	2 teach.
Video re- cordings	Activity 1 2 teach. 4 child.	Activity 3 2 teach. 5 child.	Activity 5 1 teach. 2 child.		
	Activity 2 2 teach. 4 child.	Activity 4 2 teach. 8 child.	Activity 6 2 teach. 3 child.		
Video- Stimu- lated Re- call In- terviews (VSRI)^b	VSRI 1 2 teach.	VSRI 3 ^b 2 teach.	VSRI 5 1 teach.	VSRI 7 2 teach.	VSRI 8 2 teach.
	VSRI 2 2 teach.	VSRI 4 ^b 2 teach.	VSRI 6 2 teach.		
Slow- mation^c				2 teach. 3-8 child.	1-2 teach. 6-9 child.

Notes:^a CoRe completion took place on two separate occasions, working with one Big Idea at a time. Four teachers participated on both occasions. One teacher participated only on one occasion.

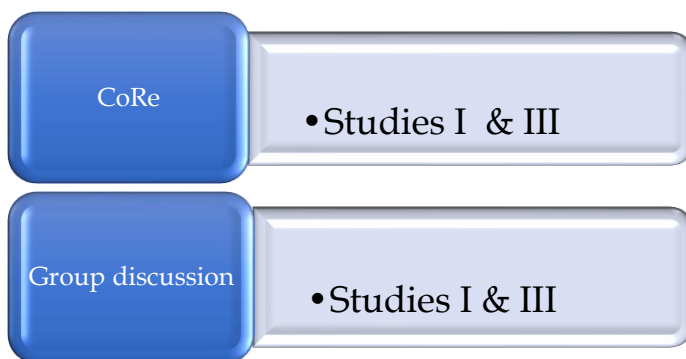
^b The same teachers participated in activities and interviews with the same number.

^c During slowmation, the total number of teachers/children varied for some of the activities.

Using different instruments for researching science practices

Investigating how digital tools stimulate teaching and learning with digital tools from different perspectives meant approaching the preschool context with different methods and instruments.

The data collection for the thesis followed two different research designs with some common methods and instruments. Employing diverse methods within the same epistemological framework can enhance the quality of research and reveal different aspects of the research subject (Mik-Meyer, 2021), and triangulation of data collection methods can be considered to enhance study validity (Larsson, 2005). These methods are depicted in Figure 5 below, and a detailed presentation and description of the methods follows in this chapter.



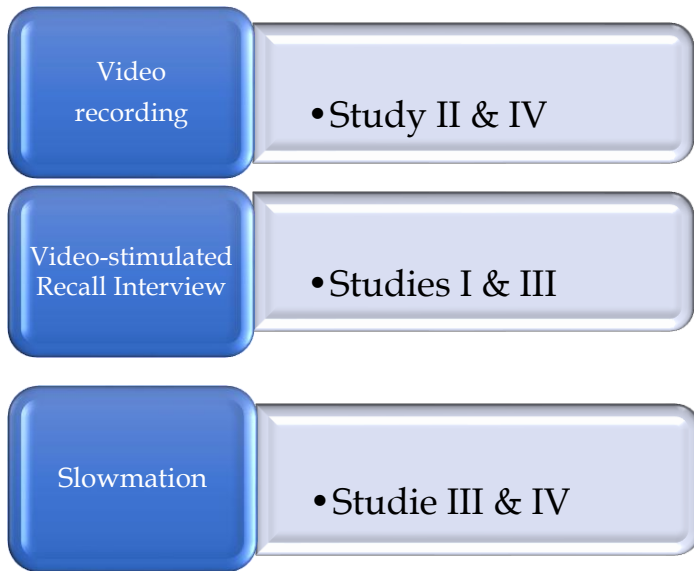


Figure 5. An overview of the main instruments employed for data collection.

Teachers' considerations in teaching science with digital tools

To find out about teachers' considerations on why they use digital tools to stimulate the teaching and learning of science content, the reflection tool Content Representation (CoRe) was employed. CoRe is a widely recognised and used instrument for researching teachers' science practices at various educational levels. The reflection tool was constructed with the intention of developing teachers' PCK by researchers in the field (Loughran et al., 2004), demonstrating the value of the reflection tool as an important cultural artefact that carries scientific knowledge. It encompasses knowledge from science scholars, which is well aligned with the theoretical and conceptual starting points of the study.

The prompts in CoRe address critical issues for the development of teaching and learning of science content. They stimulate teachers

to frame the teaching of a specific science content in regard to the articulated Big Ideas, addressing different aspects of the teaching, such as the what, the why and the how. The adaptation of CoRe concerned prompt 4, which was about how children's experiences are incorporated into teaching, in order to link it to the Swedish curriculum recommendations. Another important adaptation was not to have a specific prompt about the possibilities and limitations of digital tools, as is the case with Technological Content Representation (T-CoRe) (Nilsson, 2024). Instead, prompt 6 focused on what methods and what tools – analogue and digital – teachers might use, and how they justify their choices. This prompt provides an insight into how digital tools are considered as tools in teaching, as well as in relation to other tools. This insight would otherwise have been lost. What decisions do teachers make to include digital tools, and what do they add to the teaching and understanding of the content, for example, in relation to analogue tools? Here, it is also possible to express why a particular digital tool is relevant and why other tools are chosen. In summary, through this prompt, teachers make explicit the basis on which digital tools are chosen and how they are linked to the specific content.

One consideration in choosing CoRe as a method of data generation was that it requires teachers to articulate and make explicit their intentions with the teaching activities. Completing CoRe also provided teachers with the opportunity to discuss and develop the pedagogical considerations based on the various prompts. In order to facilitate this, it was decided that the completion of CoRe should take place in the team with their colleagues rather than individually, reflecting how the teams usually proceeded during the planning phase. Through CoRe and the discussion with their colleagues, teachers made explicit their thoughts and knowledge in relation to the content and the digital tools. In conclusion, the completion of CoRe can be understood as an “epistemology of practice” (Schön, 2017), and how knowledge is generated through practice where practitioners [teachers] use reflection as part of their work to enhance and adapt teaching and learning of science. Completing CoRe and making pedagogical considerations about the teaching can be compared to reflection on action (Schön, 2017).

The teachers' reflections were captured in writing in CoRe and verbally in the group discussions during the completion of CoRe, which was audio-recorded.

Video-stimulated recall interviews

“The interview is a conversation that has a structure and a purpose determined by one party – the interviewer. It is a professional interaction, which goes beyond the spontaneous exchange of views as in everyday conversation, and becomes a careful questioning and listening approach with the purpose of obtaining thoroughly tested knowledge. The qualitative research interview is a construction site for knowledge.” (Brinkmann & Kvale, 2018, p. 9)

To deepen and clarify teachers' pedagogical considerations, semi-structured interviews were employed. This flexible method fosters two-way communication between the researcher and participants (Brinkmann & Kvale, 2018). An interview guide was developed to provide structure during each session, consisting of open-ended questions that could be adjusted based on the participants' responses (see Appendix A). The idea of the semi-structured interviews was to gain a deeper insight into how teachers consider the use of digital tools (Study I) and how they experience this use (Study III). In this way, the interviews themselves could constitute “reflection on action” (Schön, 2017), since the teachers reflect on what has happened in practice. As such, the interviews tie together the teachers' plan–teach–reflect cycle (Carlson et al., 2019), regarding the use of digital tools.

In order to focus on what happened in the classroom/practice and to avoid teachers talking generally about their teaching and their experiences with digital tools, stimulated recall (Lyle, 2003; Malva et al., 2023) was used. Stimulated recall refers to (commonly) video sequences that show some kind of engagement and are used to prompt how, for example, teachers think about a particular topic (Lyle, 2003). This means that the video sequence shown is a starting point for the conversation between the respondent and the interviewer. Stimulated recall helps establish a shared point of attention in the conversation and fosters a more equal relationship between the interviewer and the

interviewee, as the interviewee has greater ownership of the recorded sequence. This means that sequences of video observations that are relevant to the research question can be played repeatedly for processing and analysis.

The combination of interviews with teachers based on stimulated recall (Lyle, 2003; Malva et al., 2023) and CoRe can provide a comprehensive picture of preschool teachers' pedagogical content knowledge and how digital tools contribute to the teaching and learning of science content. In this way, the relationship between teachers' planned (intended) and enacted teaching can be reflected upon with the support of digital tools.

Video recordings

To examine how digital tools were used in different teaching activities and in the construction of slowmations (Studies II, III and IV), video recordings of science activities were conducted. These video recordings also formed the basis for the stimulated recall used during the interviews (Studies I and IV) and served as observations of the science activities.

There are both benefits and challenges when observing (Robson & McCartan, 2016). One notable advantage is its directness, which can contrast with – and often complement – other methods of data collection (Robson & McCartan, 2016).

Using video recordings is especially well-suited for researching real life as it naturally unfolds, as it allows researchers to gain authentic insights into everyday behaviour and interactions by avoiding the artificiality that is otherwise presented in controlled settings (Robson & McCartan, 2016). Video recordings also enable the investigation of dynamic, multimodal interactions in preschool settings (Flewitt, 2006). The significance of a dynamic and multimodal interaction is seen when teachers and children engage with science content, for example, by exploring it and using diverse artefacts. Using video to record a practice (Heath et al., 2010) serves as both a tool for data generation and a rich methodological resource when analysing and interpreting the data.

Conducting video recordings is sometimes associated with concerns that the researcher's presence may influence the situation being observed (Robson & McCartan, 2016). To minimise this, I visited the preschool and introduced myself – and specifically the technology equipment – to the children. In Studies I and II, a video camera (sometimes placed on a tripod) was used in combination with tablets to capture the ongoing interaction between children, teachers and digital tools. However, in Study III, tablets were used almost exclusively because I felt it was easier to place the digital tools based on how the teachers and children sat in the classroom. There were some children who were curious and looked at the iPads, but after they were started, the children could participate in the activities as usual, which did not affect the activity itself. Although these video observations are time-consuming and challenging to transcribe (Robson & McCartan, 2016), they provide insights into what happened in the activities, which might otherwise be lost.

Constructing digital representations through slow-mation

Slowmation was used as a teaching approach for Studies III and IV. Slowmation can be described as a simple way to make an animated film (Hoban & Nielsen, 2010 – see chapter 2 for more details). Slowmation's five different multimodal representations can be said to constitute different steps in a process where teachers and children construct a digital representation of the content. Slowmation can be seen as both a finished digital artefact and a process of creating representations of a piece of content (Eilam & Gilbert, 2014). Slowmation is commonly used in different contexts with both younger children (Fridberg et al., 2018) and students. All steps of the process and the final artefact were video-recorded.

Analytical procedures

As stated previously, the thesis aims to provide knowledge about how digital tools support the teaching and learning of science in a preschool context. Although the four studies are interconnected, they

have their distinct aims which contribute to fulfilling this overarching aim, and the analysis has been adapted to the different aims. The data consists of different types of information such as reflection tools, audio recordings from group discussions and the video-stimulated interviews, video recordings (science activities and slowmation construction) and different representations associated with the slowmation phases (manuscripts, photos, narratives and models). In an initial stage, all the material was organised and scanned to get an overview. The analysis procedures are described in the following sections.

Analysing thematically

In three of the studies (Studies I, III and IV), the data was analysed using thematic analysis (Braun & Clarke, 2006). This method of analysis was chosen because it enables both deductive and inductive approaches, and it can be conducted regardless of the theoretical framing (Braun & Clarke, 2006; Robson & McCartan, 2016). Using thematic analysis evolved an iterative process of immersing oneself in the data, identifying patterns and merging them into common themes.

All audio recordings from the group discussions (Study I) and interviews (Studies I and IV) and video recordings (Storyboard phase and episodes across the slowmation construction) were transcribed verbatim. The procedure of transcribing the data verbatim involved getting to know the material and remembering it in its context. For instance, additional information – not only the spoken language, specifically if the teachers laughed or emphasised something in their answers – was noted in the transcripts. While this may not have directly influenced the coding process, capturing these nuances helped to recreate my experiences during data generation. It also allowed me to better understand the meaning behind the utterances by considering how they were expressed.

All transcripts were read several times, and preliminary codes from data according to the research questions were generated as meaning condensation. The different aims informed which codes to choose. Study I intended to capture teachers' considerations before and during teaching when digital tools are included to promote

children's learning of science content. The data was analysed in two parts: Codes from the reflection tool CoRe and the group discussions were merged into considerations before teaching. Subsequently, codes from the interviews were associated with considerations during teaching.

Study III focused on teachers' experiences with the slowmation construction. The codes were generated exclusively from the interview data. CoRe and the subsequent group discussion during the completion of the CoRe tool were not included in the analysis; they were used solely to provide a contextual understanding of the teachers' experiences.

In Study IV, the focus was on how the slowmation made explicit the children's conceptions of science content. I watched the video recordings several times and transcribed the recordings verbatim from the Storyboard phase. The choice to initially focus on the Storyboard phase was based on the fact that in this phase, the children were asked to make explicit what to include in the slowmations. The remaining video material was then scanned, and episodes throughout the entire construction of the slowmation – where children expressed their conceptions – were transcribed verbatim. The data was subsequently reviewed to ensure consistency with the identified themes.

Arranging and condensing extensive datasets is crucial, as it facilitates easier management and preparation for subsequent analysis (Robson & McCartan, 2016). To avoid data overload and to organise the codes, I transferred them to digital sticky notes in Miro, a digital whiteboard platform. This provided flexibility in handling the codes and enabled me to 'think visually' and elaborate on, cluster and rearrange them dynamically. After analysing the codes, several categories were identified and revised as needed, ensuring they did not belong to another category.

Categories were organised and grouped according to different aspects of the teachers' considerations, which contributed to the development of distinct themes. These themes were then compared to ensure that they captured unique dimensions and did not overlap in addressing similar considerations.

For Study I, the second research question addressed what aspects of PCK were made explicit within the preschool teachers' considerations. The themes were also analysed and discussed in relation to different components of PCK (Magnusson et al., 1999; Nilsson & Elm, 2017). This phase of the analysis (Study I) followed a deductive approach.

Finally, when presenting the different themes in the papers, I used illustrative quotations, excerpts or images to exemplify the meanings of the themes.

The different steps of conducting thematic analysis proposed by Braun and Clarke (2006), as described above, promoted guidance to manage, interpret and comprehend the data. Although this analysis is described in a sequence above, the process evolution is not strictly linear. Instead, it often involves moving back and forth, with insights from a later phase leading the researcher to revisit and rethink earlier steps (Robson & McCartan, 2016).

Analysing video recordings and selecting episodes

Regarding Study II, the aim was to investigate how digital tools stimulate the learning of science content. Here, I used a different method of analysis when approaching the data. To gain an overview of the data, all video recordings were carefully reviewed several times. The use of video recordings allows for repeated viewing, which not only supports in-depth analysis but also facilitates collaborative interpretation and analysis (Danby, 2021; Derry, 2010; Heath et al., 2010).

I then categorised (divided up) the recorded science activities into episodes based on distinct acts of engagement with the content, for the teachers and/or the children. These acts included *introduction*, *using a digital microscope* and *making an iMovie*. This categorisation allowed me to gain an overarching insight into my data material. Next, I focused on the episodes that involved engagement with the content through digital tools. These episodes were selected for closer examination, and the engagement was transcribed verbatim. The evidence of children's and teachers' engagement was analysed and coded as 'documenting', 'projecting images' or 'zooming in' in relation to the use of these tools. The various codes were then consolidated into

common characteristics to define different methods of engaging with the content using digital tools. Further, I focused on analysing and describing technology-enabled engagement by considering concepts driven by sociocultural theory, such as actions, processes, artefacts and mediation. Finally, I selected excerpts and/or images to illustrate the findings. The various transcripts were translated from Swedish into English when reporting the findings in the paper. Table 4 below provides a summary of the analysis process:

Table 4. A summary of the analysis process.

	Paper I	Paper II	Paper III	Paper IV
Science content	Water (states of water, water circulation)	Water (states of water, water circulation)	Dinosaurs	Dinosaurs
	Friction	Friction	Bees	Bees
Unit of analysis	Considerations in CoRe and interviews	Episodes of engagement with the content	Experiences explicated in CoRe and interviews	Children's conceptions/descriptions of the content (across the construction design)
Specific focus	Teachers' considerations: Verbal and written expressions	Use of digital tools: Interaction/ communication	Teachers' experiences: Verbal and written expressions	Children's perceptions: Multimodal expressions
Analysis	Thematic analysis	Thematic analysis	Thematic analysis	Thematic analysis

Synthesis of the papers' findings

An interpretive synthesis (Kakos & Fritzsche, 2017) of the papers' collective findings was conducted. This involved considering the separate contributions of the four primary papers on the use of digital tools, and comparatively analysing, reinterpreting, and bringing together insights into a coherent whole.

