Teaching and Learning about Infectious Diseases in the Aftermath of COVID-19

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Faculty of Health, Science and Technology

Biology

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ABSTRACT

The COVID-19 pandemic profoundly affected children's everyday experiences in schools worldwide. As future outbreaks are inevitable, it is essential to understand how teaching and learning about infectious diseases was shaped by the COVID-19 pandemic, in order to develop biology education to meet the needs for future epidemic-prone diseases. This thesis investigates how knowledge about infectious diseases is transformed from sources external to the school system into knowledge presented and understood in Swedish middle school classrooms. The overarching research question is: *How is the portrayal of knowledge about infectious diseases reflected in biology textbooks, teachers' practices, and pupils' understanding in the aftermath of COVID-19*? The thesis comprises four empirical studies, each examining a distinct stage in this transformation of knowledge, from academic and societal domains to what is actually taught and learned. The findings are interpreted through *contagion literacy*, a framework outlining the competencies expected of health-literate citizens and related to the concept of powerful knowledge. A comparative textbook analysis (Paper I) of editions published before and after the pandemic reveals that representations of infectious diseases remained largely unchanged, with an emphasis on functional health literacy describing content knowledge rather than how to act upon this knowledge. In practice, teaching during the pandemic was shaped by pupil-initiated, question-driven discussions about current events, rather than by an expansion of the planned biology curriculum (Paper II). Studies of pupils' understanding (Papers III and IV) show that while COVID-19 influenced their thinking, their conceptual grasp of infectious diseases and microorganisms remained limited and often based on informal sources such as the media and the internet, rather than formal biology education. The thesis argues for the deliberate integration of contagion literacy into science education with the addition of the host and its immune response as new aspects. Such knowledge constitutes potential powerful knowledge, essential for preparing pupils to navigate future public health challenges and pandemics as critically engaged citizens.

SAMMANFATTNING

COVID-19-pandemin påverkade barns vardag i skolor världen över och tydliggjorde den avgörande betydelsen av infektionssjukdomar. Eftersom framtida pandemiutbrott är oundvikliga är det viktigt att förstå hur undervisning och lärande om infektionssjukdomar formades av COVID-19-pandemin, i syfte att utveckla en biologiundervisning som bygger på denna förståelse. Denna avhandling undersöker hur kunskap om infektionssjukdomar transformeras från källor utanför skolsystemet till den kunskap som presenteras och förstås i svenska klassrum på mellanstadiet. Den övergripande forskningsfrågan lyder: *Hur återspeglas framställningen av infektionssjukdomar i biologiläroböcker, lärares undervisning och 10–12-åriga elevers förståelse i efterdyningarna av COVID-19*? Avhandlingen omfattar fyra empiriska delstudier som belyser olika steg i denna kunskapstransformation från akademiska och samhälleliga domäner till vad som faktiskt undervisas och förstås av elever. Resultaten tolkas genom begreppet contagion literacy, ett ramverk som beskriver den kunskap och de kompetenser som förväntas av hälsokunniga medborgare, samt i relation till begreppet kraftfull kunskap. En jämförande läromedelsanalys (I) av utgåvor före och efter pandemin visar att framställningen av infektionssjukdomar i stort sett förblivit oförändrad, med fokus på biologiska begrepp snarare än hur man kan agera utifrån sin kunskap. I praktiken präglades undervisningen under pandemin av elevinitierade, frågedrivna diskussioner om aktuella samhällshändelser, snarare än av en utvidgning av den planerade biologiundervisningen (II). Studier av elevers förståelse (III-IV) visar att coronaviruset och pandemin har en framträdande plats i deras föreställningar, men att deras begreppsliga förståelse av infektionssjukdomar och mikroorganismer är begränsad. Eleverna hämtade ofta sin kunskap från informella källor såsom medier och internet, snarare än från skolans biologiundervisning. Avhandlingen argumenterar för en medveten integrering av contagion literacy i naturvetenskapsundervisningen med ett tillägg av ett värd-perspektiv där immunsvaret inkluderas. Denna kunskap utgör en potentiellt kraftfull kunskap som är avgörande för att förbereda elever att möta framtida folkhälsoutmaningar och pandemier som kritiskt engagerade medborgare.

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Foreword

This thesis, “Teaching and learning about infectious diseases in the aftermath of COVID-19” is a product of my work as a member of the KÄKK graduate school (2020), a collaboration between Karlstad University, Halmstad University and University West aimed at teacher educators. The graduate school is funded by a project grant from the Swedish Research Council (ref. 2019-04419). KÄKK’s ambition is to strengthen the scientific underpinnings of teacher education by honing teacher educators’ and teachers’ basic competence in and understanding of how subject knowledge can be transformed into teaching content. The aim of the graduate school is to promote the theoretical development of primary and secondary teacher education in Sweden and internationally via a practice-oriented approach focused on powerful knowledge and how different aspects of subject transformation can occur within different school subjects and stages of education.

Preface

Through my participation in the graduate school "Knowledge, Subjects and Quality in Teacher Education and Classroom" (KÄKK), I have had the opportunity to investigate how infectious diseases are taught and understood in the aftermath of the COVID-19 pandemic. The timing of the pandemic coincided with my admission to the graduate school, making it a natural and timely focus for my research. This context provided a unique opportunity to examine educational responses to infectious disease both during and in the aftermath of the pandemic. This thesis aims to contribute to a deeper understanding of how infectious diseases are addressed within biology education, with a primary emphasis on middle school and additional insights into lower secondary education.

Acknowledgements

I want to express my sincere gratitude to my supervisors, Professor Niklas Gericke and Anna Jakobsson, for their invaluable guidance and support throughout this doctoral journey. I am also grateful to Professor Lena Tibell for her insightful feedback at the 10% seminar, which helped shape the early direction of this work. Special thanks are due to Jenny Byrne for her constructive comments at the mid-seminar, and to Professor Gail Jones for a valuable discussion at the 90% seminar.

I am particularly thankful to Kristoffer Sundberg for our enriching philosophical discussions on teaching and understanding. I also wish to acknowledge the leadership of the KÄKK graduate school for a supportive and stimulating research environment, as well as my colleagues at University West and Karlstad University for their collegiality and encouragement. Heartfelt thanks go to my fellow doctoral colleagues in KÄKK and “Lilla SMEER” for your companionship and shared sense of purpose throughout this journey. I am deeply grateful to my close friends and extended family for your unwavering support.

Finally, I extend my sincere thanks to the pupils and teachers who participated in the study, the parents who provided consent, and the headteachers who facilitated school visits during a period of restricted access. I am also thankful to Anna Linzie for her careful language revision.

List of papers

This presentation is based on the following papers.

Paper I

Rönner, A. C., Jakobsson, A., & Gericke, N. (2025). Portrayal of infectious diseases in biology textbooks – a comparative analysis of editions published before and after the COVID-19 pandemic. *Manuscript submitted for publication*

Paper II

Rönner, A. C., Jakobsson, A. & Gericke, N. (2024). Teaching infectious diseases during and in the aftermath of the COVID-19 pandemic – middle school teachers' choice of content and instructional approaches. *International Journal of Science Education*, 1–20. https://doi.org/10.1080/09500693.2024.2425872

Paper III

Rönner, A. C., Jakobsson, A., & Gericke, N. (2023a). Cough, sneeze, pass it on – pupils' understanding of infectious diseases in the aftermath of COVID-19. *Journal of Biological Education*, 58(5), 1117–1129. https://doi.org/10.1080/00219266.2022.2159492

Paper IV

Rönner, A. C., Jakobsson, A., & Gericke, N. (2023b). Bacteria are not viruses; viruses are more malicious – young pupils' understanding of bacteria and viruses in the aftermath of COVID-19. *Journal of Biological Education*, 58(5), 1434–1447. https://doi.org/10.1080/00219266.2023.2247409

Author's contributions

The initial research ideas and overall project design were developed by me and subsequently refined in collaboration with my supervisors, Niklas Gericke and Anna Jakobsson. They introduced me to the field of biology education research and provided continuous guidance throughout the project. Together, we formulated the research questions. I was responsible for collecting and processing all data, and I conducted both the thematic and content analyses with regular input from my supervisors. I drafted all four papers included in this thesis; these were reviewed, revised, and commented on by my supervisors during the manuscript development process. I also managed the submission and peer review procedures. A detailed description of the contributions to each paper is provided below.

Paper I

The research design for the textbook study was developed jointly with my supervisors. I selected the textbooks and carried out the content and thematic analyses independently. My supervisors contributed to the development and validation of the thematic categories. I wrote the initial manuscript draft, which was subsequently refined through monthly supervision meetings.

Paper II

The general research design was developed in collaboration with my supervisors. I designed the interview guide, conducted and transcribed the semi-structured interviews, and performed the thematic analysis independently, with monthly supervisory support. I prepared the manuscript draft, which was revised during regular supervision.

Papers III and IV

The research design was developed collaboratively. I independently initiated, planned, and conducted the interviews, transcribed the data, and carried out the thematic analyses. My supervisors contributed to the development and validation of the thematic categories. I wrote the initial drafts of both manuscripts, which were further developed through monthly supervisory input.

1. Introduction

The COVID-19 pandemic profoundly disrupted societies worldwide, with schools emerging as central arenas where the effects of the crisis were acutely experienced. The pandemic underscored the critical importance of knowledge concerning pathogenic microorganisms, hygiene, and infectious diseases, not only for public health management but also for science education. In this context, Sweden presents a particularly compelling case. Unlike many countries that implemented strict lockdowns and school closures, Sweden adopted a comparatively lenient approach, relying on voluntary compliance and individual responsibility (Haverty, 2021). Middle schools remained open throughout the pandemic, except during severe local outbreaks. This continuity of schooling created a unique opportunity to examine how biology education adapted in real time to an unfolding global health crisis.