Firstly, the results from each paper were extracted and summarised separately. These findings were then viewed inductively and interpreted to condense what the use of digital tools entails for teaching and learning. Here, it was crucial to consider the use of digital tools in relation to what they contribute (or do not contribute) to the teaching and learning of science content. The four summaries were juxtaposed side by side, to identify and interpret 'ways' of how the use of digital tools supports teaching and learning of science content, across the investigated contexts.

The interpretive synthesis (Kakos & Fritzsche, 2017) has meant looking beyond the summary of the respective article's findings. Instead, details from the different papers have been integrated to generate new insights into the research question. These interpretations were then anchored in the thesis's theoretical framework to integrate important nuances from findings on various aspects of how digital tools support the teaching and learning of science content in preschool, rather than simply restating the findings from each paper.

These insights provide the point of departure for the synthesis below. The following section explains the process through which the insights were generated, demonstrating how the findings from the papers were brought together to address the overarching research question.

These synthesised insights from the different findings from the four papers is conducted to more clearly address the overarching research question.

Method discussion

Research quality is assessed in terms of validity and reliability. Validity concerns whether research investigates what it intends to, while reliability refers to the consistency and transparency of the research process, ensuring the reproducibility of the research findings (Robson & McCartan, 2016).

Validity

In qualitative research, validity can be understood in relation to description, interpretation and theory (Robson & McCartan, 2016).

The validity description was supported by verbatim transcriptions of audio and video recordings, providing detailed descriptions of how the digital tools supported engagement with the science content. Images were used to illustrate excerpts where relevant. Although the data were translated from Swedish to English and some nuances may have been lost, care was taken to preserve the meaning of what was being said.

Interpretation validity concerns understanding the meanings and perspectives of the participants, while setting aside prior assumptions and allowing meaning to emerge from the data (Robson & McCartan, 2016). To support this, the analysis process has been carried out transparently, and the findings were elaborated on and discussed with supervisors. At different stages of the research, the findings were also discussed at academic forums and underwent peer review. This process provided valuable input and helped ensure that interpretations were unbiased and free of personal assumptions.

Theory validity involves considering alternative interpretations of the research object. Drawing on a sociocultural perspective, teaching and learning are viewed as emerging through interactions and engagements in meaningful contexts. Studying authentic teaching and learning situations made it possible to capture how digital tools are used and how participants interact with or communicate about science when using them.

Validity can also be discussed in relation to various quality criteria, such as presentation aspects, results and validity (Larsson, 2005). These include awareness of perspective and coherence between research questions, assumptions, methods and analysis, where all elements are connected as a cohesive system (Larsson, 2005).

The overall research question of the thesis can be characterised as both descriptive and exploratory, which is consistent with a qualitative approach. Methods such as CoRe and semi-structured interviews allowed teachers to articulate their reflections and experiences. Additionally, the theoretical and conceptual framework, data types and analytical procedures are outlined.

Regarding the quality of the results, Larsson (2005) emphasises the importance of precise meaning. Providing nuance makes the interpretation more precise. This was addressed through “thick descriptions” (Geertz, 2000) and thematic analysis (Clarke & Braun, 2006). Thematic analysis was used to interpret the phenomenon by identifying distinct themes. The analysis captures teachers’ considerations and experiences (Studies I and III), children’s and teachers’ engagement with science content (Study II) and children’s conceptions (Study IV) when using digital tools. Transcripts and images are used to demonstrate these nuances.

The thesis provides empirical insights into how digital tools are used in a preschool context to stimulate the teaching and learning of science content, for example, by mediating and visualising this content. When it comes to constructing slowmations, as previous research has mostly focused on older learners, this adds knowledge to early childhood education and science education.

There is little research on RCM in the preschool context. This thesis focuses on the use of digital tools from the perspective of preschool teachers’ intended, enacted and reflected teaching. It demonstrates preschool teachers’ considerations based on the full teaching cycle (plan-teach-reflect) and thus provides empirical data on preschool teachers’ ePCK according to RCM.

Although generalisation is limited, the thesis contributes to knowledge by offering perspectives that may enable researchers and practitioners to see aspects of reality in new ways

Another validity criterion is triangulation. In research, this involves demonstrating a theory or methodology using different sources (Larsson, 2005). Technical triangulation involves using different methods to generate the same data (Larsson, 2005). Mik-Meyer (2021) emphasises that using various methods within the same epistemological perspective can improve research quality and reveal different aspects of the research object.

In Study I, diverse methods were used to capture teachers' considerations, including the CoRe tool, audio recordings of group discussions and video-stimulated interviews. This has led to nuanced data on pedagogical considerations related to the RCM teaching cycle (Carlson et al., 2019).

A triangulation of contexts has also been used between Studies I and II in relation to Studies III and IV. In Studies I and II, the focus is on the use of different digital tools, while Studies III and IV involve the implementation of a specific digital tool. These insights between the 'two contexts' have helped to give an understanding of the overarching research question and to cross-fertilise the insights into how digital tools support teaching and learning in a preschool context.

Reliability

Reliability refers to the trustworthiness of the study and the extent to which the results can be replicated if the study were conducted again. The thesis is based on qualitative data consisting of teacher responses (the CoRe tool, group discussions and video-stimulated interviews) and video recordings from teaching activities. The data have been analysed and interpreted by the researcher. The reliability of this process will be discussed in terms of trustworthiness, including criteria such as credibility, transferability, dependability, confirmability and authenticity, as well as aspects such as fairness, ontological authenticity, educative authenticity, catalytic authenticity and tactical authenticity (Bryman, 2002).

Trustworthiness

The credibility of the thesis can be ensured through several strategies. Credibility refers to the research being conducted in accordance with existing rules (Bryman, 2002). The studies have been conducted in accordance with guidelines for good research practice (Swedish Research Council, 2024).

Checking for representativeness is a strategy for assessing data quality (Robson & McCartan, 2016), which emphasises the credibility of the thesis. The teachers included in the study are representative of those working in Swedish preschools. Preschool teams include preschool teachers and childcare workers who work together in teams. In this way, the representativeness of the participants is credible with regard to how the data was collected.

Furthermore, accountability can be ensured through respondent validation, whereby researchers report to respondents, as described by Bryman (2002). All teachers were offered access to the interview and group discussion transcripts. Teachers from Rainfall Preschool took part in this process, while the rest declined. This was interpreted as an indication of trust in how the transcripts were handled. The articles have been delivered to preschools after publication.

Weighting the evidence (Robson & McCartan, 2016) is another strategy to ensure credibility. The data can be characterised as strong because they were observed and collected directly, with the researcher present and performing all data collection and analysis steps. The analysis was strengthened by discussions with supervisors and input from peer reviewers.

Since the thesis draws on a qualitative approach, it is difficult to generalise the findings. Transferability entails the relevance of the findings beyond the studied contexts and settings (Robson & McCartan, 2016). This means that qualitative research makes a significant contribution through its situatedness in the context under investigation (Braun & Clarke, 2021). Therefore, thick descriptions (Geertz, 2000) of the research context enhance the transferability to other contexts.

Efforts have been made to provide sufficient detail to enable readers to transfer the findings to their own contexts or practices by

describing the preschools, teachers, science activities and the digital tools used, and illustrating these with extracts and images where appropriate.

Dependability is achieved through a scrutinising approach, such as auditing, which can enhance reliability. As Braun and Clarke (2019, p. 591) argue, the final analysis involves “deep and prolonged data immersion, thoughtfulness and reflection – an active and generative process”. In line with this, a scrutinising approach was applied throughout the project, with the studies presented at graduate school events.

Key documents, including the study plan, ethics application, learning portfolio, research plan, and supervision summaries, were revisited to maintain focus and form an audit trail. During Study III, which included several steps, personal reflections were recorded before or after preschool visits to capture my observations and guide future actions. These procedures supported a focused and reflective research process (Robson & McCartan, 2016).

Confirmability refers to a researcher’s personal values not having deliberately influenced the research conduct and findings, thereby minimising bias. It emphasises that the data and interpretations are grounded in the context of the study (Bryman, 2002). To ensure confirmability, I approached the studied context with an ‘open mind’. Across all studies, teachers determined the science content or Big Ideas, digital tools and activities.

Authenticity

Another measure of reliability is authenticity, which refers to a fair and balanced representation of what has been studied (Bryman, 2002). Authenticity is described through five dimensions by Guba and Lincoln (1989): fairness, ontological authenticity, educative authenticity, catalytic authenticity and tactical authenticity.

Authenticity is supported through its qualitative and *in situ* approach. All studies capture interactions with digital tools in preschool settings. Methods such as CoRe and interviews (Studies I and III) reveal teachers’ pedagogical considerations and experiences. The teachers used CoRe to articulate their pedagogical considerations and

intentions for teaching, including relating to the science content and the formulated as Big Ideas.

Additionally, video recordings show how teachers and children use digital tools to visualise, document and communicate science content (Papers II and, III). In Paper III, the teachers noted that the children's representations in slowmations summarised the intended Big Ideas and demonstrated their understanding. This can be interpreted as the teachers having developed deeper insight into their own teaching context (ontological authenticity), and into the children's perspectives (educative authenticity).

Several methodological steps supported teachers' to stimulate their science practice, aligning with catalytic and tactical authenticity. These included CoRe, the workshop and the implementation of slowmations. Across the studies, the teachers had the opportunity to practise new ways of planning and teaching, which may be useful in their future practice. Comparable claims have been reported by Forsler (2024). The CoRe prompts and stimulated recall interviews served as a catalyst for reflection.

Contextual and methodological considerations

The thesis's findings are based on data from four preschools and do not aim for broad generalisation, reflecting the qualitative approach of the thesis. Accordingly, there are limitations that must be acknowledged when considering how transferability can be assured. Teachers' pedagogical considerations may be influenced by the specific pedagogical culture within each studied preschool. Decisions about using digital tools are shaped by their Pedagogical Content Knowledge (PCK), including personal (pPCK), enacted (ePCK) and collective (cPCK) aspects. These aspects reflect the teachers' accumulated knowledge across various teaching contexts and experiences. The preschool learning context, alongside collaboration with colleagues during the data collection period, played a key role in shaping these aspects of PCK and the learning context in which the teachers practise and interact. A larger and more varied selection of preschools could

provide more nuanced insights into the use of digital tools identified in this thesis.

The results are based on the different digital tools that have been used in the studies. Other digital tools can be used in various ways to support the teaching and learning of the same science content. Furthermore, focusing on a single digital tool in the teaching and learning of science content could have provided a deeper understanding of its use. Similarly, studies focusing on the same science content across contexts could have provided 'thicker' descriptions of the use of digital tools. As for the children's conceptions of science content during the construction of slowmation, supplemented interviews with the children could have provided more detailed insights.

The participating teachers' teaching experiences varied, indicating differences in their educational backgrounds and/or professional development focused on digital tools. Their preparedness and capacity to integrate digital tools may therefore differ. Moreover, the availability of digital tools may have constrained teachers' pedagogical considerations regarding which digital tools to include.

Ethical considerations

Conducting research also includes adopting an ethical approach to uphold and follow good research practice characterised by principles such as reliability, honesty, respect and responsibility (Swedish Research Council, 2024). Reflecting on ethical aspects and one's own role as a researcher is part of taking responsibility for the research, and this reflection has been ongoing throughout the thesis project. This section presents how different ethical aspects have been ensured during the research process.

Research involving humans or sensitive personal data can be subject to ethical review (SFS 2003:460; Swedish Research Council, 2024). Although a reading of the act made it clear that the different studies were not subject to formal ethical review, the inclusion of researching younger children (3–5 years) and the fact that my own background as a preschool teacher could influence my reflexivity meant that it felt important that the entire thesis project was reviewed

externally. The thesis project was therefore reviewed and obtained approval from the Swedish Ethical Review Authority (Dnr: 2022-02782-01) with an advisory opinion (Swedish: *Etiskt rådgivande*). The ethical guidelines (Swedish Research Council, 2024) regarding consent, participation, trust and confidentiality were followed throughout the research process.

Initially, principals were contacted and informed about the project due to their overarching responsibility for the preschool's organisation and quality. Their awareness of the study was essential for providing appropriate conditions for the teachers' participation. The principals were contacted via email or phone call, followed by written information. They then informed preschool teachers/work teams about the project and forwarded contact details of interested preschool teachers/work teams to the researcher. It was important that participating teachers were interested in working with science and using digital tools to provide meaningful contexts for both children and teachers. Although science is a focus area in the preschool curriculum (Swedish National Agency for Education, 2018), content focus varies over time. It was therefore essential that the science activities to be studied constituted a meaningful context for both children and teachers, ensuring minimal impact on the preschool's regular activities.

Contact was then established with interested teams, and a meeting was booked with the teachers. Teachers were informed about the study's purpose and design, and information about consent, confidentiality, storage and the four requirements for individual protection was provided orally and then in writing.

The researcher and the teachers agreed on the time needed to consider participation, with at least one week provided. The teachers were given time to reflect and the opportunity to ask questions before consenting. All the teachers in a working team received the same information about CoRe, even if not everyone was responsible for engaging in their teaching or participating in the interview. In this way, the reflection tool supported the whole team and provided an opportunity for use in future projects.

Written information about the purpose and structure of the study was then sent to the guardians of the children attending the

preschools/departments with interested preschool teachers/work teams. Guardians were given at least one week to consider participation. The teachers forwarded both the information and the consent forms to the researcher.

The researcher informed the children about the study in what Larsson et al. (2021) refer to as a child-friendly way (i.e. simple and age-appropriate). The researcher visited the preschools and gathered the children before introducing herself and explaining the purpose of the study in a simple manner, including what would happen during the visit. The children were also familiarised with the technology, such as the video camera, tablet and tripod/stand, and were encouraged to interact with the researcher and the equipment.

In addition, a few days prior to the video recordings, the researcher visited the preschools and participated in activities on a few occasions. These visits allowed the children to become acquainted with the researcher. It was important that children not participating in the project also met the researcher, ensuring that all children felt informed and confident about what would happen in their preschool environment. Guardians and children were additionally prepared through notices posted on preschool notice boards, including the researcher's photo and visit dates.

Children, with parental consent, were included in the research. The introduction to the reflection tool took place within the same preschool to ensure the teachers' confidentiality.

Researcher positionality

The researcher's interest in science stems from the nature of the subject itself, combining practical activities, such as exploration, investigation and laboratory work, with theoretical elements, including explanatory models, scientific explanations, and logical reasoning. Science offers a context for researching the surrounding world, made suitable for preschool education by 'quenching' children's curiosity. Given the researcher's background as a preschool teacher and an educator in science education for future preschool teachers, researching the preschool context involved entering a mostly familiar

environment. At the same time, it also involved critical reflection on personal assumptions throughout the thesis project. These positions are described in this section.

There are various roles that a researcher may adopt during a research project. Throughout the research process, the researcher primarily drew on the role of a researcher grounded on substantial knowledge of preschool contexts, guided by a moral compass and an open mind. This approach provided essential tools for exploring digitalised science practices in preschools. In the two study designs, the researcher introduced teachers to the CoRe framework. In the second study design, the slowmation framework was also introduced and guided the teacher to conduct a slowmation in practice. During these phases, the researcher alternated between a teacher role (i.e. explaining what the teachers need to be able to implement, introducing it at a feasible level and guiding the teachers) and a researcher role, in order to maintain objectivity and scientific rigour when presenting the study designs, CoRe and slowmation.

Another role adopted by the researcher was that of a facilitator. This role was enacted on several occasions, for example during group discussions when the teachers completed CoRe. Although CoRe had been introduced to the teachers, completing it was not a familiar or routine practice for them. The role of facilitator was adopted in case any questions surfaced during group discussions that had not been addressed during the initial introduction. Enacting this role required careful balance, supporting the teachers without interfering in their discussions or providing answers to the prompts.

Being present during group discussions could be perceived as influencing the teachers, so at the beginning of that session the researcher emphasised that there were no right or wrong answers. If something was unclear, a neutral stance was maintained, encouraging the teachers to elaborate on their responses.

Ethical considerations, such as confidentiality, were addressed throughout the thesis project. Interviews were conducted at the preschool to minimise disruption and to make the process more convenient for the teachers. Interview times were scheduled based on what

suiting the teachers best. The video recordings were carried out at times that were compatible with the preschools' daily activities.

On other occasions, the researcher adopted the role of an observer and an outsider. Attending during completion of CoRe served not only to generate data, but also to gain a preliminary contextual understanding through the teachers' collective reflections. It also served as a kind of preparation and pre-observation ahead of the video recordings. Approaching with minimal involvement could be interpreted as an outsider stepping into a context to learn more about it, which is a researcher's role.

Due to previous experience as a preschool teacher, the researcher also adopted the role of an insider. This background informed decisions concerning the design of the studies, including the reflection tool CoRe. Given that a cross-disciplinary approach is common when working with theme projects in preschool (Swedish National Agency for Education, 2018), the researcher's experience informed the selection of CoRe, as a well-established research method and evidence-based reflection tool to focus on the teaching and learning of science content by unpacking Big Ideas. The researcher saw this as an advantage and a form of support for the participating teachers when focusing on core science ideas as a basis for teaching and deciding on methods and tools, including digital tools. Subsequently, it also helped me as a researcher to focus on and capture the research subject, which provides knowledge about how digital tools support the teaching and learning of science content in a preschool context.

At the same time, the researcher's preunderstanding has also supported understanding the context, for instance when interpreting the data. For example, when referring to routines in preschool, it was easy to grasp what was meant. Even in their narratives, when teachers left sentences unfinished, their intended meaning was often clear. This familiarity required me to adopt a reflexive stance when interpreting the data, consciously stepping away from my role as a preschool teacher. This was particularly important during coding and when analysing the results, not only based on what was explicitly written, but also by reading between the lines. There was also a risk that my own preconceptions and experiences would be biased. I worked

actively to mitigate this influence by engaging in a critical review of literature, to support my arguments with empirical and theoretical grounds.

Findings

The overall aim of this thesis is to provide knowledge about how digital tools support the teaching and learning of science content in a preschool context. The thesis comprises four empirical studies that investigate and shed light on various perspectives on the teaching and learning of science content supported by digital tools, encompassing the reflections of teachers (as considerations and experiences) regarding the teaching, how children conceive the science content, and the unfolding of children's and teachers' engagement with the science content. The studies are presented in four papers, which are appended at the end of this thesis. In this chapter, the main findings from each paper are presented separately, followed by a synthesis that addresses the overarching research question.

Paper I

Published as: Papantonis Stajcic, M., & Nilsson, P. (2024). Teachers' Considerations for a Digitalised Learning Context of Preschool Science. *Research in Science Education* 54, 499–521.

<https://doi.org/10.1007/s11165-023-10150-5>

Paper I starts with the premise that pedagogical content knowledge (PCK) (Shulman, 1986; 1987) and various knowledge components (Magnusson et al., 1999) inform teachers' pedagogical considerations concerning the use of digital tools in preschool science teaching, and highlights the need to investigate these considerations in connection with teachers' enacted teaching practices. Paper I addresses the following two research questions: "What considerations do preschool teachers make before and during teaching when digital tools are included to develop children's learning about science content?" and "What aspects of PCK are made explicit within the preschool teachers' considerations?"

The RCM of PCK (Carlson et al., 2019) provided the conceptual framework for this study, and the findings were discussed as components of knowledge. The empirical data was generated through the reflection tool CoRe, group discussions, video recordings of teaching activities and video-stimulated recall interviews. Sixteen teachers and 20 children from three preschools in Sweden participated.

The findings from the thematic analysis highlighted the teachers' considerations as considerations *before* teaching and *during* teaching. The considerations before teaching concern preconditions for science teaching. Overall, these considerations can be understood as the teachers' pPCK. These will be described in the following.

Approaching the content involves thoughtful considerations on how to make science content accessible to children. Although digital tools are not directly addressed, these considerations provide a foundation for learning in a digitalised context.

Accessing children's learning emphasises the use of digital tools in engaging with children's current understanding of science content as a starting point for further learning. This includes using digital tools for documenting children's learning, sharing with guardians, and supporting continuous planning and development of science teaching.

Digital technologies as enablers refers to considerations on how digital tools enrich the learning context by creating learning environments, providing virtual experiences and facilitating collaborative investigation.

Digital technologies as inhibitors includes considerations that highlight the importance of thoughtful integration for digital tools in terms of the missing learning opportunities. The teachers emphasise the importance of creating a reflective learning environment, noting that children often experience 'presence loss' during screen-based activities. It also highlights the need to maintain meaningful, shared interactions to promote deeper engagement with science content.

Considerations during teaching concerns the interaction between content, learners and digital tools, and how learning is facilitated.

These considerations can be understood as the teachers' enacted PCK (ePCK). A description of the considerations follows below.

Digital technologies in a contemporary learning refers to considerations reflecting their significance in modern daily lives. Teachers see digital tools as valuable for building children's digital competence, supporting compensatory learning, and bridging the gap between children's use of technology at home and in preschool settings.

Using digital tools to make the abstract concrete encompasses considerations for using digital tools to transform abstract content into a more concrete understanding. It involves combining digital tools with analogue artefacts and multiple modes.

Stimulating children's engagement and learning is a theme that highlights considerations framed as educational benefits of using digital tools to support children's engagement and learning in science teaching. The use of digital tools is considered to create anticipation, providing motivational strategies in engagement with the content. Additionally, they help teachers assess and document children's learning processes, facilitating insight into their experiences and progress over time.

Paper II

Papantoni, M., & Nilsson, P. (2026). Teachers' and Children's Engagement with Science Content through Digital Tools in Preschool Settings. *Research in Science and Technological Education*, 1–25. <https://doi.org/10.1080/02635143.2026.2657604>

Paper II aims to describe teachers' and children's engagement with science content and how digital tools were used to support this engagement. It provides thick descriptions of how digital tools are used in science activities in a preschool context by examining the following research question: "How are digital tools used in preschool pedagogical practices to shape children's and teachers' engagement with science content?"

The data consisted of video recordings of eight science activities, totalling almost four hours, carried out in three preschools where eight teachers and 22 children engaged with science content. Activities such as hands-on investigations, watching educational films, reflecting and creating new digital artefacts (iMovies and PicCollages) were supported using tablets, phones, projectors or digital microscopes.

The thematic analysis of different episodes of engagement identified four themes that describe the ways in which digital tools are used to engage with science content:

- 1) Creating an environment to engage with the content includes the use of digital tools to convey a certain environment or atmosphere. Projected images, such as those of a waterfall, enhanced the virtual experience of the content and brought it to life in the preschool. Another aspect of creating an environment was that the teachers prompted the children to capture their point of view of the content and what happened in the activities, adding children's experiences to other contexts outside the activity.
- 2) Recreating the engagement with the content summarises how the use of digital tools contributes to a relocation of the engagement to new venues and participants. It includes an unfolded practice, where projected images and videos from previous activities were used to elicit children's memories, reflect on the content, come up with scientific explanations and summarise collective experiences in new artefacts to share with others. This re-engagement provided opportunities for extended learning of the content across space and time.
- 3) Visualising the abstract content refers to the use of digital tools to provide additional ways of engaging with the content. For instance, a film was used in combination with other artefacts and exploration to support children's conceptualisation of the different phases of water (content). The film, depicting an explanatory model enhanced by combined modes such as narration, symbols and images, and movement, visualised the different phases of water and how molecules behave in these phases. Digital tools, such as digital microscopes and tablets, were also used for a detailed exploration of leaves and ice cracks.

- 4) Facilitating the communication of the content concerns the use of digital tools as facilitating artefacts in the communication between teachers and children about the content. Projected images and films serve as starting points for communication and actions among the children such as joint reflection and explanation with gestures. Facilitation also involves the opportunity for the teachers to intervene and highlight aspects for understanding the content to focus on. For example, teachers paused the images to ask questions and to point out and emphasise details of what was being shown to stimulate communication about the content.

The results reveal that digital tools are used for various pedagogical purposes in the teaching and learning of science content. These tools are used not only to enhance children's understanding of the content, but also to support the shaping of different learning environments and situations. The use of digital tools fostered children's engagement in a way that can be repeated and shared with others. The paper discusses how engagement with the content occurs as a social practice, where children and teachers collaboratively explore and use digital tools to construct knowledge about science concepts. Furthermore, the paper presents digital tools as cultural artefacts that stimulate learning and mediate content, connecting children's prior experiences with new ones.

Paper III

Papantoni, M., Nilsson, P., & Cederqvist, A.-M. (2025). When science content becomes animated: preschool teachers' experiences of slow-motion implementation. *Research in Science & Technological Education*, 1–23. <https://doi.org/10.1080/02635143.2025.2545369>

Paper III aims to fill the research gap of empirical research on teachers' pedagogical underpinnings that ground the integration of slow-motion (Hoban & Nielsen, 2010; Flear & Hoban, 2012), a tablet-based artefact with animations, in the preschool context for visualising and representing science content. The implementation was based on

teachers' pedagogical considerations concerning the science content to be taught and represented during the slowmation. The paper was guided by the following research question: "How do teachers experience the implementation of slowmation for teaching and learning science content in preschool?"

A total of five teachers from two working teams in a preschool participated in the study. Initially, the participants received a presentation of the slowmation and the different phases/ representations (Background, Storyboard, Models, Digital photographs, and the Animation) and, accompanied by interested colleagues, practised constructing a slowmation. The teachers then clarified their pedagogical considerations on the science content of bees and dinosaurs using the reflection tool Content Representation (CoRe) (Loughran et al., 2004; Nilsson & Elm, 2017). In CoRe, the teachers explicitly formulated science Big Ideas which the slowmations should address as a way to articulate the science content that children were supposed to learn. After the construction of the slowmation with children, the teachers made explicit their experiences in semi-structured interviews, where video sequences from the teaching during the construction of slowmation were used as stimulated recall (Lyle, 2003).

The transcribed interview data from the two interviews was analysed thematically (Braun & Clarke, 2006), outlining the following themes: (1) (Re)framing the content, (2) Children's engagement, (3) Repeated opportunities to engage with the content and (4) Preparation and support needs. See Figure 6 below.

The first theme, '(Re)framing the content', involved experiences in terms of framing and teaching the science content through the identification of the Big Ideas as a common starting point, and guiding through the slowmation construction process and children's representations of the content. Reframing the content involved using different teaching methods and tools, such as digital tools, to clarify and concretise the content and provide children with an understanding of why it is essential to know about the content.

The second theme, 'Children's engagement', included experiences of taking children's interest as a point of departure for implementing the slowmation. Emphasising children's interest concerned

the children's learning, curiosity, involvement, participation or abilities. The teachers' experiences also demonstrated how the different representations in slowmation offer opportunities for engagement.

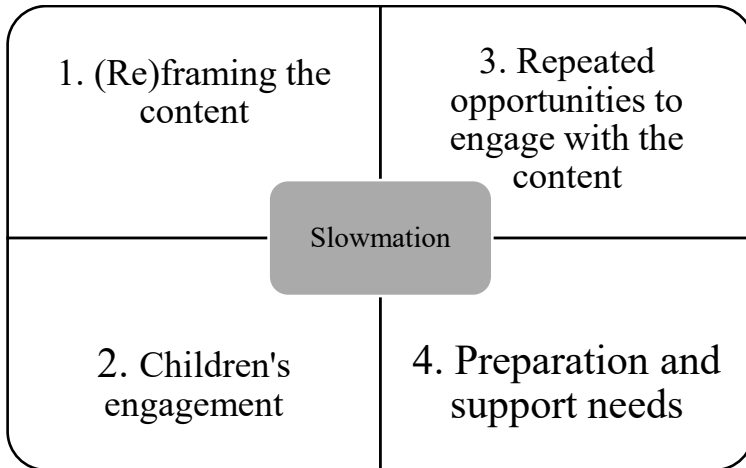


Figure 6. Teachers' experiences of slowmation implementation

The figure was published in Papantoni et al. (2025) under a CC BY licence.

The third theme encapsulated experiences relating to the design and construction of slowmation, and what these contributed to the teaching and learning of the content. Slowmation was experienced, providing a process with repeated opportunities to revisit and represent the content. Furthermore, it served as an artefact that encapsulated children's understanding of the content being taught and summarised the process of constructing the slowmation. The teachers also experienced the given slowmation design as a structured and controlled approach when teaching science content to preschool children.

Experiences relating to preparation and support needs are summarised in the fourth theme. Here, the teachers emphasised the need to prepare the children before the construction of the slowmation by showing and explaining what a slowmation looks like. Another concern teachers experienced was that some representations or steps in

the construction of a slowmation might be difficult for younger children to grasp, for example following the manuscript when taking digital photographs or incorporating the digital photographs into an application and transforming them into an animated film. They further highlighted the importance of teachers guiding children through these ‘invisible’ steps during the construction. They also underscored the requirement of careful preparation for a teacher and the need to have access to different technological resources.

The paper highlights slowmation both as a technology-promoted artefact through which to teach and learn science and as a representation of the science content being taught. The findings build on previous research, revealing that constructing slowmation provides multiple opportunities to engage with science content and stimulate children’s engagement through active involvement. The paper also highlights the combination of slowmation and the reflection tool CoRe as important in learning practices that integrate digital tools. The CoRe tool served as a valuable resource for teachers, guiding them in unpacking specific science content into key Big Ideas and prompting reflection on effective strategies to support children’s learning of the content. Since using CoRe alongside identifying Big Ideas and pedagogical considerations was experienced as a ‘backbone’ for the implementation of the slowmation, the findings indicate a need for ‘pedagogical structure’ to underpin digital learning practices aimed at stimulating children’s science learning. Previous research underscores the vital role preschool teachers play in composing quality learning experiences that foster children’s learning of science. Using CoRe might therefore support teachers in fulfilling this role by helping them develop intentional teaching activities that promote science learning and represent science content.

Moreover, the paper also discusses practical implications for effectively implementing digital representation tools in preschool settings, such as opportunities for reliable access to digital tools, hands-on training in relevant software and support for building professional networks.

Paper IV

Manuscript submitted for publication as: Papantoni, M., Nilsson, P., & Cederqvist, A.-M. (2025). Using Slowmation to Visualise Preschool Children's Conceptions of Science Content.

The fourth study of this thesis focuses on how the construction of the technology-based artefact, slowmation, might stimulate and capture preschool children's conceptions of the content. Slowmation is a tablet-based artefact with animations, that is constructed through different phases of background research, storyboarding, model building, taking digital photos and producing the animation. Each phase allows for the representation of content in various multimodal ways, such as verbal communication, narratives, drawings or animations. By constructing a slowmation, children revisit the science content and make their understanding of it explicit. The study aims to answer the following research question: "How can the construction of a slowmation make explicit preschool children's conceptions of the science content?"

Two teacher teams, including five teachers and 17 children from the same preschool that worked with dinosaurs and bees as content, were part of the study. The teachers had articulated and defined their pedagogical ideas for the teaching in advance of the construction as part of the Background phase, using the reflection tool CoRe (Loughran et al., 2004; Nilsson & Elm, 2017). The thematic analysis departed initially from transcripts from the video-recorded storyboard phase as the children made explicit what to include in the slowmations. Additionally, episodes from the remaining video recordings were scanned and episodes throughout the entire construction of the slowmation were transcribed verbatim.