Although the teaching of infectious diseases is a mandated component of the Swedish biology curriculum, it has historically received limited attention in both classroom practice and educational research worldwide (Jones & Rua, 2006; Byrne & Grace, 2018). As early as 2008, Jones emphasised the need for comprehensive public education on infectious diseases, while Byrne (2011) argued that pupils should be well informed about these aspects of science. More recently, Byrne, Marston and Grace (2021) and Simard (2021) have noted that the pandemic brought both opportunities and challenges for biology education. On the one hand, the crisis heightened public interest in microbiology and health-related topics, offering authentic contexts for learning. On the other hand, teachers were tasked with navigating rapidly evolving information, implementing new hygiene routines, and addressing pupils' questions and concerns, all while maintaining curricular coherence.

In light of these developments, it becomes essential to understand how knowledge about infectious diseases is shaped within the educational system. Did the real-time experience of a pandemic trigger shifts in the content and methods of biology teaching? Were textbooks and teaching materials revised to reflect the new societal context? How did pupils make sense of microorganisms and disease in light of their lived experiences and media exposure? These questions are particularly salient in middle school settings, where pupils are developmentally positioned to engage with both scientific and socio-scientific aspects of health and disease.

This thesis investigates the transformation of knowledge about infectious diseases as it moves from societal and academic domains into the classroom. Transformation refers to the reconstructing of subject-specific knowledge into content that is both meaningful and accessible to pupils (Gericke, Hudson, Olin-Scheller & Stolare, 2018). The thesis comprises four empirical studies, each examining a distinct stage in this transformation process, from academic and societal knowledge domains to what is actually taught and learned in school. Paper I presents a comparative analysis of biology textbooks published before and after the pandemic. Paper II investigates how middle school teachers approached the teaching of infectious diseases during the pandemic. Papers III and IV explore pupils' understanding of infectious diseases, bacteria, and viruses in the aftermath of the COVID-19 pandemic.

The findings are interpreted through contagion literacy (Kilstadius & Gericke, 2017) and related to the concept of powerful knowledge (Young, 2008). Powerful knowledge refers to systematic, specialised, and conceptually coherent disciplinary knowledge that enables pupils to transcend their everyday experiences and engage with the world in more informed and critical ways (Young, 2008). By analysing how this knowledge is selected, reshaped, and communicated in the school context, the thesis contributes to broader discussions about the role of science education in providing pupils to navigate complex public health challenges as critically engaged citizens.

2. Aim and research questions

This thesis investigates how knowledge about infectious diseases is transformed from sources external to the school system into knowledge that is taught and understood in Swedish middle school classrooms. In this context, *transformation* refers to the process of reconstructing subject-specific knowledge into content that is both meaningful and accessible to pupils, while retaining its conceptual depth and disciplinary integrity (Gericke et al., 2025). By investigating this transformation in the aftermath of the COVID-19 pandemic, this thesis aims to explore whether pupils are being educated in ways that foster comprehensive understanding of infectious diseases (including their prevention and treatment) or if there is a need to re-evaluate and transform curricular content and pedagogical approaches to better prepare young people for future public health challenges, such as future pandemics.

The overarching research question is: *How is the portrayal of knowledge about infectious diseases reflected in biology textbooks, teachers' practices, and pupils' understanding in the aftermath of COVID-19*?

A central concern underpinning this inquiry is whether pupils are provided with the knowledge and understanding necessary to navigate public health crises such as pandemics. This includes the development of contagion literacy (Kilstadius & Gericke, 2017), a set of capabilities that may be linked to powerful knowledge (Young, 2008). Such knowledge encompasses scientific understanding of disease transmission, prevention strategies, and the broader societal implications of infectious diseases.

The specific research questions addressed in this thesis are designated IA–IV, corresponding to the four empirical studies included (see List of Papers). The first two studies each address two research questions, while the final two focus on one question each.

- To what extent and how does the prevalence of contents supporting contagion literacy differ between biology textbook editions published before and after the beginning of the COVID-19 pandemic (IA)?

- How does COVID-19 appear in textbooks published after the start of the pandemic (IB)?

- What content themes and levels of health literacy from the contagion literacy framework are emphasised by teachers when describing teaching about infectious diseases in the aftermath of COVID-19 (IIA)?

- What teaching approaches do teachers specify when describing their teaching about infectious diseases in the aftermath of COVID-19, and how do these approaches relate to the levels of health literacy (IIB)?

- How do middle school (10–12-year-old) pupils understand infectious diseases and what are their perceived sources of knowledge in the aftermath of COVID-19 (III)?

- How do middle school pupils understand and reason about bacteria and viruses in the aftermath of COVID-19 (IV)?

3. Literature review

3.1. Textbook representations of infectious diseases

In Sweden, biology textbooks are widely used to support the teaching of infectious diseases, particularly in compulsory school settings. Bohlin and Höst (2015), for instance, underscored their role in addressing antibiotic resistance in secondary education. However, research specifically examining how infectious diseases are represented in biology textbooks at the compulsory school level remains limited.

Prior to the COVID-19 pandemic, studies by Byrne (2011) in England and Jones and Rua (2006) in the United States explored how microorganisms were depicted in school textbooks. Byrne found that British textbooks most frequently portrayed bacteria, while Jones and Rua observed that American textbooks often included photographic images of bacteriophages. While visually striking, the choice to include bacteriophages may be problematic in an educational context. Bacteriophages are viruses that infect bacteria—not human cells—and are therefore not responsible for human infectious diseases (Keen, 2012). Although bacteriophages are scientifically significant, having played a role in microbial evolution and currently used in therapeutic medicine, food preservation, aquaculture, and environmental remediation (Sharma et al., 2017), their relevance to human infectious diseases is indirect. This is because bacteriophages are used to treat bacterial infections when other treatments, such as antibiotics, fail—unlike most viruses, which are themselves pathogens. Without sufficient explanation, their inclusion in school textbooks may lead to confusion, particularly among younger pupils, who may struggle to distinguish between different types of pathogens and their respective treatments (Jones & Rua, 2008). Even upper secondary students have been shown to have difficulty differentiating between disease prevention and treatment (Barenholz & Tamir, 1987).

A small but growing body of research has begun to examine textbook representations of infectious diseases in the aftermath of the COVID-19 pandemic. Studies conducted in Austria (Hoffer, Lex, & Simon, 2022), Greece (Ampatzidis & Armeni, 2024), and Indonesia (Fikri, Suwono & Susilo, 2024) have analysed biology textbooks aimed at upper secondary students. However, none of these studies directly investigated whether or how textbook content has changed over time in response to the pandemic. Hoffer et al. (2022) reported that many textbooks fail to distinguish clearly between viruses and bacteria, explain the non-living nature of viruses, or clarify that antibiotics are ineffective against viral infections.

Similarly, Fikri et al. (2024) found that pathogens are often discussed regarding symptoms but are rarely explicitly linked to the infectious diseases they cause. This lack of clarity risks obscuring the distinction between symptoms and diseases, making it more difficult for pupils to understand the clinical and epidemiological characteristics of conditions such as COVID-19. Fikri et al. also noted frequent misrepresentations and overgeneralisations in Indonesian textbooks, what Hoffer et al. (2022) describe as a lack of precision and scientific accuracy. Furthermore, Hoffer et al. (2022) emphasised the need to strengthen vaccination-related content in textbooks, particularly in light of recent outbreaks of preventable diseases such as measles. These outbreaks illustrate how contemporary efforts to transform and communicate scientific knowledge have, in this instance, failed to achieve their intended impact, underscoring persistent gaps in public understanding and educational practice.

Ampatzidis and Armeni (2024) examined Greek biology textbooks and found that microorganisms are often portrayed negatively, a trend linked to the impact of the COVID-19 pandemic and frequent mentions of SARS-CoV-2. They call for a more balanced depiction that also draws attention to the beneficial roles microorganisms play in human health.

In spite of these contributions, no existing studies have examined directly whether and how biology textbooks have revised their portrayals of infectious diseases and pandemics in response to COVID-19. While the literature stresses the importance of accurate distinctions between infectious agents, comprehensive vaccination content, and attention to pupils' prior conceptions, it has yet to address how textbook narratives may have evolved in response to a global health crisis marked by widespread mortality and societal disruption.

3.2. Teaching infectious diseases in compulsory schooling

Existing literature on the teaching of infectious diseases and microorganisms has primarily focused on secondary and tertiary education (e.g. Dumais & Hasni, 2009; Lundström, 2015; Lundström, Ekborg & Ideland, 2012; Simonneaux, 2000; Thanasas et al., 2020), while studies at the compulsory school level remain limited. This gap is problematic, as teaching about infectious diseases in middle school presents distinct pedagogical challenges (Byrne & Grace, 2018). Insights from studies specifically addressing this age group are therefore particularly valuable.

Some research has explored targeted teaching interventions. For example, Shoker et al. (2021) emphasised the need for updated strategies in primary education, including international modules aimed at preventing viral infections. Similarly, Webb (2016) proposed service-learning approaches in which undergraduate microbiology students engage with primary school pupils to enhance learning outcomes. There is also limited research on how infectious diseases are taught in middle school and the challenges that educators face. A recurring issue identified in the literature is the persistence of misconceptions—among both pupils and teachers—regarding microorganisms and infectious diseases (Arroita, Iradi, Ortega-Lasunen & Diez, 2022; Jones & Rua, 2006, 2008; Nagy, 1951, 1953; Prout, 1985). Jones and Rua (2006) note that confusion often arises from the broad use of terms such as “viruses,” which can obscure distinctions between specific diseases like influenza and pneumonia. Similar ambiguity is evident when the term “corona” is used to refer both to the infectious disease and the causative agent (see also Papers I and IV). Such lack of clarity may hinder pupils’ understanding of how microorganisms replicate and cause infection (Hoffer et al., 2022).

Misconceptions tend to emerge in contexts where information is incomplete or where scientific questions remain unresolved. In such cases, individuals often rely on intuitive explanations to fill knowledge gaps, which can lead to misunderstandings (Center for Disease Control and Prevention, 2021). Understanding how misconceptions and conspiracy theories influence public health behaviours is therefore essential for developing effective educational responses, particularly regarding vaccination. Teachers’ awareness of pupils’ misconceptions is crucial in this process, as these misconceptions often persist even after instruction and may hinder the development of scientifically accurate understanding (Driver et al., 1994a). Winters et al. (2021) further emphasise that targeted communication strategies, such as explicitly addressing and correcting misinformation, can significantly improve public understanding and acceptance of health interventions.

Teaching and learning about vaccinations involve a range of pedagogical challenges that have been explored in previous research. Lundström (2015) discusses the difficulty of aligning curricular intentions with the realities of classroom practice. Jones and Rua (2008) focus on the importance of stimulating learners' curiosity and encouraging scientific engagement, while Thanasas et al. (2020) draw attention to how gaps in teachers' subject knowledge may hinder effective instruction. These studies collectively point to a recurring tension between educational aims and the conditions under which teaching occurs, where limited conceptual clarity and pedagogical support can constrain meaningful engagement with vaccination-related content. This tension is further exemplified in the work of Kwella et al. (2025) and contributors such as Bryce (2025), who observe that vaccination is often treated superficially in school biology curricula. Ethical dimensions are rarely addressed, which may restrict 13–18-year-old pupils' ability to critically engage with the topic in relation to real-world contexts.

Arroita et al. (2022) argue that current science education is not sufficiently aligned with contemporary research on microorganisms and infectious diseases. This misalignment contributes to persistent misconceptions and limits pupils' ability to engage critically with microbiological concepts, particularly in public health contexts. Merkel (2012) similarly contends that microbiology is underrepresented in primary and secondary education and often lacks connections to everyday life, underscoring the need for real-world examples to support deeper understanding.

While health education and infectious diseases are addressed in the biology curriculum, they are also embedded within broader health initiatives in schools, including routines and responsibilities managed by staff such as school nurses (Borawski et al., 2015). However, little is known about what is actually taught in schools regarding infectious diseases, or whether and how this teaching has changed in response to the COVID-19 pandemic. Nonetheless, the emergence of COVID-19 has revealed both opportunities and challenges for science education in this area (see also Simard, 2021).

3.3. Pupils' understanding of infectious diseases

3.3.1. Informal knowledge and conceptual development

Learners' understanding of infectious diseases is shaped not only by formal instruction but also by informal sources such as family, media exposure, and everyday experiences (Driver et al., 1994a; Jones & Rua, 2006). These informal influences often precede formal education and contribute to the development of early conceptions about health and disease. Media exposure, including television, newspapers, and digital platforms, can introduce vivid and emotionally resonant representations of microorganisms and illness, which may persist and influence later learning (Simonneaux, 2000; Carvalho, 2016).

Research in science education has shown that children begin constructing ideas about natural phenomena, including biological processes, well before encountering these topics in school (Driver, 1994b; Kalish, 1997, 1999). These early ideas are often intuitive and shaped by everyday experiences, resulting in a coexistence of informal and scientific conceptions. Driver et al. (1994a) emphasise that learners frequently hold both types of understanding simultaneously, which can lead to conceptual tensions but also provide opportunities for learning.

From a sociological perspective, Prout (1985) argues that everyday knowledge, including beliefs about health, is embedded in broader cultural and social contexts. This knowledge is not easily replaced by formal instruction but interacts with it in complex ways, influencing how individuals interpret and respond to scientific information. Understanding this interplay is essential for designing science education that acknowledges learners' prior experiences and supports the development of more robust conceptual frameworks. Understanding this interplay is essential for designing science education that acknowledges learners' prior experiences. Recent research highlights how children's increasing exposure to digital media (especially post-COVID) shapes their understanding of health-related concepts, reinforcing the importance of educational approaches that critically engage with media influences and acknowledge the sociocultural contexts in which such knowledge is formed (Ponti, 2023; Sobel, 2023).

3.3.2. Conceptual challenges and pupils' ideas

Conceptual challenges in understanding infectious diseases often arise from the interaction between informal knowledge and formal science education. Byrne (2011) examined how learners distinguish between school science and everyday beliefs, particularly regarding the causes of the common cold. Her findings suggest that knowledge emerges from diverse social contexts and experiences, and that these influences shape how microorganisms are conceptualised. This issue has become increasingly relevant in the post-pandemic context, where children are exposed to a wider range of information sources than before.

Direct experiences with illness also contribute to learners' ideas about disease causation (e.g. Piko, 2006). Persistent misconceptions such as the belief that colds result from exposure to cold weather (Byrne, 2011; Prout, 1985; Sigelman, 2012), or that antibiotics are effective against viral infections (Arroita et al., 2022; Bracko & Simon, 2022; Jones & Rua, 2008) can impede scientific understanding. These ideas often stem from everyday knowledge shaped by personal experience and cultural traditions. While such knowledge may serve as a foundation for learning, it can also conflict with scientific explanations. Studies have also identified gaps in people's understanding of the function of vaccines (e.g. Jones & Rua, 2008). These include limited and often inaccurate conceptions of vaccine contents and immune responses among pupils and teachers, which are further illuminated by research into how social and media factors influence decision-making.

Lundström et al. (2012) explored decision-making around influenza vaccination in upper secondary education, showing that scientific knowledge and risk perception are influenced by social factors such as family, solidarity with family members, and media exposure. Later work by Lundström et al. (2016) analysed representations in the media of human papillomavirus (HPV) vaccination in middle school contexts, revealing tensions between individual autonomy and collective responsibility. These findings underscore the importance of recognising pupils' preconceptions and integrating media literacy and ethical reasoning into science education, particularly when addressing topics related to infectious diseases and public health.

3.3.3. Microbial scale and ontology

Understanding the size and scale of microorganisms is essential for grasping their diversity and potential for dissemination (Juhas, 2023). Previous studies have shown that learners often struggle to differentiate between bacteria and viruses, due to misconceptions about their relative size and morphology (Arroita et al., 2022; Byrne, 2011; Jones & Rua, 2006; Simonneaux, 2000; Tretter et al., 2006). The term *microscopic* typically refers to entities invisible to the naked eye and observable only through magnification. However, this concept is not consistently understood, particularly regarding the absolute size of microorganisms (Byrne, 2011; Simonneaux, 2000; Nagy, 1953).

In Byrne's (2011) study (involving 7–14-year-old participants) many learners demonstrated limited understanding of microbial scale. Similarly, Arroita et al. (2022) found that while a substantial proportion of 15-year-olds recognised that microorganisms require magnification to be seen, misconceptions about their relative size persisted. Tretter et al. (2006) reported that learners aged 10–11 were more likely to grasp relative rather than absolute size, yet struggled to rank microscopic entities accurately, indicating that scale remains a challenging concept.

Children's conceptualisations of microbial morphology have also been explored through drawing-based studies conducted prior to the COVID-19 pandemic (Byrne, 2011; Byrne, Grace & Hanley, 2009; Jones & Rua, 2006; Simonneaux, 2000; Vasquez, 1985; Maxted, 1984; Nagy, 1953). Byrne (2011) found that microorganisms were often imagined as miniature animals (sometimes resembling worms or insects) and frequently anthropomorphised with facial features or limbs. Similar patterns were observed in other studies, where microorganisms were depicted as beetles or other insect-like forms (Ballesteros, Panos & Ruiz-Gallardo, 2018; Giordan, 2015; Simonneaux, 2000; Nagy, 1953). Confusion between bacteria and viruses is also common. In a study by Simonneaux (2000), 17–18-year-olds used the terms interchangeably, and Jones and Rua (2006) reported that learners viewed bacteria, viruses, and unicellular fungi as essentially the same. These findings suggest that learners face difficulties in identifying differences in size, morphology, and biological function.

To address these challenges, Knippels and Waarlo (2018) proposed a "yo-yo" pedagogical strategy, which supports learners in navigating between different levels of biological organisation: molecular, cellular, and organismal. This approach encourages perspective-shifting and integration of knowledge across contexts, helping to clarify structural and functional distinctions. Pettersson, Tibell, and Löfgren (2021) and Thyberg, Schönborn, and Gericke (2024; 2025) also support this strategy as a means of guiding learners between organisational levels.

Misconceptions about the ontological status of microorganisms, whether they are living or non-living, have been documented prior to the pandemic. Jones and Rua (2006) found that many learners considered all microorganisms to be non-living, which is accurate for viruses but not for bacteria. In contrast, Simonneaux (2000) reported that older learners viewed viruses as living organisms capable of independent movement and growth, despite lacking a host.

Ecological aspects such as occurrence, function, and pathogenicity are central to understanding the nature of microorganisms. However, limited knowledge in these areas has been identified as problematic (Simard, 2021; Ballesteros et al., 2018). Earlier studies (Byrne, 2011; Jones & Rua, 2006, 2008; Nagy, 1953) found that learners often associate microorganisms primarily with humans. Byrne (2011) identified three additional conceptualisations of microbial localisation: microorganisms were thought to exist everywhere, in dirty or unhygienic places, or in proximity to animals. This anthropocentric framing can obscure the ubiquity and ecological diversity of microorganisms (Simard, 2021; Ballesteros et al., 2018).