The findings provide an insight into how the construction of a storyboard allows children to make explicit their conceptions of science content. The different themes emphasise how children verbally express their conceptions of the content by answering questions and giving descriptions and explanations. The children's conceptions can be summarised as three themes, **identification of a species**,

characteristics of a species and **conditions for life**, constituting aspects of content as described in Figure 7 below:

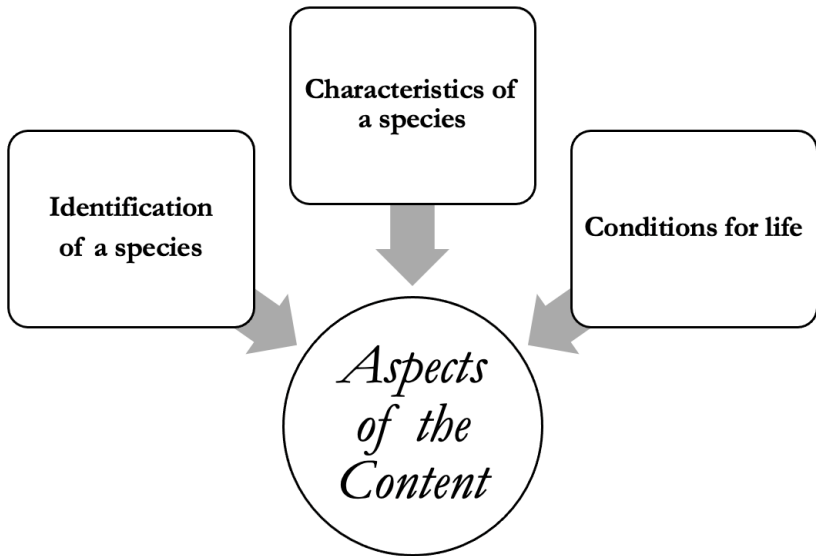


Figure 7. Children’s explicit conceptions of science content during the slowmation construction.

Comments on Figure 7:

Identification of a species: Conceptions in terms of names and attributes that label, define and classify the species.

Characteristics of a species: Conceptions of the species’ physical behaviours and characteristics.

Conditions for life: Conceptions of the environment and prerequisites for life, for the species and for humans.

The children’s conceptions were content-focused and aligned with the teaching provided by the teachers, who articulated their pedagogical intentions in CoRe. This emphasised the importance of the intended teaching. Additional findings revealed alternative conceptions, indicating emergent conceptions, highlighting the importance of constructing representations to stimulate and challenge children’s learning.

The findings showed that the construction of slowmation allows children to express their conceptions of bees and dinosaurs repeatedly through various forms of representation. Examples of these multimodal representations include verbally articulated descriptions, manuscripts, drawings, crafted models, narratives and music. The findings demonstrate that slowmation as a context ‘gives space’ to represent content in diverse ways, supporting previous research which states that multimodal artefacts enhance learning (Ainsworth, 1999; Prain & Tytler, 2012).

Overall, the findings indicated that the construction of the slowmation visualised children’s conceptions, highlighting it as a valuable tool for supporting science learning and enhancing children’s understanding.

Synthesis of the findings in relation to the overarching research question

The four empirical studies that form the basis of this thesis address different aspects of the use of digital tools in authentic teaching and learning contexts in preschool. To directly address the overarching research question, “How does the use of digital tools support the teaching and learning of science content in the preschool context?”, a synthesis of the four empirical papers was conducted. This synthesis highlights two central interrelated findings:

- Use of digital tools must be grounded in teachers’ reflections
- Digital tools as catalysts for science teaching and learning

Together, these findings demonstrate not only how the use of digital tools supports science teaching and learning, but also how this support is based on their purposeful integration and enactment in teaching, learning and representing science content. When deliberately integrated, used, and reflected on, digital tools add value to science practices.

Use of digital tools must be grounded in teachers' reflections

Taken together, the synthesised findings highlight that digitalised science teaching and learning require the coordination of several pedagogical aspects. Based on CoRe, teachers make deliberate pedagogical considerations before, during and after using digital tools. These considerations are informed by different components of their PCK (Carlson et al., 2019; Magnusson et al., 1999), and relate to various aspects of teaching when implementing and using digital tools. For instance, teachers consider how to ensure that science content is accessible to children and how to build upon their prior understanding. Another related aspect concerns the balance between the possibilities and constraints that the use of digital tools may entail for teaching. While such tools can help bridge gaps in teachers' knowledge and broaden children's experiences, they may also act as obstacles that interfere with children's ability to communicate or reason independently. This highlights the importance of foreseeing the potential and limitations of digital tools before using them in direct interaction with children. Reflective opportunities are therefore considered significant for preservation.

The synthesised findings also underscore the importance of teachers' PCK for addressing specific content, for children's learning needs and processes, and for focusing on the use of tools in ways that enhance rather than counteract these aspects.

Collectively, the findings reflect the enacted aspect of science teaching, showing how digital tools facilitate teachers' direct interaction with children and support the unpacking of complex science content in ways that align with young children's learning needs and processes. The synthesised findings suggest a purposeful approach in which digital tools complement hands-on experiences, and (re)frame and concretise the content. They also reveal that digital tools as contemporary learning artefacts that are familiar to children, help sustain engagement. By connecting engagement, teaching approaches and the complexity of science content, digital tools can make science content more tangible, understandable and relatable for children.

Another highlighted aspect concerns teachers' experiences and awareness of what is required for the efficient use of digital tools for teaching, learning and representing science content (e.g. constructing slowmations). This includes technical preparedness to address potential hands-on challenges for both children and teachers, without compromising on intended learning objectives. Such preparedness involves identifying the technical support needed in digital science practices. This preparedness reflects an instructional perspective that suggests the value of teachers being familiar with digital devices and applications when addressing potential difficulties and preparing children accordingly.

Concerning teachers' preparedness, the synthesised findings also reflect a structural perspective that can interfere with teachers' intentions for teaching, such as reliable technical support and access to applications and devices. These conditions are crucial, indicating that digitalised science teaching and learning are vulnerable and need to be tailored to children's needs, supported by teachers for effective future implementation.

Through reflection on and articulation of their considerations and experiences, teachers can develop strategies to better scaffold children in digitalised science practices in preschool. Such reflection also enhances their preparedness for using digital tools to reinforce science teaching and learning. In relation to this, the use of reflection tools such as CoRe (Loughran et al., 2004) serves as a guiding structure, as described by the teachers, for supporting intentional content selection and implementation of digital tools. Overall, these findings underscore the significance of teachers' reflective practice and highlight that teachers' pedagogical content knowledge and intentional planning are significant for enabling digital tools to function as effective mediators of science learning in preschool.

Digital tools as catalysts in the teaching and learning of science content

The ways in which the use of digital tools supports the teaching and learning of science content need to be understood in relation to other

methods and resources, as highlighted in the teachers' group discussions and interviews, as well as in the practical implementation of teaching activities across the studies. The synthesised findings indicate that, when purposefully integrated, digital tools serve multiple roles in science practices. In these roles, digital tools act as catalysts by enabling, initiating, stimulating and facilitating processes and actions.

Reinforcing the engagement with science content

An important aspect indicated by the synthesised findings is that preschool science teaching and learning are enhanced when digital tools are integrated into a diversified teaching approach. Such hybrid teaching and learning, in which digital tools are used alongside various methods and analogue artefacts, provides multiple means of engagement. For example, the teaching about bees during slowmation construction consisted of showing educational films, participating in forest excursions and creating representations of the content through crafts or drawings. These findings not only demonstrate that teaching with digital tools is compatible with traditional methods and analogue artefacts, but also suggest that digital tools *complement* them.

Furthermore, blending digital tools with analogue ones appears to provide a versatile engagement that may contribute to a more synthesised experience and understanding of the content. For instance, during a science activity, children can engage with the states of water through animated models and visual representations, as well as through hands-on interaction with materials such as ice and liquid water, contributing to multimodal engagement. Similar findings have previously been described by Otterborn et al. (2024).

The teachers expressed that digital tools provided children with *additional* ways to develop an understanding of the science content, by offering distinct representations alongside other methods and artefacts. Consistent with a sociocultural perspective (Vygotsky, 1978), the findings suggest that digital tools are embedded within science practices and are intertwined with other resources that support interaction and meaningful engagement involving complex concepts. The findings also align with the notion of digital tools not as isolated

artefacts (Hatzigianni, 2018), but as strategically used components in combination with traditional methods and analogue artefacts, to enhance the overall educational experience for preschool children. Here, too, the importance of teachers' PCK in selecting and using appropriate tools to address particular science content and support children's learning is highlighted.

Creating immersive and dynamic learning environments

The synthesised findings suggest that digital tools have played an enabling role in shaping the learning context in various ways, aligning with the notion that digital technologies generate new educational resources and provide new opportunities (Chen & Ding, 2024).

The findings further reveal that digital tools (e.g. projectors) created environments that enhanced children's immersive experiences with the content. For example, projecting a waterfall onto a screen offered a sensory experience that would otherwise be inaccessible within the preschool setting. This illustrates how digital tools can simulate non-existent environments in preschool, supplementing the learning context, and strengthening connections to the science content. These findings align with previous research demonstrating that projected images can trigger engagement with science content (Lund et al., 2024; Samuelsson, 2019).

Another aspect that was emphasised in the synthesised findings is the role of digital tools in creating dynamic learning environments. Illustrative examples include teachers and children using digital tools to search collectively for information on the internet when answers were needed, or to explore science content by viewing and projecting images and discussing the characteristics of the studied dinosaurs. This aligns with the findings of Bittner (2019), who highlights children and teachers as co-educators when using technology.

Subsequently, the findings suggest that digital tools are significant artefacts for learning and experiencing science in an active and interactive way between teachers and children. The enabling role of digital tools can be characterised as supporting interactive science learning by supplementing the learning context, and as compensating

for teachers' potentially limited content knowledge during interactions with children.

Conceptualising abstract content

Across the synthesised findings, the supporting role of digital tools in terms of conceptualising abstract science content is highlighted. This is evident both in teachers' reflections on integrating and using digital tools and in how the technical capabilities of these tools enable abstract content to be visualised during science activities. By coordinating multiple modes, digital tools appear to mediate representations that enable complex concepts and processes (e.g. states of water) to be illustrated and concretised, thereby scaffolding preschool children's understanding of scientific explanations.

Likewise, the findings reveal that constructing digital artefacts, such as slowmation, emerged as 'visualisation in the making'. During this process, the content was represented multimodally, i.e. verbally through descriptions, visually through drawings and models, and dynamically through digital animations. By offering multiple modes of representation, digital tools facilitate the visualisation of content that may be difficult to relate to in the physical world, as illustrated in the examples of dinosaurs. It can be assumed that digital tools are deliberately considered and used to reinforce understanding of content by reducing its abstractness through varied representations.

The synthesised findings further demonstrate that using digital tools facilitates a double-edged visualisation. On the one hand, digital tools, such as projectors, tablets and microscopes, magnify details and structures of physical objects, such as ice and leaves, on screens when exploring science content. On the other hand, constructing digital artefacts captures and visualises children's conceptions of the content. This aligns with Yelland's (2018) description of digital artefacts as a dynamic and permanent record of children's experiences and learning journey. Since representations convey understandings of an object or phenomenon (Waldrip et al., 2010), digital artefacts such as slowmations play an essential role in science practices for visualising children's understanding. Thus, the findings suggest that digital tools not only serve as artefacts to visualise science content, but also support

teachers in enhancing their ‘knowledge of children’ and ‘assessment knowledge’.

Viewed through a sociocultural lens, digital tools function as facilitating artefacts in the construction of knowledge (Säljö, 2021; 2023; Vygotsky, 1978). Overall, the findings underscore the role of digital tools as mediating artefacts that support both representation of science content, and, how children conceptualise it.

Connecting learning experiences beyond contexts

Across the studies, the role of digital tools in enabling children to re-engage with and experience the content beyond the original learning situation is highlighted. The synthesised findings indicate that digitally mediated documentation supported the unfolding of new activities and allowed both children and teachers to revisit science content on multiple occasions. For instance, projected videos and images, capturing engagement in prior activities, served as visual aids that scaffolded children’s reconnection with science content in subsequent science activities. In this way, digital tools elicited reflection and promoted active participation among children. These artefacts visually supported cognitive and communicative processes, such as remembering, reflecting and explaining scientifically, confirming previous research (Samuelsson, 2019).

Constructing digital artefacts and representations, such as Pic-Collages, iMovies and slowmations, became carriers of children’s collective experiences, enabling them to be shared with others, including children who had not participated in the original activity and also with guardians outside the preschool. As Hatzigianni (2018) emphasises, digital tools are reshaping pedagogical approaches in early childhood education. From this perspective, re-engaging with science content and sharing children’s collective experiences can be understood as a teaching and learning approach that creates new opportunities for learning while also fostering conditions for potential learners to engage with the content.

When considered as a whole, digital tools, therefore extend the teaching and learning of science content beyond temporal (from past, to present and future), spatial (across different contexts) and personal

(between participants) boundaries. These findings align with Otterborn et al. (2024), who demonstrate how digital tools allow children to revisit places and push the boundaries of multidimensional science teaching. Furthermore, the present findings extend previous research by incorporating a personal perspective.

The synthesised findings have implications for teachers' science practices and children's science learning. Digital tools connect children's prior experiences with new learning opportunities, framing engagement as a social and shared process. Repeated engagement opportunities that digital tools provide also demonstrate an alternative way of engaging with knowledge (Säljö, 2023), offering users flexibility (Selwyn, 2022) in terms of how, when and with whom learning takes place.

Bridging to children's learning and engagement

A child-centred focus on teaching and learning science content has been consistently observed across all studies. These examples illustrate how digital tools connect content learning with children's engagement and motivation, underscoring their role as valuable artefacts for learning science in meaningful ways.

Taken together, the findings demonstrate that digital tools not only support content-focused learning but also capture and mediate children's emergent understanding, through their technological capabilities. In this sense, digital artefacts serve as a 'medium' representing children's understandings while also conveying them to others. As such, they play a crucial role in enabling teachers to gain insights into children's learning and engagement through recurrent engagement with the content across different contexts. For example, the construction of slowmation confirmed teachers' understanding of the children's conceptions and generated important insights into how teaching could be refined or adapted to further support children's learning. Such insights are vital for supporting and stimulating children's learning in meaningful and sustained ways.

From an integrated perspective, digital tools serve as catalysts for reflection and communication within and beyond the preschool context. Besides promoting reflection, these artefacts facilitated the

simultaneous sharing of children's experiences and understandings with other children and teachers within the preschool. Significantly, they also enabled sharing and communication beyond the preschool context with guardians through learning walls and logs, including documentation on children's engagement with the content. In sum, the technology-promoted artefacts not only facilitate the sharing and connection of children's learning with peers, teachers and guardians, but also underscore learning science in preschool as a collective and shared endeavour.

Through the combined lens of a sociocultural perspective and PCK, these synthesised insights demonstrate that teachers, grounded in their PCK, acknowledge digital tools as meaningful artefacts to reach young children effectively and affectively.

Overall conclusion

Overall, the synthesis clearly demonstrates that digital tools play a vital role in supporting science teaching and learning in multiple ways. Across the four papers, the intentional use of digital tools, grounded in teachers' reflective practices as expressed through their CoRes, illustrates the importance of pedagogical considerations in establishing conditions for meaningful science learning in preschool.

The combination of well-planned and reflective pedagogical structures (e.g. CoRe) with creative, multimodal digital artefacts such as slowmations enables both teachers and children to explore, communicate and expand their understanding of science in appropriate and engaging ways. Digital tools fulfil a twofold role in science activities. Firstly, digital tools function as learning artefacts that support children and teachers in instantly exploring and experiencing science content. Secondly, in a mediated way, they facilitate the creation of digital artefacts, such as videos, images or animations, that can be (re)used in future learning situations and shared with others within and outside the preschool context. Through these processes, digital tools enable science practices to unfold, offering children repeated opportunities to refine their understanding of the content. In this way, digital tools support preschool science teaching and learning both directly, by being used during activities, and indirectly, by acting as

mediators that facilitate documentation, communication and reflection on science content.

By initiating, facilitating and enabling processes and actions, digital tools act as catalysts for teaching and learning in science in preschool.

Discussion

The overarching aim of this thesis is to provide knowledge about how digital tools support the teaching and learning of science content in a preschool context. This aim was explored through four empirical studies, each focusing on different aspects and perspectives on the use of digital tools in preschool science teaching and learning.

This chapter presents a discussion that situates key findings within a broader context, linking to previous research, the theoretical framework, and implications for preschool practice and science education. Theoretical and methodological contributions, implications, limitations and future research directions are also outlined, thereby highlighting the thesis's overall contributions and areas for development.

Digital tools – multifunctional pedagogical artefacts

The diverse ways in which digital tools supported preschool science teaching and learning suggest that their role extends beyond being only a technological tool. By enhancing engagement with science content, creating immersive learning environments, facilitating the conceptualisation of abstract content and connecting children's experiences across various contexts, digital tools function as mediating artefacts that shape children's meaning-making processes.

The findings indicate that digital tools play versatile yet interrelated roles in shaping environments, practices, and processes, acting as *catalytic*, *reinforcing* and *transformative*.