Further misconceptions include the belief that differences between bacteria and viruses are based on symptoms experienced by humans (Jones & Rua, 2006), and a lack of understanding of the term pathogenic agent among older learners (Simonneaux, 2000). Nagy (1953) observed that younger children (5–11 years old) were often unaware that specific infectious diseases are caused by distinct microorganisms. Arroita et al. (2022) found that participants performed better on questions related to microbial ubiquity than on those concerning microbial function. Overall, prior to the COVID-19 pandemic, learners demonstrated limited understanding of microbial localisation and ecological roles, often associating microorganisms with disease and failing to distinguish their broader biological significance (Byrne, 2011). The next section examines how the COVID-19 pandemic influenced the teaching and learning of infectious diseases, with particular attention to shifts in content, context, and pedagogical focus.

3.4. COVID-19 and its influence on the teaching and learning of infectious diseases

The COVID-19 pandemic highlighted the importance of connecting science education to lived experiences. It presented a unique opportunity to design pedagogical strategies that build informal learning and guide it toward scientifically accurate models. This perspective emphasises the potential of using everyday encounters with health-related information as a foundation for formal instruction. As Khine (2013) and contributors such as Bryce (2013) argue, textbook content plays a critical role in shaping pupils' understanding of science, particularly in primary education. Their analysis underscores the need for clear, accurate, and contextually relevant materials to support meaningful engagement with health-related topics among pupils aged 10–12.

The pandemic also revealed limitations in traditional curricula when addressing urgent socio-scientific issues, reinforcing the need for flexible and context-sensitive teaching approaches. Concomitantly, integrating vaccine education into science curricula has become essential for countering misconceptions and supporting informed citizenship. As Ratcliffe and Grace (2003) argue, science education must evolve to include informal and ethically grounded learning experiences that reflect real-world challenges, thereby fostering competence in understanding infectious diseases and public health.

Byrne, Marston, and Grace (2021) show how spontaneous questions from pupils during the pandemic can serve as valuable entry points for engaging with scientific concepts. In mid-2020, they asked 15–16-year-old participants what they wanted to know about COVID-19 and identified seven thematic areas: causes and origin, incidence and distribution, risk factors and virulence, control measures, safety rules, symptoms and immune response, and personal and future concerns. Their findings suggest that learners seek accurate and reliable information to support decision-making and deepen their understanding.

A Spanish study by Idoiaga et al. (2020) explored the social and emotional portrayals of the pandemic among children. The coronavirus was often depicted as an enemy being fought by medical professionals. The study concluded that future science education must address learners' emotional and cognitive needs in response to pandemics. These findings point to new opportunities for responsive teaching practices that reflect learners' concerns and curiosities. This aligns with arguments that science education should be attuned to affective experiences and ecological perspectives, especially in times of crisis.

Vaccine education has emerged as a central component in advancing infectious disease literacy. This includes addressing conspiracy beliefs, vaccination intent, and the communication of critical events in vaccine trials (Ghaddar et al., 2022; Memenga et al., 2022; Mousoulidou et al., 2023). A particularly urgent challenge is the spread of conspiracy theories, which often offer unfounded explanations involving hidden actors and lack empirical support (Douglas et al., 2019; Vaino, Semilarski & Semilarski, 2023). Empirical studies confirm that pupils often lack foundational knowledge about vaccine development, underscoring the need for targeted vaccine education in schools (Hoffer et al., 2022). These narratives tend to proliferate during crises, undermining public trust in science. Addressing such claims in the classroom is essential for strengthening scientific literacy and protecting public health. Providing learners with analytical tools to evaluate such claims is crucial. Emotional influences and social narratives also shape learners' understanding of health crises, suggesting that science education must incorporate socio-emotional dimensions to be effective (Iverson-Cabral, 2021; Hoffer et al., 2022).

Research has documented the multifaceted impact of the COVID-19 pandemic on science education, revealing both challenges and opportunities. Learners' lived experiences, spontaneous questions, and emotional responses have become valuable resources for developing competence in understanding infectious diseases. Concomitantly, the spread of misconceptions and conspiracy theories underscores the need to provide learners with critical reasoning skills and a scientifically grounded understanding. These insights support the development of responsive pedagogical strategies that bridge formal and informal learning.

The pandemic also prompted shifts in pedagogical priorities, with teachers increasingly relying on pupils' lived experiences and spontaneous questions to guide instruction (Byrne et al., 2021). This shift underscores the importance of integrating informal knowledge into formal science education, especially when addressing urgent socio-scientific issues. As documented in Paper II, teaching practices often became reactive and discussion-based, reflecting a need for flexible pedagogical frameworks that accommodate real-time societal developments.

These findings align with broader calls for science education to support emotional engagement and critical reasoning. Idoiaga et al. (2020) emphasise the importance of addressing learners' emotional and cognitive needs during health crises, while Iverson-Cabral (2021) demonstrates how interdisciplinary approaches to teaching quarantine and isolation can foster deeper understanding. Hoffer et al. (2022) further shed light on the need for scientifically grounded instruction to counter misconceptions and support informed decision-making in the context of infectious diseases.

4. Theoretical framework

This section outlines the theoretical framework guiding the study, with a central emphasis on the concept of contagion literacy (Kilstadius & Gericke, 2017). Drawing on the foundation of health literacy, contagion literacy offers a structured lens for examining how learners engage with infectious disease content in compulsory school biology education. It is used as the primary analytical tool in Papers I and II and informs the analysis in Papers III and IV. This framework enables a coherent interpretation of how knowledge about infectious diseases is approached, understood, and communicated across varied educational contexts.

Health literacy is included to conceptualise the cognitive and social competencies required to navigate health-related information. It has informed the development of contagion literacy, which extends these competencies to encompass the specific challenges of understanding and responding to infectious diseases.

Although the concepts of powerful knowledge and transformation were not directly operationalised in the empirical studies, they are introduced here to shed light on the broader educational significance of the thesis. These perspectives align with the aims of the graduate school KÄKK (Knowledge, Subjects and Quality in Teacher Education and Classroom), situating the thesis within a wider discourse on science education and public health engagement.

4.1 Health literacy

The focus on literacy in this thesis stems from the recognition that even basic functional literacy skills enable individuals to expand their knowledge, pursue personal goals, and participate more fully in society, both socially and economically.

The concept of *health literacy* was introduced by Nutbeam (1998) and is included in this thesis as it informed the development of the theoretical framework *contagion literacy* (see section 4.2). Nutbeam (2000) identified three dimensions of health literacy: functional, interactive, and critical (p. 263–264).

Functional health literacy refers to the ability to understand, apply, and critically evaluate health-related information to make informed decisions and adopt preventive measures. It includes reading and writing skills relevant to health and disease (Nutbeam, 2000). Interactive health literacy encompasses more advanced cognitive and communicative abilities that support active participation in everyday situations. It involves extracting essential information, interpreting meaning, and applying new knowledge in response to changing conditions (Nutbeam, 2000). Critical health literacy involves the highest level of cognitive and social competencies. These skills enable individuals to critically analyse health information and use it to exert greater control over life circumstances. This includes the capacity to proactively influence future health-related decisions and environments (Nutbeam, 2000).

Each of these dimensions plays a distinct role in supporting the development and application of health-related knowledge. Together, they provide a foundation for engaging with health information in a way that strengthens the capacity for informed decision-making and responsible public health behaviour.

4.2. Contagion literacy – what to teach about infectious diseases

Kilstadius and Gericke (2017) used the health literacy framework, specified it to school knowledge and infectious diseases and developed parts of it (levels) into a more specific framework named *contagion literacy*. The aim was to identify specific knowledge and competencies necessary for understanding and responding to infectious diseases, particularly regarding what to teach in compulsory school. Kilstadius and Gericke (2017) report on a Delphi panel including various experts in infectious diseases which identified six content themes to teach: (1) contagions, (2) transmission routes, (3) hygiene, (4) vaccinations, (5) antibiotics and antibiotic resistance and (6) sexually transmitted diseases. These areas of knowledge were considered by the panel to be pivotal for someone to be considered literate and have the ability to act against infectious diseases (Kilstadius & Gericke, 2017).

Thereafter, Kilstadius and Gericke (2017) formulated three cognitive levels of literacy by combining the framework of health literacy (Nutbeam, 2000) with an updated version of Bloom's taxonomy of learning objectives (Airasian et al., 2001). The three literacy levels are explained briefly by the following definitions. (a) Functional health literacy, which refers to factual knowledge regarding health risks, health conditions, and how the health system can be used. (b) Interactive health literacy encompasses the personal competencies required to act in ways that support individual and public health. (c) Critical health literacy, which pertains to social and cognitive skills related to analysis and critical reflection. The last literacy level enables understanding of infectious diseases from a societal perspective, including the proactive decisions and skills necessary to protect others. The individual should, at the appropriate level, have understanding and skills to critically review health information by different sources as well as reflect on the fact that infectious diseases are dependent on social, economic and environmental aspects (Kilstadius & Gericke, 2017).

The different contagion literacy levels offer distinct advantages for developing learners' ability to help prevent and manage infectious disease outbreaks and pandemics (Kilstadius & Gericke, 2017). Functional literacy is essential for understanding the science of infectious diseases, which in turn could motivate action. Interactive instructions are useful to engage someone actively or to establish routines for action without necessarily providing ample reasons for such engagement. Critical health literacy is important for understanding causal relationships, making informed decisions, and learning from prior experiences, as well as being able to respond to future events. Also, it includes the ability to transfer knowledge across different contexts, such as from one infectious disease or pandemic to another.