Taken together, these findings can be interpreted as positioning digital tools as cultural artefacts that promote learning (Barron & Levinsson, 2019; Murphy, 2022). Moreover, they suggest that digital tools are not only educational devices, but multifunctional pedagogical artefacts that catalyse, reinforce and transform science teaching and learning. Such versatility in their role underscores the importance

of pedagogical considerations regarding integrating digital tools to foster science learning.

Catalytic roles

Catalytic roles emerged from the tools' technological capabilities, which enabled access and, consequently, opportunities to engage with otherwise inaccessible content. Digital tools supported children in envisioning content that was absent spatially (e.g. waterfalls, bees), temporally (e.g. dinosaurs) or visually (e.g. molecules). They also enabled detailed investigations, such as zooming in on the structures of objects like ice and leaves. Catalytic functions were manifested when projected images and videos triggered memories, and stimulated activities and processes such as collaborative discussions. These findings align with those of Lund et al. (2024), Samuelsson (2019) and Fridberg et al. (2018), who emphasise the significance of digital tools for stimulating, visualising and processing science content in collaborative environments. Moreover, using digital tools can spark curiosity and interest (Bittner, 2019; Mou et al., 2021), as children actively engage in documentation and discussions, expressing their own understandings and taking part in others' perspectives.

Reinforcing roles

Reinforcing roles appeared when digital tools complemented analogue artefacts within a diversified teaching approach, providing children with multimodal experiences of the science content. For example, the combination of projected animations with physical objects offered varied and distinct experiences in conceptualising abstract content and phenomena, such as the water states. These findings align with the existing literature, suggesting that digital tools are complementary to analogue tools (Walan & Enochsson, 2024) and enable children to gain multimodal experiences of science content (Otterborn et al., 2024). These findings suggest that, from a pedagogical perspective, the use of digital tools has clear value for science teaching and learning in preschool. When considering the findings in relation

to the existing recommendations of only using analogue tools in the Swedish preschool context, this may have important implications for children's learning in science. In particular, digital tools appear to complement teaching practices, including analogue approaches, through their reinforcing role, thereby supporting children's understanding of abstract scientific phenomena. By enabling multimodal experiences of science content, digital tools can enrich teaching and strengthen meaning-making processes in early science education.

Previous research has shown that digital tools support the visualisation of science content (Otterborn et al., 2024; Patron et al., 2024; Walan & Enochsson, 2024) as well as the use of representations that assist children in articulating and refining their developing understandings. In this way, digital tools can function as mediating artefacts that bridge abstract science content and children's experiences, supporting both engagement and conceptual development.

Transformative roles

Transformative roles became visible when digital tools reshaped the interactional space within, between and beyond science activities and contexts. Shared digital artefacts (e.g. images, videos, collages, movies) promoted collective attention, collaborative reflection and elaboration around the content, while also supporting children in refining their understanding of science content by allowing them to revisit and represent the content multiple times. Constructing digital representations, such as slowmations, prompted children to make explicit key aspects of the content, including names and characteristics, thereby strengthening previous research suggesting that representations and refinement of understandings are significant for science learning (Ainsworth, 1999; Carolan et al., 2008; Prain & Tytler, 2012). Projected images and videos created shared visual spaces that enabled joint interaction and exchanges of perspectives, thereby promoting intersubjectivity between children and teachers.

Overall, the findings highlight the transformative role of digital tools in creating interconnected learning contexts, and in mediating science knowledge across time and space. Concerning learning

processes, Hatzigianni (2018) emphasises that digital tools can transform preschool pedagogies. Rather than merely supporting existing activities, the use of digital tools contributed to changes in how interaction, participation and meaning-making were structured within and between science practices. By transforming how information is accessed and used, digital tools give rise to new ways of interacting with knowledge (Säljö, 2023). Such interactions can be understood as enriched forms of scientific practice, as digital tools provide flexibility and control for participants engaged in learning activities (Selwyn, 2022).

Beyond their pedagogical affordances, the use of digital tools in preschool science practices reflects the interconnected material, human and contextual aspects of technology (Selwyn, 2022). Through artefacts such as tablets and projectors, children and teachers engaged in investigating, reflecting on and discussing the science content. These interactions align with a sociocultural perspective (Vygotsky, 1978), viewing teaching and learning as shaped by actions mediated by artefacts.

The findings further demonstrate that digital artefacts (e.g. projected images/videos, animations) served as tools for representing science content. Through interaction with mediated representations, teachers and children co-constructed meaning about science content, such as the characteristics of bees and dinosaurs, and the different phases of water. In this way, digital tools supported science learning as a social practice in which knowledge is developed and transformed.

Taken together, these findings suggest that digital tools are not only supportive but also transformative, serving as material and cognitive resources that facilitate interaction and reflection in science education. By broadening the ways perspectives are accessed and shared in preschool science settings, digital tools enhance children's opportunities to co-construct meaning around science content.

From artefacts to practices

Previous research emphasises the role of digital tools in creating educational environments and stimulating children's learning (Chen &

Ding, 2024; Lund et al., 2024). This thesis demonstrates that, in preschool science settings, digital tools do more than just support practical tasks. They actively create interactive learning environments that foster reflection, discussion and co-construction of knowledge. The findings build on previous research by offering empirical examples of how digital tools facilitate such processes by mediating science content.

Beyond serving as material artefacts that fulfil practical needs, digital tools also encompass processes, activities and the knowledge embedded within practices (Selwyn, 2022; Säljö, 2021; 2023). Digital tools, such as tablets, digital microscopes and projectors, meet the need to observe, investigate, magnify, present or document, thereby supporting essential science activities in science teaching and learning. For example, enlarging images enables teachers and children to examine details and engage with science content in a tangible way. Importantly, digital tools not only support practical needs but also enhance cognitive and communicative processes and activities, such as remembering, reflecting, explaining, and sharing perspectives. These findings resonate with Chen and Ding (2024), who emphasise that digital tools in preschools enhance children's creative and cognitive development. However, the findings demonstrate that the use of digital tools also enables both intrapersonal and interpersonal processes between teachers and children. Drawing on a sociocultural perspective (Vygotsky, 1978), the use of digital tools shapes science practices, in which children and teachers co-construct knowledge about specific content (Bittner, 2019).

More specifically, digital tools played a key role in encouraging interaction and communication between children and teachers regarding science content. Projected images and videos stimulated reflection and discussion about the science content, encouraging children to express their thoughts and understanding. In activities involving digital microscopes, children and teachers interacted with the screen, pointing out details to support their descriptions. These interactions confirm earlier findings by Samuelsson (2019) and Lund et al. (2024), where children elaborated on science content through projected images. These interactions also exemplify an enhanced

engagement that reflects how digital tools are reshaping learning and understanding. The use of projected material not only supported communication but also served as an “external memory” for children’s prior experiences (Samuelsson, 2019), allowing them to revisit and re-experience science content (Otterborn et al., 2024).

From experiences to shared meaning

Previous studies highlight the significance of children’s experiences in science teaching and learning (Fleer, 2009a; 2009b; Larsson, 2013a). Echoing this, a child-centred teaching and learning approach, based on children’s experiences and perspectives, was central in both teachers’ considerations in CoRes and the enacted science activities examined in this thesis. Teachers planned for and co-constructed with children a variety of technology-promoted artefacts, including Pic-Collages, slowmations and iMovies. These digital artefacts captured children’s perspectives and formed a foundation for reflection and discussion about the science content being taught, learnt and represented. Consistent with earlier research, combining digital tools with children’s experiences acts as a powerful trigger in science teaching and learning (Bittner, 2019).

Previous research underscores the importance of teachers being conceptually and contextually connected with children in order to challenge them in their learning (Fleer, 2010). Considering children’s perspectives and aligning with learning objectives promotes mutual simultaneity, a type of intersubjectivity, allowing teachers to further challenge children’s thinking (Fridberg et al., 2019). In the activities studied, this was facilitated by the projected images, which served as a point of departure for reflection and scientific explanations, revealing children’s understanding of the content. Moreover, the findings indicate that projected images may contribute to a shared understanding of the content (Adbo & Vidal Carulla, 2020), both between teachers and children and among peers. This has implications for teaching and learning about science, particularly when young children are involved. By directing attention to specific visual elements and aspects

of the science content, the projected material guides what to observe and/or reflect upon.

As such, digital tools help create a unified focus by anchoring communication in shared visual representations, enabling intersubjectivity between children and teachers when interacting (reflecting, discussing and, listening to each other), as they connect teachers' and children's communication about the content with what is seen and what has been previously experienced (Lund et al., 2024; Otterborn et al., 2024; Samuelsson, 2019).

The recontextualisation of science teaching and learning

Recontextualisation within and beyond the preschool context

Understanding how digital tools support the teaching and learning of science content also necessitates considering a broader perspective and their impact beyond the current teaching and learning session. As the results reveal, digital tools contribute to the (re)creation of teaching and learning opportunities. With the support of tablets and phones, children's varied engagements with science content are captured digitally in images and videos. When projected onto screens, these recordings facilitate reflection and discussions, which are initiated and sustained through subsequent activities. This process contributes to renewed engagement with the content and emphasises the digital tools' role as mediators of science content, enabling its transmission and representation across different contexts and facilitating science processes across multiple layers. This renewed engagement contributes to extended teaching and learning of the science content. The content is being reintroduced into a new teaching and learning setting, something that was also evident in earlier findings (Otterborn et al., 2024). In the new contexts, children's thoughts and experiences about the content are distributed among children and teachers, demonstrating that knowledge is co-constructed (Bittner, 2019) and transferred across various learning contexts.

The findings of this thesis are consistent with previous research on digital tools in science education, which emphasises the role of digital tools in providing repeated interactions with content (Hoban & Nielsen, 2010) and in linking existing experiences with new ones related to the content (Otterborn et al., 2024; Samuelsson, 2019). In this context, digital tools serve both active and passive functions, acting as artefacts that shape new ways of engaging with the content. While simultaneously becoming tools for sustained and meaningful interactions, they are also projected and reused.

The recontextualisation of children's learning also extends beyond preschool. Due to their technological capabilities, digital tools support children's learning more broadly by serving as a repository for their learning and engagement with the content through documentation. When teachers share images and videos of children's learning on platforms, such as learning walls and portfolios, knowledge about children's learning and engagement with the content spreads beyond the preschool context. The digital tools function as transmitters and mediators, relocating children's learning experiences beyond the preschool and connecting it with the home environment. This transfer of children's learning experiences may positively influence their learning processes and promote further interest in science. It can create opportunities for guardians to encourage children's reflections, enhance their understanding of the content, and enrich shared discussions with peers when children return to preschool and share their insights. Thus, the use of digital tools to transfer children's learning and knowledge can be seen as creating 'ripples on water' between preschool and significant people in the children's home environments. This practice highlights the significance of digital tools in children's lives and their embeddedness in educational practices that support and enrich learning (Arnott et al., 2018; Selwyn, 2022). The recontextualisation demonstrates that teaching and learning content is a collective endeavour that is shared and co-created with others, beyond the preschool context, and enabled by the use of digital tools.

Digital tools might comprise versatile artefacts to enhance teaching and learning of the content in terms of aspects such as accessing children's learning, content visualisation (Jack & Higgins, 2019;

Otterborn et al., 2019; Undheim, 2022; Walan & Enochsson, 2024) and facilitating interaction between teachers and children (Bittner, 2019). These insights demonstrate that digital tools extend science learning beyond preschool, positioning teaching and learning as a collective, distributed process across contexts and participants. In this regard, the thesis contributes to broadening knowledge about how science content teaching and learning can be made flexible and interactive.

Conceptual and methodological contribution

Intended, enacted, reflected and experienced aspects of digitilised preschool science

The findings in this thesis stem from four empirical studies presented in the accompanying papers. What all the studies share is an explicit focus on the teaching and learning of specific science content, supported by digital tools and grounded in teachers' pedagogical considerations. This was enabled by methodically using the reflection tool CoRe (Loughran et al., 2004; Forsler, 2024; Hume & Berry, 2013; Nilsson & Elm, 2017). The teachers collaboratively articulated Big Ideas and considered them in relation to the different prompts in CoRe. These prompts addressed different aspects of teaching with a focus on teachers' knowledge of the content, the curriculum, the children, the learning context, and the intended teaching methods and tools, etc. Consequently, the use of digital tools was intentional and built on teachers' PCK. A well-developed PCK is essential for preschool teachers to effectively shape a science learning context (Behling et al., 2022; Kilic, 2024; Nilsson, 2024; Vergara et al., 2024). In this thesis, it was enabled through intentional and purposeful planning, teaching and reflection concerning children's learning of science content using digital tools (Papantonis Stajcic & Nilsson, 2024). When engaging with various science content, it is crucial not only to conduct activities but also to create meaningful contexts and frame the content in a way that promotes children's learning. This requires teachers to make well-considered pedagogical decisions informed by

knowledge of the content, the children, the intended learning outcomes, and appropriate methods and resources. These are important aspects of teachers' PCK (Carlson et al., 2019; Shulman, 1986; 1987).

The thesis builds on existing knowledge about how CoRe can support teachers in their science practice based on their (PCK). Furthermore, it adds that CoRe-based considerations provide teachers with an awareness of what to teach, why, and how to promote children's learning of science content with the support of digital tools. Using CoRes allows teachers to focus deliberately and intentionally on science content, providing a foundation for planning and implementation. Several studies emphasise teachers' PCK as a key requirement for developing various aspects of science education (Buldu & Buldu, 2021; Forsler, 2024; Mazibe et al., 2020). The findings here add to the empirical evidence on how PCK establishes the basis for supporting preschool children's learning of science content within a digitalised learning environment. The thesis broadens this knowledge by demonstrating how digital tools, implemented based on CoRe, can support science teaching and learning in preschool contexts. Additionally, it extends the use of RCM of PCK to explore both teachers' personal PCK (as captured in CoRe) and enacted PCK when planning and teaching science for preschool children in a learning context influenced by digital tools.

The empirical studies, based directly or indirectly on CoRe, provide descriptions of intentional and purposeful teaching and learning of science content. Additionally, they describe how the teaching and learning of science content, supported by digital tools, is *enacted*, specifically in terms of engagement with the science content and how it is represented and conceived. The thesis's findings build on previous knowledge of how digital tools complement other tools (Otterborn et al., 2024; Walan & Enochsson, 2024) and how engagement is prompted by projected images/videos (Lund et al., 2024; Samuelsson, 2019). As such, these thick descriptions of how digital tools are used to support science teaching and learning contribute to Selwyn's (2010) call for more research into 'the state of the actual'.

Furthermore, the thesis's findings include a reflective dimension that examines what underpins the use of digital tools across intended,

enacted and experienced teaching, thereby contributing to the whole teaching cycle of planning, teaching and reflection (Carlson et al., 2019).

Teachers need opportunities and prerequisites to formulate how digital tools can be used to support science education throughout the entire teaching cycle.

Ultimately, the thesis's results must be understood in relation to the societal context in which digital tools are situated. The learning context is influenced by factors such as the broader educational climate and prevailing policies (Carlson et al., 2019). The findings can therefore be interpreted as reflecting the ongoing discourse on digitalisation in preschool settings in the Swedish context. An earlier thesis by Nilsen (2018), which examined the use of tablets and applications in preschools, suggests that digital tools tend to replace analogue ones. By contrast, a more recent thesis by Otterborn (2023) emphasises how digital and analogue tools can reinforce and complement each other within the learning environment. These different perspectives can be understood as products of their times, mirroring current pedagogical intentions regarding the digitalisation of educational contexts.

As digitalisation progresses, new ways of engaging with – or not engaging with – content may emerge, as shown by Samuelsson (2025). Building on previous research (Otterborn, 2023), the findings demonstrate that digital tools both reinforce and complement existing teaching practices while also transforming teaching by enabling its repetition and revival in new contexts (recontextualisation). The co-existence of digital tools and traditional methods reflects a more nuanced understanding of what digital tools can contribute to teaching and learning.

Implications for digitalised preschool science

The overall aim of this thesis is to provide knowledge about how digital tools support the teaching and learning of science content in a preschool context. The results from the papers focus on teachers' considerations and experiences of intentionally using digital tools to create

conditions for teaching and learning science content. They also address the use of digital tools and their central role in stimulating learning and making explicit children's conceptions of science content in science activities. Taken together, these insights contribute to the current understanding of digital practices in early science education and serve as 'state of the actual' (Selwyn, 2010).