The relationship between health literacy and contagion literacy can be described as one of general to specific scope, where contagion literacy constitutes a focused subset within the broader domain of health literacy. Health literacy is broadly defined as the capacity to access, understand, appraise, and use health-related information in ways that promote and maintain personal and public well-being. According to the World Health Organization (WHO), health literacy encompasses the personal knowledge and competencies that individuals develop through daily activities and social interactions and is mediated by the availability of resources and organisational structures that support informed health decisions and actions (WHO, 2024). This includes cognitive and social competencies that underpin motivation and the ability to act on health information in everyday life, spanning areas such as self-care, disease prevention, and critical engagement with health services (Nutbeam, 2000; WHO, 2024).

Contagion literacy can thus be conceptualised as a distinct, application-oriented subset of health literacy, specifically focused on infectious disease awareness, prevention, and management. It involves the ability to interpret and act upon information related to communicable diseases, including information about transmission routes, risk mitigation strategies, and public health measures such as vaccination and quarantine (Kilstadius & Gericke, 2017). Robust health literacy provides the cognitive foundation for the development and exercise of contagion literacy. Individuals with higher levels of health literacy are better prepared to navigate public health guidance and respond effectively during infectious disease outbreaks (WHO, 2024).

Both constructs operate across functional, interactive, and critical dimensions (Nutbeam, 2000), but contagion literacy narrows its focus to the specific knowledge, risk perceptions, and behavioural competencies required to manage communicable disease threats. Thus, contagion literacy should be viewed as a critical component of public health preparedness, nested within the conceptual and practical framework of health literacy. It provides individuals with the tools to respond knowledgeably and responsibly to contagion risks in diverse contexts. Finally, the contagion literacy framework (Kilstadius & Gericke., 2017) aligns with important educational goals related to empowerment and equity, in line with the transformative aims of powerful knowledge as discussed in next section.

In most sections of this thesis, the full contagion literacy framework was applied, encompassing six content themes and the three levels of health literacy. However, the term “contagions” was replaced with the term “infectious agents” to eliminate the risk of confusing diseases and pathogens (such as bacteria, viruses, fungi, and parasites). This revision was informed by both linguistic and curricular considerations. In English, the word “contagion” may ambiguously denote either the infectious disease itself or the pathogen responsible for it, potentially leading to conceptual misunderstandings among younger pupils. To enhance clarity and precision, therefore, "infectious agents" was adopted as the preferred term. Likewise, sexually transmitted diseases were omitted due to their minimal representation in middle school curricula, which typically emphasise foundational topics such as hygiene practices and commonly encountered infections, rather than content requiring more advanced contextual understanding in the Swedish middle school biology curricula (Skolverket, 2022).

The contagion literacy framework provides a comprehensive overview of the implications of various content themes and literacy levels. For each combination of theme and literacy level, an example is provided in Table 1. This thesis uses the framework as an analytical tool to analyse the transformation of infectious disease-related knowledge. Paper I and II used contagion literacy as a theoretical framework. Papers III and IV used the framework partly to analyse empirical findings.

Table 1. Modified contagion literacy content themes and health literacy levels (Kilstadius & Gericke, 2017).

Content theme/ level	(a) Functional	(b) Interactive	(c) Critical
(1) Infectious agents	Identifying four different types, explaining distinctions between infectious diseases	Adopting appropriate behaviours in response to the specific type	Distinguishing harmful from beneficial, exponential growth, double-edged claims
(2)Transmission routes	Recognising different types (e.g. air, contact, drop)	Applying different personal protective behaviours to various types	Analysing and critically evaluating information about transmission routes
(3) Hygiene	Recognising and recalling how hygiene historically influenced disease transmission	Applying actions in accordance with recommendations of hygiene policies	Understanding hygiene in terms of solidarity avoiding excessive behaviours
(4) Vaccinations	Mechanisms and differences between vaccines	Relating facts to contemporary decision–making	Safeguarding the population, challenging misconceptions
(5) Antibiotics and antibiotic resistance*	Knowledge of antibiotic types, their uses and of resistance development	Implementation of knowledge about resistance into restrictive usage behaviours	Understanding the impact of antibiotic resistance on public health

*According to the World Health Organization (2023), antimicrobials are essential for the prevention and treatment of infectious diseases in humans, animals, and plants. However, antimicrobial resistance arises when bacteria, viruses, fungi, and parasites no longer respond to these treatments.

4.3 Powerful knowledge

While the concepts of knowledge and literacy are closely related, I acknowledge that their boundaries are not always clear-cut. Integrating them in educational research requires careful consideration to avoid blurring distinct epistemological and pedagogical aims. As discussed in sections 4.1 and 4.2, this thesis draws on the frameworks of health literacy and contagion literacy to explore how pupils engage with knowledge about infectious diseases. In this section, I connect the construct of contagion literacy (which underpins the empirical studies within this thesis) with the theoretical concept of powerful knowledge and the process of transformation.

Contagion literacy focuses on the specific knowledge and competencies required to understand and respond to infectious diseases (Kilstadius & Gericke, 2017). In contrast, powerful knowledge, as minted by Young (2008), refers to systematic, specialised and conceptually coherent disciplinary knowledge that enables pupils to move beyond everyday experiences and engage with the world in more informed and critical ways. By examining how contagion literacy and powerful knowledge interact and overlap within the context of biology education, I aim to explore their respective contributions to curriculum design and how they may be meaningfully related to support epistemically informed biology education about infectious diseases.

Young (2008) emphasises that powerful knowledge is typically discipline-based and valued for its capacity to explain, predict and imagine alternatives, qualities essential for promoting social justice and educational equity (Young, 2013; Young et al., 2014a). However, as Young and Müller (2013, 2014a–c) argue, the relationship between knowledge and learners' capabilities is not straightforward. They caution against conflating knowledge with skills, asserting that while capabilities are important, they must be grounded in access to powerful knowledge to be genuinely transformative. That is, knowledge becomes powerful when it enables individuals to act meaningfully in their everyday lives (Deng et al., 2025) and understand why to.

This distinction is particularly relevant in the context of contagion literacy, which seeks to cultivate pupils' critical awareness and agency in navigating complex socio-scientific issues such as pandemics. While contagion literacy includes practical and critical health literacy competencies, its potential as powerful knowledge lies in its ability to connect disciplinary understanding with societal relevance, thereby enabling pupils to participate in public discourse in meaningful ways and make informed decisions.

Young and Müller (2013) further argue that not all knowledge holds equal epistemic value. Powerful knowledge is transformative because it offers insights that challenge assumptions and support informed participation in society. Including such knowledge in the curriculum is therefore essential, as it enables pupils to imagine alternative futures and engage critically with societal challenges. Young (2009) argued that access to powerful knowledge is a fundamental educational entitlement.

A key question is how to identify and establish powerful knowledge within specific subject domains such as infectious diseases. Gericke et al. (2018) argue that this should be treated as an empirical question, to be addressed through subject-specific educational research. In the context of biology education, Gericke (2024) proposed the use of Delphi methodology to identify powerful knowledge. Following this line of reasoning, the contagion literacy framework developed through a Delphi study may be understood as a subject-specific articulation of powerful knowledge in the domain of infectious diseases.

Although the concept of powerful knowledge was not explicitly used as a guiding framework in the empirical studies included in this thesis, its relevance is considered in the theoretical discussion. It offers a lens through which the potential of biology education—particularly in relation to infectious diseases and contagion literacy—can be understood as structured and conceptually rich. This type of content supports pupils' understanding and strengthens their sense of agency in the context of pandemics. It may also contribute to a more inclusive and epistemically informed science education.

4.4. Exploring contagion literacy as a form of powerful knowledge

This section builds on the discussions in sections 4.1 to 4.3 by further exploring the relationship between powerful knowledge, knowledge transformation, and contagion literacy. Although the empirical studies in this thesis did not explicitly apply the concept of powerful knowledge, the framework is considered here as a theoretical lens. Contagion literacy can be viewed as a subject-specific articulation of powerful knowledge within biology education, particularly in relation to infectious diseases and pandemics. It may offer guidance for identifying essential disciplinary knowledge in compulsory school biology, with potential applications discussed in the Implications section (see section 7.3).

The concept of knowledge transformation (Gericke et al., 2018) refers to the dynamic process of adapting disciplinary knowledge for educational purposes across academic, societal and pedagogical contexts. This process recognises that knowledge is not static but must be shaped by educational aims and societal needs (Gericke et al., 2022; Hudson et al., 2023). In science education, transformation is essential for bridging the gap between complex scientific understanding and pupils' experiences. It enables the development of powerful knowledge that supports conceptual depth, critical thinking and engagement with real-world issues such as infectious diseases.

This thesis investigates how disciplinary knowledge about infectious diseases is transformed within the educational system and whether this transformation facilitates the teaching and learning of powerful knowledge. It explores how pupils may progress from intuitive, everyday conceptions to more systematic and explanatory scientific understandings. Gericke et al. (2018) argue that powerful knowledge should not be defined solely by disciplinary boundaries, but by how content is transformed into teachable forms. While pupils may bring prior knowledge from home or the media, formal education can provide a more structured and generalised understanding. Without such transformation, instruction risks remaining grounded in fragmented or everyday knowledge, limiting pupils' conceptual development and their capacity to act in informed ways.

In the context of biology education, particularly when addressing infectious diseases, everyday knowledge may conflict with scientific understanding (Driver, 1994b). Pupils' initial conceptions (currently often shaped by family, culture and the media) form the lens through which they interpret new information. Schools have the potential to challenge and refine these understandings by offering structured disciplinary insights. For instance, knowledge about pathogens, immunity and epidemiology enables pupils to engage critically with public health issues and make informed decisions.

Clarifying the meaning of key concepts is essential when considering what constitutes powerful knowledge. One illustrative example is the distinction between isolation and quarantine. In everyday discourse, isolation is often understood as staying at home when ill to avoid infecting others. This interpretation is grounded in personal experience. Quarantine, by contrast, reflects a more systematic and collective approach to managing public health risks. It involves societal-level strategies for containing disease spread and managing uncertainty. In this sense, quarantine exemplifies what Young and Müller (2014a–c) describe as powerful knowledge, the kind of knowledge that enables individuals to understand and navigate complex societal structures beyond their immediate experience.

This distinction does not diminish the value of everyday knowledge but reinforce it by introducing a more analytical and collective perspective. It illustrates how powerful knowledge can enhance pupils' understanding, support effective teaching and inform future decision-making.

Contagion literacy may be viewed as one possible expression of powerful knowledge in biology education, particularly in relation to infectious diseases. This interpretation is proposed here as a tentative framework for exploring how structured and conceptually rich content might support pupils' understanding and engagement. It aims to highlight the importance of transforming disciplinary content into accessible and meaningful knowledge that can help pupils think critically, engage with societal challenges, and participate responsibly in public discourse. While the current contagion literacy framework offers a valuable foundation, this thesis suggests areas for further development (see section 7.3).

5. Methodology

A range of methodological approaches is employed in this thesis to investigate disciplinary knowledge transformation into taught and learned knowledge. This section outlines the methods used, detailing a multi-method design that includes textbook analysis and semi-structured interviews with teachers and pupils across studies. It also addresses issues of trustworthiness, ethical considerations, and the limitations inherent in the methodological research design.

5.1. Context of the study – Swedish compulsory school

The Swedish school system is governed by the Education Act and the national curriculum issued by Skolverket (2022). While the curriculum is centrally regulated, the system operates with a high degree of decentralisation in practice as municipalities and individual teachers exercise considerable autonomy. Compulsory education spans ten years, beginning at age six, and includes early years, primary (years 1–3, ages 7–9), middle (years 4–6, ages 10–12), and lower secondary (years 7–9, ages 13–15).

In this context, teachers are typically referred to as class teachers, meaning they are responsible for teaching most subjects, including biology. However, many class teachers have limited formal training in biology and science, often amounting to less than one semester during their teacher education. Health-related topics are included in the biology curriculum, but they are also addressed through broader school-based health initiatives. Swedish schools commonly have health teams comprising nurses, counsellors, and psychologists who work with pupils based on individual and collective needs. For example, vaccinations are routinely administered within schools.

During the COVID-19 pandemic, most Swedish compulsory schools remained open, although restrictions varied across regions. Compared to many other countries, Sweden implemented relatively mild public health measures (Haverty, 2021). Papers II, III, and IV were drawn from the middle school level, where health and disease are explicitly addressed in the biology syllabus (Skolverket, 2022). During the pandemic, teachers were required to adapt rapidly to evolving public health guidance, respond to learners' questions, and manage the extensive media coverage surrounding the virus and its societal implications. These circumstances demanded pedagogical flexibility and responsiveness to ensure that learners received accurate and relevant information. School visits for this research (Papers II, III, and IV), during which individual interviews were carried out with both teachers and learners, were conducted at the end of the pandemic period (2022–2023).

5.2. Selection of methods for this thesis

The aim of this thesis is to investigate how scientific knowledge related to infectious diseases is transformed from disciplinary science into school science. Also, it examines how this transformation might influence pupils' understanding. The research design incorporates an analysis of textbook content aimed at pupils aged 10–15, alongside interview data collected from middle school teachers and 10–12-year-old pupils. Lower secondary school textbooks were included in the first paper, since these were updated more frequently after the COVID-19 outbreak than middle school textbooks.

Individual, semi-structured interviews with teachers and pupils (Papers II, III and IV) enabled an in-depth exploration of participants' perspectives, experiences, and interpretations. This method supports the investigation of how scientific knowledge is received, reshaped, and enacted in practice, particularly in the context of the COVID-19 pandemic. Content analysis of textbooks (Paper I) and children's annotated drawings (Paper IV) provides a systematic approach to examining how scientific concepts are visually and textually represented, offering insights into the formal and informal ways in which knowledge is conveyed. These analyses are essential for understanding the transformation of disciplinary knowledge into forms accessible to young learners. The use of thematic analysis across all four studies (Robson & McCartan, 2016) allows for the identification of patterns in how knowledge is constructed, communicated, and interpreted within educational contexts. Table 2 outlines methods employed for data collection and data analysis across the four constituent papers, each of which is subsequently described in more detail.

Table 2. Methods used in the doctoral thesis.

Method	Paper I	Paper II	Paper III	Paper IV
Data collection				
Textbook and text selection	x	-	-	-
Semi-structured interviews	-	x	x	x
Drawings	-	-	-	x
Data analysis				
Content analysis of text	x	-	-	-
Thematic analysis	x	x	x	x
Analysis of annotated drawings	-	-	-	x

5.3. Data collection

This study is based on the analysis of four data sets: textbook and text selection (Paper I), semi-structured interviews with pupils and with teachers (Papers II, III and IV), and annotated drawings made by participating pupils (Paper IV).

For textbook analysis, I chose biology textbooks commonly used in school years 4–9 in Swedish schools, for which there were one edition published before the start of the COVID–19 pandemic in 2019 and one edition published after. This resulted in four textbook pairs (one pair for years 4–6, three pairs for years 7–9). The selected books are published by leading publishers of biological teaching materials (Bohlin & Höst, 2015) and developed in line with the latest Swedish curriculum for biology (Skolverket, 2022). All relevant content addressing contagions and infectious diseases was extracted into separate text files for each of the eight selected books.

Individual, semi-structured interviews were used for data collection in Papers II, III, and IV. Transcribing interviews and conversations from an oral to a written format not only transforms the data into a structure for closer analysis but also serves as an initial analytical step (Brinkmann & Kvale, 2018). The audio-recorded interviews underpinning Papers II–IV lasted approximately 30–60 minutes each. The transcriptions were carried out verbatim.

5.4. Data analysis

5.4.1. Content analysis of textbooks

During the content analysis of biology textbooks, all relevant material addressing contagions and infectious diseases was extracted into separate text files for each of the eight selected books. The initial analysis followed a deductive approach (Robson & McCartan, 2016, p. 349), guided by the contagion literacy framework (Kilstadius & Gericke, 2017), which incorporates six thematic areas and three levels of health literacy. The unit of analysis was defined as the smallest meaningful segment of text describing infectious diseases in relation to these themes, typically a sentence, though occasionally a part of a sentence. Also, a coding unit could consist of a word in a sentence plus the next sentence if that word was necessary for the sentence to be meaningful in terms of describing a function or a phenomenon.

In addition to the main text, supplementary elements such as image captions, table legends, and embedded text within illustrations were also coded. Headings and pupil-directed questions were excluded. A principle of double coding was applied, allowing a single unit to be assigned multiple codes if it addressed more than one thematic area. This was relatively rare, except in the case of sexually transmitted diseases, which frequently intersected with other themes.

The categorisation of literacy levels was embedded within the coding process. Segments reflecting functional health literacy were identified through factual descriptions of biological functions, phenomena, or applications related to the six contagion literacy themes. Instances of interactive health literacy were recognised where the text encouraged normative, personal-oriented behaviours based on scientific knowledge. Meanwhile, critical health literacy was coded when the material presented open-ended situations or contexts requiring analysis, reflection, or consideration of multiple outcomes, often involving values or ethical dimensions. These distinctions supported a nuanced understanding of how textbook content engages learners at different cognitive and social levels.

5.4.2. Thematic analysis

Thematic analysis was employed to analyse the data in all four papers (Robson & McCartan, 2016, p. 467). The second paper mainly used a deductive approach, while an inductive analysis was used in all papers. The process began with familiarisation with the data, where the data was read and re-read, and initial ideas were noted to gain a comprehensive understanding. Interesting features of the data were systematically coded across the selected data set, and data relevant to each code was compiled.

A collaborative approach between my supervisors and me was employed, involving transcript sharing and extensive discussions, in order to ensure a triangulated analysis, mitigate subjectivity, and achieve a robust understanding of the interview data (Robson & McCartan, 2016).

5.4.3. Analysis of children's annotated drawings

Learners' illustrations of bacteria and viruses were subjected to analysis based on pupils' annotated drawings (Paper IV). As elucidated by Reiss et al. (2002), drawing offers a distinctive perspective on individual pupils' understanding.

Morphological aspects of the drawings were analysed by using partially deductive categories, encompassing shape (circle, oval, irregular, and other), surface texture (lines, spikes, boils, thicker tails, irregular, and other), and internal features (organelle structure, applicable solely to bacteria). Additionally, a figurative interpretation of the drawings was developed to further understand the pupils' portrayals.

The analysis of pupils' drawings was informed by a systematic and comprehensive approach to examining how 10–12-year-old children represent microorganisms. This analytical framework was developed via a synthesis of insights from three earlier research studies (Byrne, 2011; Jones & Rua, 2006; Nagy, 1953).

5.5. Trustworthiness and limitations of the methodology

As noted by Brinkmann and Kvale (2018), various approaches exist for defining validity in qualitative research. Internal validity pertains to the meticulousness of the execution, encompassing aspects such as study design, precision in measurements, and considerations regarding exclusions. External validity, on the other hand, concerns the degree to which research designers have considered alternative explanations for the relationships they investigate.

In qualitative inquiry, however, the concept of trustworthiness offers a more nuanced framework for evaluating research quality. Trustworthiness encompasses the criteria of credibility, transferability, dependability, and confirmability (Guba & Lincoln, 1989), and is particularly relevant when interpreting participants' perspectives on sensitive topics such as infectious diseases. There are several potential confounders and biases pertaining to interviews that introduce limitations to this approach (Brinkmann & Kvale, 2018; Robson & McCartan, 2016). Firstly, the issue of a restricted sample size must be acknowledged. Small-scale interviews may not offer a representative cross-section of the broader population of pupils and teachers. The perspectives expressed by a small group may not necessarily mirror those of the wider community. Another limitation involves the potential for social desirability bias. Participants (at least adults) might provide responses that align with societal expectations rather than express their own genuine opinions or experiences.