Conceptual implications

Despite the different approaches of the included papers, the findings support a sociocultural perspective of learning (Vygotsky, 1978) and the conceptual framework of PCK (Carlson et al., 2019). Specifically, the findings reinforce foundational assumptions of a sociocultural perspective about how various practices evolve and how individuals (re)construct knowledge through interaction and using artefacts. The findings demonstrate that digital tools, as important contemporary cultural artefacts, shape the learning context and influence the various processes that evolve within it. They support the idea that tools facilitate practice by connecting significant science activities, actions, and processes among participants in meaningful ways.

Implications for teaching practice

The diverse ways digital tools are used and how they support the teaching and learning of science content have been discussed based on the teacher's knowledge (RCM of PCK) (Carlson et al., 2019) and the role digital tools play in the preschool context. Since the use of digital tools is deliberate and guided by CoRe, the findings emphasise teachers' vital role in planning, enacting, and reflecting on science teaching. A key implication for practice is the significant importance of preschool teachers' responsibility and opportunity to align their teaching with policy goals and their knowledge that supports children's learning. Namely, teachers – collectively and/or individually – should be given the opportunity to make informed decisions about using digital tools for teaching and learning science content, including why they should be used, which tools may be most suitable for teaching science content, and how they should be used. This presupposes the articulation of teachers' pedagogical intentions for eliciting and

addressing children's different knowledge in relation to specific science content and using digital tools to meet their learning needs. Likewise, using digital tools requires opportunities to reflect on their enacted use, further developing teaching and children's learning (Chen & Ding, 2024).

Content representation, CoRe (Loughran et al., 2004), can serve as a valuable tool to ground the teaching and learning of science content. Since the tool focuses on articulating Big Ideas, the prompts are considered in relation to the core elements of the science content rather than teaching about the science content in a general manner. Using CoRe and clarifying the core ideas of the teaching might be useful and constructive, particularly in interdisciplinary work, which is common in Swedish preschool education. Digital tools, like other mediating tools, need to be accommodated in ways that reinforce the defined Big Ideas, making science learning purposeful, meaningful and coherent.

Implications for Teacher education and professional development

In order to implement various digital tools for teaching and representing science content in preschool settings, it is essential to offer teachers practical experiences and to provide them with the necessary professional development. Teachers need hands-on training in using digital tools, including various software and applications tailored to different learning purposes. Additionally, they also require consistent access to digital tools and reliable technical support. Educational leaders can support teachers by creating conditions that facilitate the development of skills in producing digital artefacts and by providing time for this development. Another implication for practice is to facilitate networking among teachers to share pedagogical experiences and approaches to implement digital tools. From a broader perspective, teacher education should incorporate digital tools and representations into its courses, giving future preschool teachers the opportunity to learn about them both in theory and in practice.

Policy and contextual Implications

The results demonstrate that teachers purposefully use digital tools to create conditions for digitalised science teaching and learning. Digital tools are used to visualise abstract content, facilitate communication, and create environments that foster new and repeated learning opportunities where children can engage with and revisit content (Papantoni & Nilsson, 2026). A notable point within the Swedish preschool context is that the use of digital tools is currently not considered a priority in preschool practices. This shift may affect the (non-)use of digital tools and result in missed opportunities to support children in engaging in and learning science content in the ways outlined in this thesis. Such missed opportunities may be reflective encounters supported by projected images or the visualisation of abstract content. Therefore, the use of digital tools – like other tools – in supporting science teaching and learning in preschools should be thoughtfully integrated based on their contribution to the teaching process and their relevance to the specific content being taught.

Directions for further research

The thesis findings provide rich, detailed descriptions of how digital tools are intentionally employed to create meaningful learning environments, ultimately enhancing children's understanding of science content. As such, they have important implications for early science education and teacher professional development.

Several aspects within teaching and learning contexts present potential avenues for future research to advance the field of science education. One such aspect involves exploring and developing teachers' digital practices. This includes extending knowledge about how teachers incorporate digital tools into their teaching, informed by their pedagogical content knowledge (PCK). An interesting direction for future research would be to examine teachers' detailed planning of specific digitalised activities, an aspect that was beyond the scope of this thesis. It is also essential to examine how digital science practices evolve over time through intended, enacted and reflected teaching, including

the CoRe tool, detailed planning, and teachers' evaluation of both the intended teaching and enacted teaching.

The thesis's findings also shed light on child-centred science teaching and learning, which can be further explored in order to understand children's perspectives and knowledge in science education. For example, the construction of digital representations, such as slow-motions, revealed children's content-focused perspectives. Further research is pertinent to explore children's conceptions, including alternative conceptions, as well as their use of everyday and scientific language, which can be visualised and mediated through various digital representations.

The results of this thesis are based on the intentional use of various digital tools such as tablets, projectors and digital microscopes. A valuable direction for future research would be to investigate the use of a specific digital tool in the teaching and learning of a particular science content. Since the thesis's findings are based on the teaching of diverse science content, it may be pedagogically valuable for future investigations to focus on the same content or phenomenon, but investigated using different digital tools.

In summary, the thesis underscores the central role digital tools can play in and for purposeful teaching and learning of science content in a preschool context. By functioning as multifunctional pedagogical artefacts with catalysing, reinforcing and transformative roles, they offer pedagogical potential in science practices.

Svensk sammanfattning

I det här kapitlet sammanfattas avhandlingen på svenska.

Inledning

Naturvetenskaplig kunskap är avgörande för att förstå vår omvärld och hantera olika samhällsutmaningar. Den möjliggör att kunna förklara fenomen vetenskapligt, tolka vetenskapliga undersökningar samt analysera information och dra välgrundade slutsatser (Roberts & Bybee, 2014; Roy et al., 2025).

Tidiga erfarenheter är centrala för barns förståelse av naturvetenskapligt innehåll (Eshach & Fried, 2005; Fleeer, 2009a; Larsson, 2013a), eftersom de utmanar alternativa föreställningar (missuppfattningar) (Skamp, 2021), främjar fortsatt lärande (Eshach & Fried, 2005; Siry et al., 2023).

Digitala verktyg har i allt högre grad integrerats i utbildningskontexter (Selwyn, 2022). Digitala verktyg är ett sätt att visualisera abstrakta naturvetenskapliga processer och fenomen (Eilam & Gilbert, 2014; Hoban & Nielsen, 2010), något som kan vara särskilt betydelsefullt för yngre barn när de utvecklar sin förståelse för naturvetenskap. Tidiga erfarenheter är avgörande för att bygga naturvetenskaplig kunskap, och digitala verktyg kan berika dessa erfarenheter genom att visualisera det som är abstrakt. Naturvetenskaplig undervisning i förskolan kan utgöra en potentiell kontext där barn kan utveckla digital kompetens, vilket innefattar exempelvis kunskap om hur digitala verktyg används samt att utveckla ett ansvarsfullt och kritiskt förhållningssätt till att hantera teknologi och värdera information (EU, 2019; Skolverket, 2018). Forskning belyser behovet av att kritiskt utvärdera hur barn interagerar med dessa verktyg i hem- och förskolemiljöer (Holloway, Green & Livingstone, 2013).

I skrivande stund är användningen av digitala verktyg som pedagogisk resurs för yngre barn omdebatterad i Sverige, eftersom oro har uttryckts över överdriven skärmtid för små barn. Medan vissa

framhåller analoga verktyg som mer gynnsamma för utvecklingen av relationella färdigheter samt grundläggande läs- och skrivkunnsighet (Utbildningsdepartementet, 2023), lyfter andra fram de utbildningsförluster som kan uppstå när digitala verktyg inte integreras i förskolan (Pramling Samuelsson et al., 2024).

I den reviderade läroplanen för förskolan betonas användningen av analoga resurser, samtidigt som förskollärarens ansvar för undervisning grundad på vetenskaplig grund och beprövad erfarenhet stärks (Skolverket, 2025). I detta sammanhang ger förskolan unika möjligheter för barn att producera, snarare än enbart konsumera, digitalt innehåll, genom lärarstöd, samspel med kamrater och utbyte av idéer (Nilsen & Kjellander, 2023).

Förskollärarens roll är central i att stödja och vägleda en reflekterande praktik kring när, hur och varför digitala verktyg används med barn i syfte att främja meningsfulla interaktioner med utbildningsinnehåll (Gibbons, 2010; Selwyn, 2010). Huruvida lärare inkluderar digitala verktyg i undervisningen kan bero på olika kontextuella faktorer (Blackwell et al., 2014; Nilsen, 2018). Forskning visar att digitala verktyg används för olika pedagogiska syften (Jack & Higgins, 2019; Otterborn et al., 2019; Undheim, 2022; Walan & Enochsson, 2024), men också att de i vissa fall väljs bort (Aldhafeeri et al., 2016; Bird & Edwards, 2015).

Ur ett sociokulturellt perspektiv sker undervisning och lärande i interaktion med andra och med stöd av artefakter (Säljö, 2000; Vygotsky, 1978; Wertsch, 1985). Naturvetenskaplig undervisning i förskolan kan därmed förstås som en komplex process där barn, i interaktion med lärare och kamrater, utforskar och skapar förståelse för fenomen med hjälp av olika resurser och artefakter (Fragkiadaki et al., 2019; Siry, 2013; Siry & Max, 2013).

Tidigare forskning har uppmärksammat digitala verktyg i relation till barns lek (Fleer, 2018) samt hur de kan stödja barns resonemang om naturvetenskapliga fenomen (Fridberg et al., 2018). Vidare visar studier att integrering av digitala verktyg med andra resurser kan stärka barns utforskande och främja kollaborativt lärande mellan lärare och barn (Bittner, 2019).

Mot denna bakgrund undersöker denna avhandling användningen av digitala verktyg i förskolans naturvetenskapliga undervisning utifrån lärares planerade, genomförda och reflekterade undervisning av naturvetenskapligt innehåll.

Avhandlingen bidrar med täta beskrivningar (Geertz, 2000) av digitaliserade lärandekontexter i förskolan genom att undersöka varför och hur digitala verktyg används.

Syfte och forskningsfrågor

Syftet med avhandlingen är att bidra med kunskap om hur digitala verktyg stödjer undervisning och lärande av naturvetenskapligt innehåll i förskolans kontext. Utgångspunkten är lärares pedagogiska överväganden om att integrera digitala verktyg i den naturvetenskapliga undervisningen. Avhandlingen bygger på empiriska studier av naturvetenskapliga aktiviteter i autentiska förskolemiljöer där lärare och barn engagerar sig i innehållet med stöd av digitala verktyg. Följande övergripande forskningsfråga vägleder avhandlingen: *Hur stödjer användningen av digitala verktyg undervisning och lärande av naturvetenskapligt innehåll i förskolan?*

Bakgrund och tidigare forskning

Förskolekontexten

Avhandlingen utgår från en svensk förskolekontext. Förskolans utbildning regleras av skollagen (SFS 2010:800) och Läroplanen för förskolan, Lpfö18 (Skolverket, 2018).

Utbildningen i förskolan utgår från en helhetssyn på barnet, där omsorg, utveckling och lärande integreras. Undervisningen ska stimulera barnens förståelse av sin omgivning, genom utforskande, nyfikenhet och lek utifrån deras behov, erfarenheter och intressen (Skolverket, 2018). Naturvetenskap skrivs fram som ett centralt innehållsområde för undervisning och lärande, vilket betonar att naturvetenskapliga kunskaper är viktiga för barns lärande. Lärarens pedagogiska roll, som är framskriven i läroplanen, innefattar att stimulera barns utveckling och lärande genom både planerad och spontan

undervisning. Undervisningen ska utgå från målen i läroplanen samt bygga på barnens tidigare erfarenheter och kunskaper.

Naturvetenskapsundervisning i förskolan – Att undervisa och lära sig naturvetenskap

Forskning om naturvetenskapernas didaktik i förskolan har blivit allt mer framträdande de senaste åren (Siry et al., 2023). Naturvetenskap har integrerats i läroplaner globalt (European Education and Culture Executive Agency, 2011; National Research Council, 2012), och förskolan kan förstås utgöra en mötesplats för barns utveckling och lärande genom interaktioner och erfarenheter avsiktligt utformade för att stödja barns lärande (Skolverket, 2018).

Larimore (2020) betonar att naturvetenskapernas didaktik för förskolan bör förena det bästa från både early childhood education och science education. Det innebär ett barncentrerat arbetssätt som fokuserar på hela barnets utveckling, där holistiska naturvetenskapliga arbetssätt prioriteras framför enskilda processfärdigheter. Planeringen och genomförandet av undervisningen bör utgå från barns erfarenheter av fenomen i lokala kontexter samt använda sociokulturella metoder såsom interaktioner mellan barn och lärare.

Siry et al. (2023) betonar att undersökande arbetssätt inom naturvetenskapsundervisning ger barn möjlighet att utforska olika vetenskapliga fenomen och utveckla processfärdigheter såsom att observera, ställa frågor, göra förutsägelser, ge förklaringar, dokumentera och kommunicera. Detta understryker att förskolan bör stödja barns förståelse av naturvetenskapliga fenomen, främja deras nyfikenhet och vetenskapliga tänkande, samt erbjuda varierade lärsituationer som medierar den verkliga världen. Ett viktigt fokus i naturvetenskaplig undervisning är hur barn förstår och engagerar sig i naturvetenskapliga fenomen.

Emergent science

Ett centralt begrepp är emergent science som syftar på barns begynnande lärande och förståelse av naturvetenskap genom utforskande och experimenterande i vardagliga aktiviteter (Siraj-Blatchford,

2001). Fokus ligger inte på att barnen ska uppnå specifik begrepps-förståelse, utan på att väcka deras nyfikenhet och intresse för naturvetenskap (Larsson, 2013b; Siraj-Blatchford, 2001). Genom gemensamma undersökningar med kamrater och lärare utvecklas deras naturvetenskapliga färdigheter, attityder, språk och förståelse (Otterborn, 2023). Emergent science kan även inkludera planerad undervisning men kännetecknas framför allt av att den utgår från barnens egna erfarenheter och utforskande (Otterborn, 2023). I relation till detta betonas att barns begynnande naturvetenskapliga kunskap är en pågående process (Larsson, 2013a).

Att engagera sig i naturvetenskapligt innehåll

Att engagera sig i naturvetenskapligt innehåll innebär att barn aktivt deltar i naturvetenskapliga praktiker genom att möta, utforska och undersöka olika fenomen och begrepp. Det är en interaktiv process där barn och pedagoger, eller barn sinsemellan, använder olika (digitala) artefakter för att utveckla förståelse.

Att ge barn möjlighet att uttrycka sin förståelse genom olika medier, såsom bilder och videor, stärker deras förståelse samtidigt som det främjar positiva känslor och motivation (Siry et al., 2023). Detta har implikationer för pedagogers praktik, både vid planeringen och i genomförandet av undervisningen, eftersom det tar hänsyn till barnens intressen, erfarenheter och förförståelse – samt när och hur artefakter kan användas för att engagera barn i naturvetenskapligt innehåll.

Forskningen visar också att barn kan förstå abstrakta begrepp som friktion och fäsförändringar (O'Connor et al., 2021). Samtidigt utvecklar de alternativa föreställningar som hjälper dem att tolka vardagliga erfarenheter (Skamp, 2021; Vosniadou & Skopeliti, 2017). Genom att erbjuda rika möjligheter att engagera sig i naturvetenskapligt innehåll läggs grunden för tidig utforskning och förståelse av naturvetenskapligt innehåll.

Lärarnas roll i att skapa möjligheter för engagemang i naturvetenskap

Lärare har en central roll i att hjälpa förskolebarn att förstå olika naturvetenskapliga begrepp (Fleer, 2009a; 2009b; Yıldız Taşdemir & Güler Yıldız, 2024). Att undervisa i naturvetenskap är komplext eftersom det kräver att abstrakta idéer förklaras på ett begripligt sätt. För att främja förståelsen bör pedagoger utveckla undervisningsmetoder som fokuserar på visuella representationer, vilket gör det möjligt för barn att använda och manipulera dessa element. Dynamiska representationer, såsom animationer, kan illustrera processer mer effektivt än statiska bilder (Eilam & Gilbert, 2014). Att skapa digitala berättelser, till exempel genom sagoberättande och animationer, berikar dessutom lärandeupplevelsen. (Hoban et al., 2013). Ett exempel på detta är så kallade slowmations, där barn skapar berättande digitala animationer för att visualisera naturvetenskapligt innehåll. Att delta i sådana aktiviteter fördjupar inte bara barnens förståelse, utan ger också pedagoger möjlighet att stödja deras lärande.

Digitala verktyg i förskolans undervisning

I avhandlingen används termen digitala verktyg som ett samlingsbegrepp för olika digitala artefakter, resurser och teknikbaserade hjälpmedel som används för att stödja undervisning och lärande av naturvetenskapligt innehåll. Digitala verktyg i förskolan omfattar skärmbaserade (t.ex. surfplattor, mobiltelefoner), icke-skärmbaserade (t.ex. kameror, projektorer), utforskande (t.ex. digitala mikroskop), Internet of Toys (t.ex. robotik), digitala resurser (t.ex. applikationer) samt medier (Undheim, 2022).

Digitala verktyg förstås som mer än tekniska hjälpmedel (Hatzianni, 2018). De innefattar materiella, mänskliga och sociala aspekter och används i praktiker där kunskap skapas (Selwyn, 2022). De utgör kulturella verktyg som är inbäddade i sociala sammanhang och delar av kunskapssystem som delas över generationer (Selwyn, 2022; Säljö 2023).

Forskning betonar att digitala verktyg kan förstärka andra resurser, stödja multimodalt lärande (Yelland, 2018) samt bidra till utveckling av kreativitet, kritiskt tänkande och kommunikation (Chen och Ding, 2024; Yelland, 2018).

I takt med digitaliseringen har digitala verktyg blivit en integrerad del av dagens undervisning (Arnott et al., 2018; Selwyn, 2022). De omdefinierar undervisningen eftersom de inte ses som något perifert utan som en del av de processer och praktiker där kunskap skapas, förstås och utvecklas (Hatzigianni, 2018).

Selwyn (2022) menar att digitala verktyg och digitala praktiker ger användare ökad kontroll och flexibilitet. De innebär en betydande förändring i hur vi lär, minns och förstår, på grund av hur vi hämtar, bearbetar och använder information och kunskap. Detta bidrar till ett förändrat sätt att interagera med kunskap (Säljö, 2023). De digitala verktygen skapar nya undervisningsmetoder på flera sätt, särskilt genom sin förmåga att simulera verkliga situationer samt bearbeta information i en omfattning, hastighet och komplexitet som tidigare varit svåra att uppnå (Selwyn, 2022).

I förskolan kan digitala verktyg i kombination med andra resurser, förstärka lärandeupplevelser (Otterborn et al., 2024). De kan bidra till interaktiva och dynamiska undervisningsformer där barn och lärare är medlärande (Bittner, 2019).

Slowmation – En digital artefakt för att visualisera naturvetenskapligt innehåll

Slowmation (förkortning av slow animation) är en förenklad form av stop-motion-animation som används för att stödja lärande inom naturvetenskap. Den innebär att korta animationer skapas och berättas med en hastighet av två bilder per sekund. Slowmation gör det möjligt för barn att visuellt representera naturvetenskapliga begrepp på ett praktiskt och engagerande sätt (Hoban & Nielsen, 2010).

En slowmation byggs upp genom fem sekventiella, multimodala steg:

- 1) Bakgrund - Insamling av grundläggande kunskap om innehållet).
- 2) Storyboard – Uppdelning av innehåll i scener och planering av ordning och resurser.
- 3) Modeller – Skapande av 2D- eller 3D-modeller för att representera centrala delar av innehållet.
- 4) Digitala fotografier – Fotografering och sekvensering av modellerna för att visa rörelse.
- 5) Animationen – Sammanställning av bilder med berättarröst och ljud.

Processen uppmuntrar barn att fördjupa sig i naturvetenskapligt innehåll genom att skapa mening via flera uttrycksformer (Hoban & Nielsen, 2010, Mou et al., 2021, Fridberg et al., 2018). Genom att kombinera lekfullhet med strukturerat lärande bidrar slowmation till att konkretisera och visualisera abstrakt innehåll. Forskning visar att slowmation stärker reflektion, förståelse och motivation, samtidigt som den stödjer vetenskapligt resonemang och kommunikation (Mou et al., 2021; Fridberg et al., 2018; 2019).

Teoretisk referensram

Avhandlingens teoretiska referensram utgörs av ett sociokulturellt perspektiv och Pedagogical Content Knowledge (PCK).

Ur ett sociokulturellt perspektiv betraktas undervisning och lärande som sociala praktiker situerade i den kulturella kontext där de uppstår (Säljö, 2021; Vygotsky, 1978). I dessa interaktioner spelar artefakter en central roll. Artefakter, exempelvis språkliga, fysiska eller digitala, fungerar som medierande verktyg mellan individ och omvärld (Vygotsky, 1978; Wertsch, 1985; Säljö, 2000).

(PCK) (Shulman 1986; 1987) avser en sammansmältning av ämneskunskap och den pedagogiska kunskap som en lärare använder sig av för att undervisa och stötta barns lärande i en specifik situation. Flera modeller av PCK har utvecklats för att förklara dess karaktär. Magnusson et al. (1999, s. 97) har till exempel definierat olika

komponenter av PCK. Avhandlingen utgår från den förfinade konsensusmodellen (Refined Consensus Model, RCM) (Carlson et al., 2019). Modellen beskriver den kunskap och de erfarenheter som formar och påverkar lärarens praktik samt medierar elevers lärande.

RCM omfattar tre lager:

- kollektiv PCK (cPCK), innefattar lärares PCK som är publik och kan delas med andra lärare och forskare
- personlig PCK (pPCK), som avser lärares individuella PCK
- genomförd PCK (ePCK), som innefattar den PCK som läraren faktiskt använder i underpraktiken.

Dessa lager samverkar med lärandekontexten, som avser den plats och tid där ett specifikt lärande äger rum samt lärarens professionella kunskapsbaser som läraren besitter, såsom pedagogisk kunskap eller kunskap om barn. Modellen beskriver också hur kunskap utbyts mellan de olika lagren samt hur lärandekontexten integreras i PCK:s olika lager.

I studierna användes reflektionsverktyget Content Representation (CoRe), (Loughran et al., 2004). CoRe stödjer lärares reflektion vid planering av undervisning inom ett specifikt naturvetenskapligt ämnesinnehåll. Genom att formulera centrala idéer (Big Ideas) och besvara frågor om intentioner och överväganden för undervisningen, fångar och representerar CoRe lärarens PCK.

Reflektionsverktyget hade anpassats till förskolekontexten med inspiration av Nilsson och Elm (2017).

Kombinationen av ett sociokulturellt perspektiv och RCM bidrar till förståelsen av hur digitala verktyg kan mediera interaktioner mellan lärare och barn samt stödja meningsfullt naturvetenskaplig undervisning i förskola. Den möjliggör också analys av hur planerade, genomförda och reflekterade praktiker är förankrade i lärarnas PCK.

Metodologi

En kvalitativ ansats (Silverman, 2021) användes för att undersöka hur användningen av digitala verktyg stödjer undervisning och lärande av naturvetenskapligt innehåll i förskolekontexten.

I studierna deltog 21 förskollärare och 37 barn (3–6 år) från fyra förskolor i södra Sverige, benämnda som Rainfall, Waterfall, Windfall och Wingfall. Förskolorna valdes på frivillig basis och de deltagande lärarna hade för avsikt att arbeta med naturvetenskapligt innehåll och digitala verktyg i sin undervisning.

Lärarnas erfarenhet varierade från knappt 2 till 46 år, liksom deras erfarenheter av digitala verktyg och fortbildning om dessa. Avhandlingen består av fyra delstudier (I–IV). Data samlades in vid två tillfällen, en för studierna I–II och studierna III–IV. Studiernas design och datainsamling kan sammanfattas enligt följande:

Introduktion av reflektionsverktyget CoRe

- CoRe introducerades för lärarna i deras respektive arbetslag.
- Fokus låg på att förstå vad en *Big Idea* och verktygets frågeställningar.
- Skriftligt material delades ut för att stödja en fördjupad förståelse.

Gruppdiskussioner och CoRe

- Lärarna fyllde i CoRe under planeringsmöten i sina arbetslag.
- Gruppdiskussionerna ljudinspelades (cirka 1–1,5 timme per grupp).
- Forskaren deltog som facilitator och bidrog vid behov med förtydliganden och sammanfattningar.

Undervisningsaktiviteter med digitala verktyg (Studie II) samt Konstruktion av slowmation (Studie III och IV)

- Lärarna planerade och genomförde undervisning med utgångspunkt i CoRe.

- I studierna I–II videofilmades aktiviteter som inkluderade digitala verktyg.
- I studier III– IV videofilmades hela processen med att konstruera slowmotion.

Videostimulerade intervjuer

- Utvalda videoklipp användes för att stödja lärarnas reflektioner (Studie I och III).
- Lärarnas ifyllda CoRe användes som stöd under intervjuerna.

Resultat

Artikel I

Artikel I undersöker förskollärares didaktiska överväganden kring användningen av digitala verktyg samt vilka aspekter av lärares PCK (Magnusson et al., 1999; Shulman, 1986; 1987) som kommer till uttryck. Studien behandlar följande två forskningsfrågor: Vilka överväganden gör förskollärare inför och under undervisningen när digitala verktyg inkluderas för att utveckla barns lärande om naturvetenskapligt innehåll? Vilka aspekter av PCK synliggörs i förskollärarnas överväganden?

Den tematiska analysen identifierade överväganden före och under undervisning. **Övervägandena före undervisning** rör förutsättningar för naturvetenskaplig undervisning och kan förstås som lärarnas personliga PCK (pPCK). Överväganden beskrivs nedan:

- **Att närma sig innehållet** innefattar hur naturvetenskapligt innehåll kan göras tillgängligt för barn.
- **Att få tillgång till barns lärande** berör användningen av digitala verktyg för att dokumentera, synliggöra och stimulera barns lärande.
- **Digitala teknologier som möjliggörare** avser hur digitala verktyg kan berika lärandekontexten genom att skapa

lärmiljöer, virtuella upplevelser och möjliggöra kollaborativt undersökande.

- **Digitala teknologier som begränsningar** belyser vikten av en medveten användning av digitala verktyg i relation till uteblivna lärmöjligheter.

Överväganden under undervisning rör interaktionen mellan innehåll, barn och digitala verktyg, samt hur lärande möjliggörs i praktiken. Dessa överväganden kan förstås som lärarnas **genomförda PCK (ePCK)**. En beskrivning av dessa överväganden följer nedan.

- **Digitala teknologier i samtida lärande** avser de digitala verktygens betydelse i dagens samhälle och barns vardagsliv. De digitala verktyg ses som värdefulla för att utveckla digital kompetens, stödja kompensatoriskt lärande samt överbrygga skillnader mellan hem och förskola.
- **Att använda digitala verktyg för att göra det abstrakta konkret** innefattar hur digitala verktyg kan användas för att omvandla abstrakt naturvetenskapligt innehåll till en mer konkret förståelse, ofta i kombination med analoga artefakter, olika uttrycksformer och representationer.
- **Att stimulera barns engagemang och lärande** berör hur användningen av digitala verktyg kan skapa motivation och förväntan i mötet med innehållet samt stödja dokumentation och synliggörandet av barns lärprocesser över tid.

Artikel II

Artikel II ger detaljerade beskrivningar av hur digitala verktyg används i naturvetenskapliga aktiviteter i förskolan genom att undersöka följande forskningsfråga: Hur används digitala verktyg i förskolans pedagogiska praktiker för att forma barns och lärares engagemang i naturvetenskapligt innehåll?

Den tematiska analysen av olika episoder från aktiviteterna identifierade fyra sätt på vilka digitala verktyg används för att forma engagemang i naturvetenskapligt innehåll:

- **Skapa lärmiljöer för engagemang med innehållet:** Digitala verktyg används för att skapa en atmosfär kring

innehållet, exempelvis genom projicerade bilder. Digitala verktyg används också för att dokumentera barns perspektiv och föra deras erfarenheter vidare till andra sammanhang.

- **Återskapa engagemang med innehållet:** Digitala verktyg möjliggör att engagemang flyttas mellan aktiviteter, platser och deltagare. Genom att använda bilder och videos från tidigare aktiviteter kan barn återkalla erfarenheter, reflektera, formulera förklaringar och dela gemensamma upplevelser, vilket stödjer lärande över tid och rum.
- **Visualisera abstrakt innehåll:** Digitala verktyg erbjuder fler sätt att närma sig innehållet, exempelvis genom filmer och representationer som kombinerar olika uttrycksformer. Det innebär också att digitala verktyg används för detaljerade undersökningar.
- **Stödja kommunikationen om innehållet:** Digitala verktyg fungerar som stöd i kommunikationen om innehållet. Projicerade bilder fungerar exempelvis som utgångspunkt för gemensam reflektion och samtal. De ger också lärarna möjlighet att rikta uppmärksamhet genom att exempelvis pausa, ställa frågor och rikta uppmärksamhet på viktiga detaljer.

Sammantaget visar resultaten att digitala verktyg används för olika syften samtidigt som de medierar innehåll och länkar samman barns tidigare erfarenheter med nya lärandesituationer.

Artikel III

Artikel III fokuserar på lärares erfarenheter av hur slowmation, i kombination med CoRe, stödjer barns lärande och engagemang i naturvetenskapligt innehåll. Studien guidades av följande forskningsfråga: Hur erfar lärare implementeringen av slowmation i undervisning och lärande av naturvetenskapligt innehåll i förskolan?

Följande fyra teman identifierades genom en tematisk analys och sammanfattar lärares erfarenheter:

- **(Åter)inramning av innehållet** innebär att rama in och undervisa naturvetenskapligt innehåll utifrån Big Ideas samt att vägleda barn i slowmationprocessen. Digitala verktyg används för att förtydliga och konkretisera innehållet samt synliggöra dess betydelse.
- **Barns engagemang** rör hur barns intresse utgör utgångspunkt i arbetet med slowmation och kopplas till barnens nyfikenhet, delaktighet och förmågor.
- **Upprepade möjligheter till engagemang** beskriver slowmation som en process med återkommande möjligheter att bearbeta innehållet. Den fungerar även som en artefakt som synliggör och sammanfattar barns förståelse. Slowmation designen upplevs som ett stöd i undervisningen.
- **Förberedelser och behov av stöd** betonar vikten av att introducera slowmation och att vägleda barnen genom mer komplexa steg i konstruktionen. Tillgång till tekniska resurser och noggrann planering framhålls som centrala.

Sammantaget fungerar slowmation både som undervisningsverktyg och som representation av innehållet. Kombinationen av slowmation och CoRe framstår som betydelsefull och utgör en viktig pedagogisk struktur i arbetet med digitala verktyg.

Artikel IV

Artikel IV fokuserar på hur konstruktionen av slowmation kan stimulera och synliggöra förskolebarns föreställningar om naturvetenskapligt innehåll. Studien vägledades av följande forskningsfråga: Hur kan konstruktionen av slowmation göra förskolebarns föreställningar om det naturvetenskapliga innehållet explicita?

Den tematiska analysen identifierade tre aspekter av barns föreställningar om innehållet, vilka kan förstås som aspekter av innehållet och omfattade:

- **Identifiering av en art:** föreställningar i form av namn och attribut som benämner, definierar och klassificerar arten.

- **Karaktärsdrag hos en art:** föreställningar om artens fysiska beteenden och egenskaper.
- **Livsvillkor:** föreställningar om miljön och förutsättningarna för liv – både för arten och för människan.

Sammantaget framträder barnens föreställningar som innehållsfokuserade och i linje med undervisningen i Bakgrundsfasen, som lärarna planerade med stöd av CoRe. Samtidigt synliggörs alternativa föreställningar, vilket indikerar en begynnande förståelse, vilket också understryker betydelsen av att konstruera representationer som stimulerar och utmanar barns lärande.

Syntes i relation till den övergripande forskningsfrågan

Avhandlingens fyra studier visar hur digitala verktyg stödjer undervisning och lärande av naturvetenskap i förskolan. Syntesen av resultatet i de fyra studierna lyfter två centrala resultat:

- **Användningen av digitala verktyg behöver förankras i lärares reflektioner**
- **Digitala verktyg fungerar som katalysatorer för undervisning och lärande**

Sammantaget visar syntesen tydligt att digitala verktyg spelar en central roll i att stödja naturvetenskaplig undervisning och lärande på flera sätt. Genom de fyra delstudierna framgår att en medveten användning av digitala verktyg, förankrad i lärares reflekterade praktik och uttryckt genom CoRe, belyser betydelsen av pedagogiska överväganden för att skapa förutsättningar för meningsfullt lärande i förskolan.