The limitation of the predetermined scope of questions in semi-structured interviews should be noted. My guiding set of questions may not encompass all pertinent aspects of the topic, potentially overlooking additional insights or experiences that participants might hold. Moreover, the issue of limited generalisability arises. Findings derived from small-scale interviews may not be readily applicable to other contexts or populations. Finally, the potential for researcher bias, inherent in both the interviewer (me) and my supervisors, should be acknowledged. This research may harbour its own biases or preconceptions that could influence the interpretation of the findings. However, I tried to ensure reflexivity and transparency throughout the research process to achieve trustworthiness at all stages.

5.6. Ethical considerations and research approval

This thesis adheres to the ethical guidelines established by the Swedish Research Council (Vetenskapsrådet, 2017), which identify four core principles for research involving human participants: information, consent, confidentiality, and appropriate use of data. According to the Swedish Act concerning the ethical review of research involving humans, only specific types of studies require formal approval by the national ethical review authority. This project did not fall within those categories. Instead, it was reviewed and approved by the ethical advisor at the Faculty of Health, Science and Technology, Karlstad University (Dnr. HNT 2022/638, 2023/306).

All participants and their parents received an information letter outlining the purpose of the study, the type of data collected, how the material would be handled, and their right to withdraw at any time. The letter stressed that participation was voluntary and that all data would be treated with the highest possible confidentiality. In accordance with Robson and McCartan (2016) and my ethical guidelines, both participants and their parents were given time to consider their involvement before providing written consent.

Ethical research design involves balancing potential risks with the value of the knowledge produced. While research should avoid causing harm, some level of risk may be justified if the anticipated benefits are significant (Vetenskapsrådet, 2017). This principle informed the methodological choices in this work, which relied solely on audio recordings to minimise disruption and arrange for participant comfort.

6. Results

6.1. Paper I – Portrayal of infectious diseases in biology textbooks

This paper addressed research questions IA and IB, which explored how infectious diseases are represented in Swedish biology textbooks published before and after the onset of the COVID-19 pandemic.
The comparative analysis revealed that, despite the significant societal impact of the pandemic, the representation of infectious diseases in textbooks remained largely unchanged. Textbooks published in 2022 or later did not include substantially more content on infectious diseases and continued to emphasise functional health literacy, focusing on factual information rather than on how pupils might act in response to health threats.

Only minor additions were observed in the post-pandemic textbooks. These included brief references to the emergence of pandemics, the societal role of vaccines and infection control measures, the use of pathogenic viruses as models of infectious agents, and the evolution of viruses. However, these additions were limited in scope and did not reflect a broader shift in how infectious diseases are conceptualised in textbooks.

As a result, the textbooks published after the onset of COVID-19 do not appear to prepare pupils to understand or respond to future pandemics better than those published before 2020. This is a critical finding, as it suggests that textbooks have not been sufficiently updated to support the development of contagion literacy or to provide access to powerful knowledge, knowledge that enables pupils to understand disease transmission, evaluate public health measures, and make informed decisions.

The limited responsiveness of textbooks to recent public health events places a greater burden on teachers, who may lack the formal training or resources to address these topics comprehensively. To support both teachers and pupils, textbooks should include structured content on collective strategies for disease prevention, such as vaccination, quarantine, and social distancing. These topics are essential for providing pupils with the knowledge and competencies needed to navigate future public health challenges.

6.2. Paper II – Teaching infectious diseases during and in the aftermath of the COVID-19 pandemic

This paper addressed research questions IIA and IIB, which explored how the COVID-19 pandemic influenced the teaching of infectious diseases in Swedish middle school biology classrooms, both in terms of enacted teaching and planned instruction. The findings indicate that while the pandemic had a clear impact on enacted teaching, it did not profoundly alter the planned teaching content regarding infectious diseases. Rather than expanding or adapting the formal curriculum, teaching during the pandemic was shaped by pupil-initiated, question-driven discussions centered on current events and public health measures related to COVID-19. These spontaneous discussions often took precedence over structured biology content, reflecting a shift in classroom focus without a corresponding curricular revision. The main finding is that teachers primarily emphasised hygiene practices and sought to influence pupils' behaviours through interactive discussions. However, this emphasis was not systematically linked to broader biological concepts or disciplinary frameworks. The themes and subcategories derived from the analysis of are summarised in Table 3.

Table 3. Themes and subcategories from the analysis of teaching aspects.

Theme	Subcategories
(I) Hygiene	(a) clean hands and isolation, (b) physical distancing challenging, and (c) solidarity perspective not prominently featured
(II) Transmission routes	(a) evoked by the COVID-19 pandemic, (b) quarantine and asymptomatic transmission ignored, and (c) infection control guidelines
(III) Contagions	(a) not a regular item, (b) viruses equated to "corona", and (c) pupil germaphobia
(IV) Vaccinations	(a) a controversial topic, (b) challenging to explain, and (c) rarely related to solidarity
(V) Infectious diseases	(a) teaching oriented towards COVID-19, (b) the concept of a pandemic, and (c) COVID-19 linked disease to a contagion
(VI) Antibiotics	(a) regarding current outbreaks, (b) historical context, and (c) intractable infectious diseases

Teachers reported feeling underprepared to address complex topics such as transmission routes, asymptomatic infection, and the rationale behind quarantine measures. Notably, discussions of airborne, droplet, and surface transmission were largely absent, and topics such as antibiotics and antimicrobial resistance received minimal attention. Teachers also expressed hesitation in addressing misinformation and vaccine-related controversies, often due to concerns about potential conflict with parents. While some interdisciplinary collaboration (particularly with social science) was reported, the findings suggest that the pandemic was a missed opportunity to embed contagion literacy more systematically into biology education. The lack of curricular guidance and limited teacher training contributed to a reliance on informal, reactive teaching strategies rather than structured, conceptually grounded instruction. The teaching approaches described by participants related to activities and choice of teaching materials when teaching about infectious diseases (t1= teacher 1 etc.) are summarised in Table 4.

Table 4. Teaching approaches related to activities and choice of teaching materials when teaching about infectious diseases articulated by participants (n=8).

Approaches	Descriptions	Teachers
Media	news to schools and films etc.	t1–t8
Group discussions based on pupils' interest and questions	often related to COVID-19	t1–t8
Biology textbooks	Understanding contents	t1–t3, t6–t7
Interdisciplinary collaboration	historical and novel diseases	t1, t5, t7
Illustrations	visualise bacteria and viruses	t1

Overall, the study highlights a gap between the societal relevance of infectious diseases and the curricular and pedagogical responses within biology education. While teachers demonstrated adaptability and responsiveness to pupils' interests, the absence of structured content and conceptual depth limited the potential for developing powerful knowledge. The findings underscore the need to strengthen syllabus content and provide targeted teacher support that explicitly integrates contagion literacy into biology education. Such efforts can enable pupils to engage critically with public health issues and future pandemics.

6.3. Paper III – Pupils' understanding of infectious diseases in the aftermath of COVID-19

This paper addressed research question III, which explored how middle school pupils understand infectious diseases in the aftermath of the COVID-19 pandemic.

The findings indicate that the pandemic significantly shaped pupils' conceptions of infectious diseases. Their understanding was largely informed by personal experiences and media representations of the coronavirus, which they frequently cited as their primary reference point. However, their perceptions were often marked by ambiguity, reflecting the diverse and sometimes contradictory manifestations of the virus in public discourse and daily life.

A key feature of pupils' reasoning was the use of dichotomous thinking, such as framing individuals as either infected or healthy, or diseases as either dangerous or harmless. These binary distinctions, such as comparing asymptomatic illness ("playing") with severe outcomes ("dying"), were rooted in their lived experiences during the pandemic. Such simplified conceptualisations may influence how pupils interpret health-related information and understand disease transmission and prevention.

Notably, pupils rarely termed specific infectious diseases. Instead, they focused on symptoms and personal or familial experiences. In spite of this, many expressed an awareness of the importance of caring for oneself and others, indicating an emerging sense of social responsibility. Vaccines were also frequently mentioned, though pupils assigned them varied roles, ranging from curative to preventive, and in some cases, as sources of uncertainty or fear.

Importantly, pupils' knowledge of infectious diseases appeared to originate primarily from informal sources, including news media, the internet, and family discussions. Formal biology education was mentioned far less frequently, suggesting a gap between pupils' lived experiences and the content addressed in school science. Table 5 summarises the themes and subcategories identified through thematic analysis.

Table 5. Themes and subcategories from the analysis.

Theme	Subcategories
Elusive diseases (I)	(a) contemporary-historical, (b) visible-invisible, and (c) playing-dying
Taking care (II)	(a) of oneself (b) of others, and (c) for recovery
Various thoughts on vaccine (III)	(a) as a cure, (b) as a preventor or (c) as a threat
Information and insights (IV) from	(a) the news, the net and the family, (b) the civics and history lessons and (c) the biology lessons

Encouragingly, none of the pupils suggested antibiotics as a treatment for viral infections such as COVID-19. Instead, they emphasised isolation and rest, reflecting the influence of national public health messaging. This suggests that some aspects of public health communication were effectively internalised. Overall, the findings highlight the dominance of informal learning environments in shaping pupils' understanding of infectious diseases. While pupils demonstrated engagement with real-world health issues, their conceptual grasp was often fragmented and lacked scientific coherence. These results underscore the importance of integrating contagion literacy into formal biology education to support the development of powerful knowledge, knowledge that enables pupils to move beyond personal experiences and engage critically with complex public health challenges.