Kombinationen av välplanerade och reflekterande pedagogiska strukturer (t.ex. CoRe) och kreativa, multimodala digitala artefakter, såsom slowmation, möjliggör för både lärare och barn att utforska, kommunicera och utveckla sin förståelse av naturvetenskap på ett ändamålsenligt och engagerande sätt. Digitala verktyg har en dubbel funktion i undervisningen. För det första fungerar de som

läranderedskap som stödjer barns och lärares direkta utforskande av naturvetenskapligt innehåll. För det andra fungerar de som medierande resurser i skapandet av digitala artefakter, såsom filmer, bilder och animationer, som kan återanvändas i nya lärandesituationer och delas med andra inom och utanför förskolan.

Genom dessa processer möjliggör digitala verktyg att naturvetenskapliga praktiker utvecklas och ger barn återkommande möjligheter att fördjupa sin förståelse. På så sätt stödjer de undervisning och lärande både direkt, genom användning i aktiviteter, och indirekt, genom att underlätta dokumentation, kommunikation och reflektion.

Genom att initiera, stödja och möjliggöra olika processer fungerar digitala verktyg som katalysatorer för naturvetenskaplig undervisning och lärande i förskolan.

Diskussion

Digitala verktyg–Multifunktionella pedagogiska artefakter

Resultaten visar att digitala verktyg kan förstås som multifunktionella pedagogiska artefakter som stödjer lärandet och undervisningen genom mångsidiga, men sammanlänkade, roller i utformningen av undervisningsmiljöer, praktiker. De fungerar *katalytiskt* genom att möjliggöra utforskande och stimulera reflektion. De agerar även *förstärkande* genom att komplettera analoga resurser och bidra till multimodala erfarenheter. Vidare fungerar de *transformativt* genom att förändra lärandekontexten och möjliggöra gemensam uppmärksamhet och återkommande interaktion med innehållet.

Då digitala verktyg används för att beskriva, representera och förklara naturvetenskapligt innehåll, stödjer denna användning samkonstruerandet av mening kring olika innehåll. Detta är i linje med ett socio-kulturellt perspektiv där lärande formas genom interaktioner med andra och med hjälp av artefakter (Vygotsky, 1978). Digitala verktyg fungerar därmed som kulturella artefakter som främjar lärande och skapar en social praktik för kunskapsutveckling i tidig

naturvetenskaplig undervisning. Mångsidigheten i de digitala verktygens roll för undervisningen väcker viktiga pedagogiska frågor om hur lärare integrerar digitala verktyg för att främja naturvetenskapligt lärande.

Från artefakter till praktiker

Utöver att fungera som materiella artefakter som uppfyller olika behov, omfattar digitala verktyg även processer, aktiviteter och den kunskap som är inbäddad i praktiker (Säljö, 2021; 2023). De stödjer centrala naturvetenskapliga aktiviteter samt kognitiva och kommunikativa processer och aktiviteter, såsom att reflektera, förklara eller dela perspektiv.

Resultaten bekräftar tidigare forskning om att verktyg stärker barns kreativa och kognitiva utveckling (Chen & Ding, 2024). Vidare visar resultaten att användningen av digitala verktyg också möjliggör intra- och interpersonella processer mellan lärare och barn. Dessutom formar användningen av digitala verktyg en praktik där barn och lärare samkonstruerar kunskap om specifikt innehåll (Bittner, 2019). Tillsammans pekar dessa insikter på att digitala verktyg inte bara är stödjande utan också transformerande, och fungerar som materiella och kognitiva resurser som medierar interaktion och reflektion i naturvetenskaplig undervisning. De kan vidga gränserna för hur olika perspektiv nås och delas i olika kontexter i förskolan, vilket kan stödja meningsskapandet kring naturvetenskapligt innehåll.

Från erfarenheter till delad mening

Digitala verktyg i kombination med barns erfarenheter skapar möjligheter för naturvetenskapligt lärande. Genom att utgå från barns perspektiv kan lärare och barn samkonstruera representationer (t.ex. PicCollages, slowmations) som stimulerar reflektion och vidare lärande. Projicerade bilder bidrar till att skapa gemensam uppmärksamhet och intersubjektivitet mot specifika aspekter av innehållet och möjliggör intersubjektivitet, vilket skapar förutsättningar att utmana och utveckla barns tänkande vidare.

Omkontextualiseringen av naturvetenskaplig undervisning och lärande

Digitala verktyg möjliggör återkommande interaktion med innehåll genom dokumentation. Innehållet placeras, omkontextualiseras, i ett nytt sammanhang, något som också visades i tidigare studier (Otterborn et al., 2024). I de nya sammanhangen delas barnens tankar och erfarenheter om innehållet och utvecklas vidare.

Resultaten stämmer överens med tidigare forskning som understryker de digitala verktygens roll i att möjliggöra upprepade interaktioner med innehåll (Hoban & Nielsen, 2010) och i att koppla befintliga erfarenheter till nya, relaterade till innehållet (Otterborn et al., 2024; Samuelsson, 2019). Digitala verktyg kan därför sägas fylla både passiva och aktiva funktioner och fungera som artefakter som formar nya interaktioner med innehållet. Samtidigt som de projiceras och återanvänds (passiv funktion), initierar och promptar de meningsfulla interaktioner (aktiv funktion). Dessa fynd belyser den transformativa roll som digitala verktyg har i att skapa sammankopplade lärandekontexter, och positionerar dem som förmedlare av naturvetenskaplig kunskap över tid och rum.

Användning av digitala verktyg möjliggör en omkontextualisering av barns lärande bortom förskolans kontext genom delning av bilder och videos med vårdnadshavare. Denna process knyter samman förskola och hem, vilket kan berika barnens lärande och stimulera reflektion och diskussion både hemma och i förskolan. På så sätt bidrar digitala verktyg till att göra undervisning och lärande till en gemensam, samskapad angelägenhet mellan barn, lärare och vårdnadshavare.

Denna process definierar ett sätt att producera och dela kunskap (Bittner, 2019), både om innehållet och barnens lärande. Den visar att digitala artefakter har en nyckelroll i att synliggöra barns lärandeprocesser och uppfattningar. Digitala artefakter påverkar hur människor interagerar med kunskap, inte minst i hur vi hämtar och använder information (Säljö, 2023; Selwyn, 2022). När det gäller lärandeprocesser betonar Hatzigianni (2018) att digitala verktyg kan förändra förskolepedagogiken. Dessa insikter visar att digitala verktyg, förutom att stödja, även utvidgar det naturvetenskapliga lärandet bortom

förskolans gränser. Det synliggör naturvetenskaplig undervisning och lärande som en kollektiv, distribuerad process över kontexter och deltagare. I detta avseende bidrar avhandlingen till att bredda kunskapen om hur undervisning och lärande om naturvetenskapligt innehåll kan göras flexibelt och interaktivt.

Avhandlingens konceptuella och metodologiska bidrag

Planerade, genomförda och reflekterade aspekter av digitaliserad undervisning och lärande i förskolan

Förankring i PCK och CoRe:

Studier visar att undervisning och lärande av naturvetenskapligt innehåll med digitala verktyg är förankrade i lärarnas överväganden och reflektion med stöd av CoRe. Avhandlingen bidrar till förståelsen av hur CoRe kan stödja lärares digitaliserade praktik och användningen av digitala verktyg baserad på lärares PCK.

Integration av digitala verktyg utifrån PCK: Avhandlingen bidrar till forskningen genom att med rika beskrivningar visa hur digitala verktyg stödjer naturvetenskapsundervisningen i förskolan. Genom lärarnas artikulation av Big Ideas och reflektion utifrån viktiga aspekter formulerade i CoRe, möjliggörs en avsiktlig och informerad användning av digitala verktyg. Den tillför därmed ett empiriskt bidrag till hur PCK stödjer digitaliserad naturvetenskaplig undervisning och lärande i förskolan.

Implikationer för praktiken: Resultaten visar att välutvecklad PCK och genomtänkta överväganden skapar förutsättningar för effektiv användning av digitala verktyg. Det innebär exempelvis att innehållet ramas in meningsfullt, bearbetas mångsidigt och skapar kopplingar mellan aktiviteter. Avhandlingen visar att reflektioner baserade på CoRe gör det möjligt för lärare att formulera vad, varför och hur man undervisar om naturvetenskapligt innehåll med hjälp av digitala verktyg.

Dynamisk undervisningscykel: Den avsedda, genomförda och reflekterade användningen av digitala verktyg bildar ett

dynamiskt samspel mellan verktygens roll (varför och hur) i undervisningen och lärandet av naturvetenskapligt innehåll (vad). Lärare behöver förutsättningar och möjligheter att formulera hur digitala verktyg kan användas genom hela undervisningscykeln för att stödja naturvetenskapsundervisning i förskolan.

Förslag på fortsatt forskning

Vidare forskning bör undersöka hur lärare, med utgångspunkt i PCK, integrerar digitala verktyg i sin undervisning, samt hur planering och reflektion kring digitala aktiviteter utvecklas. Det är också relevant att studera barns digitala representationer, såsom slowmations, och undersöka deras uppfattningar och språkanvändning.

Slutligen behövs studier av specifika digitala verktygs betydelse för undervisning av naturvetenskapligt innehåll.

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APRENDIX 1

INTERVIEW GUIDE

Background questions

Name:

Occupation:

Number of active years/experience of working with sciences/digital tools:

We watch film sequences from the teaching activities

- Tell me what happens in this cutscene!
- Tell me what was the idea/intention of this activity!
- What did you want the children to learn or develop knowledge about in this activity?

Questions about CoRe

You/ (you in the team) filled in the reflection tool (CoRe) before the teaching.

- Was there any question in the reflection tool that made you particularly prepared for the teaching and if so, why?
- Are there considerations that you made in the teaching that were not described in the reflection tool? If so, which ones? Why didn't these come up when you completed the reflection tool?
- When you look at what you had filled, was there anything that surprised you in the teaching?

Questions about digital tools and CoRe

- How come you used this digital tool in your teaching in relation to the specific Big Ideas that you formulated in CoRe?
- In what way do you think the tool contributed to the teaching of the specific Big Ideas you formulated in CoRe?
- In what way do you think the tool contributed to the children's learning about the specific Big Ideas you formulated in CoRe?

- In what way do you think that the digital tool enables or limits the children's understanding of the science content in question?
- If you compare the digital tool with other tools (e.g. a book), in what way did it contribute to the children's learning about the science content?

Questions about children's learning

- What is important to focus on when working with this science content together with children?
- What is important to focus on when working with digital tools together with children?
- Can you tell us about the reason why you ...(based on what happened in the teaching/ film sequence, for example gathered the children in front of/ told about ...)
- What is the idea of the (teaching) methods/s that you used in the teaching/film sequence?
- In what way do you think this activity made it easier for the children to learn about the science content? "One of the questions in the reflection tool is about the children's perceptions and misconceptions about the scientific content. What considerations guided your teaching when you introduced xx concepts/ showed xx material/ used the digital tool?
- How did the children show that they took in what you talked about?

Questions about Slowmation

- How come you chose to show (for example) (this) film (digital tool) in the teaching about the specific Big Ideas that you formulated in the reflection tool CoRe?
- In what way do you think that the film contributed to the teaching of the specific Big Ideas you formulated in CoRe?
- -In what way do you think visits to the forest/building (other methods/tools) contributed to the children's learning about the specific Big Ideas you formulated in the reflection tool CoRe?

- What representations of the content do you think the children took away through the different teaching methods?
- What do you think the children got about the content through the different representations (phases) in Slowmation?
- What is important to focus on when working on making a slowmation together with children about science content?
- In what way did the work with slowmation contribute/did not contribute to the children's learning about the content?
- Linked to any special moment?
- In what way do the children show what they have learned about this idea? In the film/during the work?
- What signs of children's learning have you seen in the teaching and during the slowmation construction?
- If you think about the whole slowmation process, what do you think the children have learned about the content?
- How would you describe that the content is presented in slowmation?
- What is your opinion that slowmation enabled/limited in the learning of this Big Idea?
- Was there anything that became difficult regarding the content through slowmation/during the work?
- What is your opinion that slowmation limited in learning about this Big Idea?
- If you had made a slowmation now about the content... What would you have focused on?

During the interview, I ask questions so that the teacher can develop his or her answer. Examples of questions are:

- Can you elaborate on it a little more?
- Can you describe a little further?
- What do you put into the term...?
- What/how do you mean by...?
- Can you help me understand...?
- You told / showed/ clarified/gestured to the children... What did you think then?

Conclusion

I ask whether the teacher (s) have anything to add. Then I thank them for the interview and explain that it will be transcribed, and the teachers will be offered to look at the transcripts for approval, or they want to add or change

Papers

The papers associated with this thesis have been removed for copyright reasons. For more details about these see:

<https://doi.org/10.3384/9789181183207>

1. Margareta Enghag (2004): MINIPROJECTS AND CONTEXT RICH PROBLEMS – Case studies with qualitative analysis of motivation, learner ownership and competence in small group work in physics. (licentiate thesis) Linköping University
2. Carl-Johan Rundgren (2006): Meaning-Making in Molecular Life Science Education – upper secondary school students' interpretation of visualizations of proteins. (licentiate thesis) Linköping University
3. Michal Drechsler (2005): Textbooks', teachers', and students' understanding of models used to explain acid-base reactions. ISSN: 1403-8099, ISBN: 91-85335-40-1. (licentiate thesis) Karlstad University
4. Margareta Enghag (2007): Two dimensions of Student Ownership of Learning during Small-Group Work with Miniprojects and context rich Problems in Physics. ISSN: 1651-4238, ISBN: 91-85485-31-4. (Doctoral Dissertation) Mälardalen University
5. Maria Åström (2007): Integrated and Subject-specific. An empirical exploration of Science education in Swedish compulsory schools. (Licentiate thesis) Linköping university
6. Ola Magntorn (2007): Reading Nature: developing ecological literacy through teaching. (Doctoral Dissertation) Linköping University
7. Maria Andréé (2007): Den levda läroplanen. En studie av naturorienterande undervisningspraktiker i grundskolan. ISSN: 1400-478X, HLS Förlag: ISBN 978-91-7656-632-9 (Doctoral Dissertation, LHS)
8. Mattias Lundin (2007): Students' participation in the realization of school science activities. (Doctoral Dissertation) Linköping University
9. Michal Drechsler (2007): Models in chemistry education. A study of teaching and learning acids and bases in Swedish upper secondary schools ISBN 978-91-7063-112-2 (Doctoral Dissertation) Karlstad University
10. Proceedings from FontD Vadstena-meeting, April 2006.
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13. Lena Hansson (2007): "Enligt fysiken eller enligt mig själv?" – Gymnasieelever, fysiken och grundantaganden om världen. (Doctoral Dissertation) Linköping University.

14. Christel Persson (2008): Sfärens symfoni i förändring? Lärande i miljö för hållbar utveckling med naturvetenskaplig utgångspunkt. En longitudinell studie i grundskolans tidigare årskurser. (Doctoral Dissertation) Linköping University
15. Eva Davidsson (2008): Different Images of Science – a study of how science is constituted in exhibitions. ISBN: 978-91-977100-1-5 (Doctoral Dissertation) Malmö University
16. Magnus Hultén (2008): Naturens kanon. Formering och förändring av innehållet i folkskolans och grundskolans naturvetenskap 1842-2007. ISBN: 978-91-7155-612-7 (Doctoral Dissertation) Stockholm University
17. Lars-Erik Björklund (2008): Från Novis till Expert: Förtroghetskunskap i kognitiv och didaktisk belysning. (Doctoral Dissertation) Linköping University.
18. Anders Jönsson (2008): Educative assessment for/of teacher competency. A study of assessment and learning in the “Interactive examination” for student teachers. ISBN: 978-91-977100-3-9 (Doctoral Dissertation) Malmö University
19. Pernilla Nilsson (2008): Learning to teach and teaching to learn - primary science student teachers' complex journey from learners to teachers. (Doctoral Dissertation) Linköping University
20. Carl-Johan Rundgren (2008): VISUAL THINKING, VISUAL SPEECH - a Semiotic Perspective on Meaning-Making in Molecular Life Science. (Doctoral Dissertation) Linköping University
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