6.4. Paper IV – Pupils' understanding of bacteria and viruses in the aftermath of COVID-19

This paper addressed research question IV, which examined how middle school pupils conceptualise bacteria and viruses in the context of infectious diseases following the COVID-19 pandemic. The findings indicate that pupils perceived viruses as more dangerous than bacteria, often associating them with severe illness. However, their ability to link specific pathogens to specific diseases was limited. Pupils frequently used the term *"corona"* interchangeably to refer to both the virus (SARS-CoV-2) and the infectious disease (COVID-19), and only occasionally connected viruses correctly to influenza and COVID-19, and bacteria to plague (as well as incorrect associations—such as the association of bacteria with the common cold). These patterns suggest that viruses have assumed a dominant position in pupils' mental models of infectious agents in the aftermath of the pandemic.

The analysis of pupils' drawings (Figure 1) further revealed that the morphology of microorganisms was often depicted in a "corona-like" manner, typically as round shapes with protruding spikes. Pupils consistently represented microorganisms as cell-like entities, without anthropomorphic or animal-like features. However, their understanding of size and scale was limited; viruses were often perceived as larger than bacteria, and both were frequently exaggerated in size. These misconceptions point to challenges in grasping abstract biological concepts, particularly those not directly observable. Overall, the coronavirus appeared to serve as a default model for all pathogenic microorganisms, shaping pupils' visual and conceptual representations of infection. Table 6 summarises the themes and subcategories generated from the thematic analysis.

Table 6. Themes and subcategories generated from the analysis.

Theme	Subcategories
Size and scale (I)	(a) bacteria enlarged in pictures and (b) viruses considered larger in size than bacteria
Ecological occurrence and locomotion (II)	(a) bacteria everywhere and viruses (only) in certain places (b) viruses walk and move around and (c) viruses spread more quickly
Life and growth (III)	(a) bacteria are alive (b) bacteria can double down
Interrelationship between contagions (IV)	(a) virus as a superior microorganism and (b) bacteria could generate viruses
Tether to disease (V)	(a) bacteria causing common cold and plague and (b) virus causing flu and COVID-19
Morphology (VI)	(a) round shape with protruding parts and (b) "corona" as figurative expression

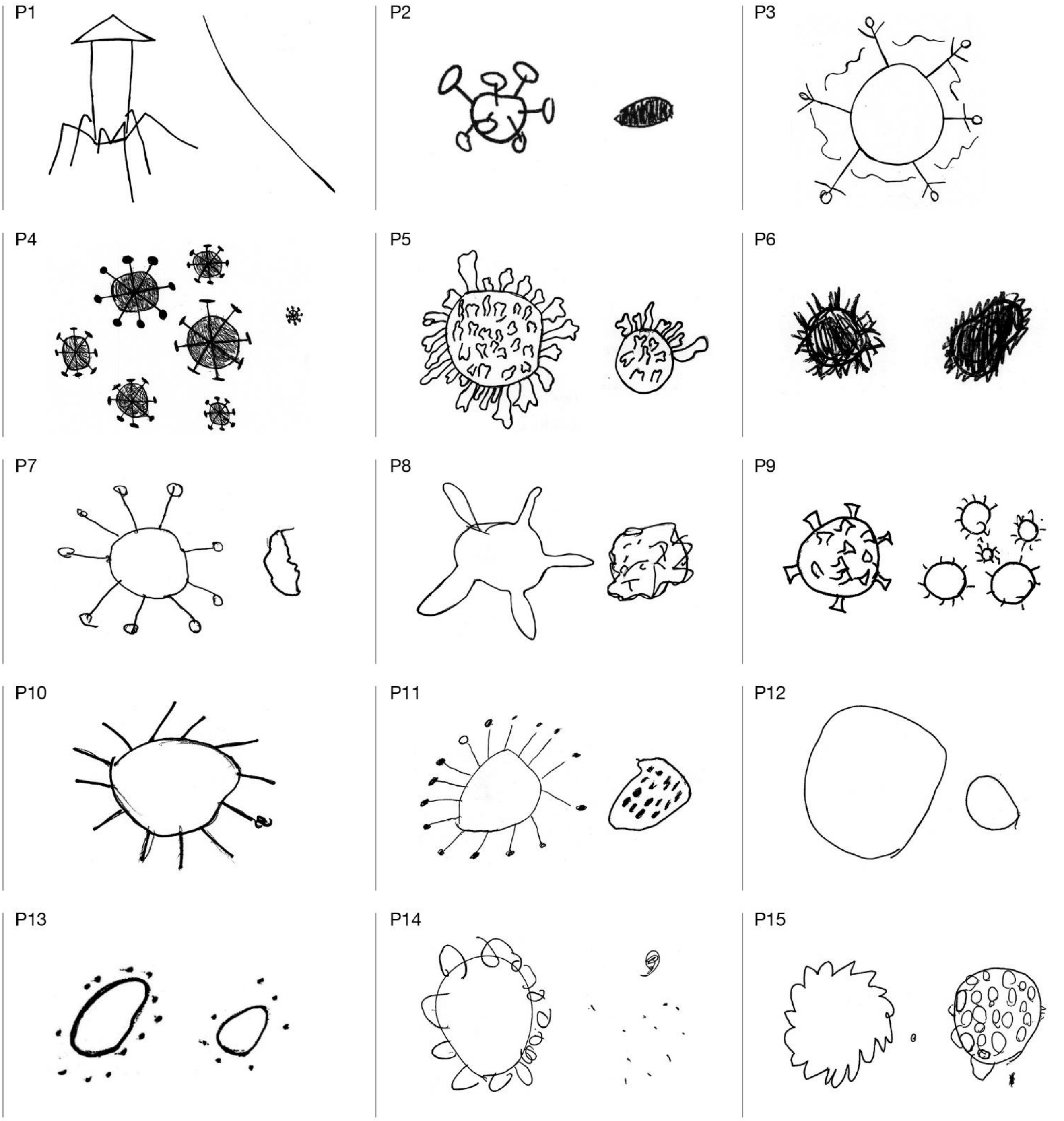

Figure 1. Pupils' drawings of microorganisms.

7. Discussion

Understanding how infectious diseases behave and how hygiene and vaccination can prevent illness, fatalities, and future pandemics has profound implications for society. Cultivating this understanding from middle school onwards lays the foundation for a scientifically grounded contagion literacy (Kilstadius & Gericke, 2017), which is essential for preparing resilient, informed, and empowered future citizens.

This section synthesises the findings from all four studies and examines how content related to infectious diseases is presented, interpreted, and understood in Swedish middle schools. It identifies key conceptual challenges that impede pupils' development of contagion literacy, including: (a) the missing connection between specific pathogens and the infectious diseases they cause; (b) the limited coverage of transmission routes and quarantine; (c) the informal and fragmented nature of hygiene education; (d) the conceptual boundaries surrounding vaccination; and (e) persistent misconceptions regarding microbial classification and scale.

The next sections trace transformation of biological content related to infectious diseases across school textbooks, classroom practices, and pupils' conceptualisations, examining both the structural and pedagogical factors that shape how this knowledge is taught and learned in Swedish middle schools. Collectively, these findings point to the need for a more coherent and epistemically rich approach to teaching infectious diseases in middle school biology.

7.1. Transformation of infectious disease content in middle school biology

Despite the fact that the curriculum mandates the inclusion of health and disease topics, explicit instruction with linkage of infectious diseases to their causative agents remains notably absent from the syllabus. This omission is particularly concerning in light of the COVID-19 pandemic, which sheds light on the societal importance of contagion literacy.

7.1.1. Conceptual challenges – pathogens and microbial scale

Paper II shows that teachers often omit infectious disease content, noting that pupils struggle to associate specific diseases with their causative pathogens. Paper IV reveals that pupils frequently confuse bacteria and viruses, often considering viruses to be *larger* and more harmful, also documented by Byrne (2011) and Jones and Rua (2006). Although pupils now rarely depict microorganisms with anthropomorphic features, as previously shown by Byrne et al. (2009), they still struggle with microbial scale and vitality, often using imprecise terminology such as "germs" or "bacilli" interchangeably.

The liaison between pathogens and the diseases they cause remains unclear to many pupils. As noted in Paper IV and supported by Nagy (1953) and Bracko & Simon (2022), pupils often fail to distinguish between the virus (e.g., SARS-CoV-2) and the infectious disease (e.g. COVID-19), using the same term ("corona") to refer to both. This confusion is reinforced by textbook representations (Paper I), which frequently conflate terminology and lack clarity.

Paper I shows that biology textbooks rarely provide structured explanations of microbial classification or scale, and often present pathogens in isolation from the infectious diseases they cause. This fragmented portrayal contributes to pupils' difficulties in forming coherent conceptual links between microorganisms and illness. In spite of the global impact of the pandemic, textbook revisions were minimal, and the representation of infectious diseases remained largely unchanged. This lack of curricular and textual clarity places a disproportionate burden on teachers to bridge conceptual gaps. Yet, as demonstrated in Paper II, many teachers feel underprepared to teach microbiology and infectious disease content, often due to limited formal training and competing curricular demands.

These findings are consistent with Amorim et al. (2023) who identify significant gaps in microbiology education across European curricula, noting that microorganisms are frequently portrayed primarily as threats, with limited emphasis on their classification, scale, or beneficial roles. Similarly, Timmis (2023) advocates for the urgent integration of societally relevant microbiology curricula in schools, emphasising that current educational materials often fail to reflect the complexity and significance of microbial science in everyday life and public health.

7.1.2. Transmission routes and quarantine

Understanding transmission routes is central to contagion literacy, yet Papers I, II, and III indicate that this content is rarely taught in a systematic manner. Pupils' ideas about transmission are shaped more by everyday experience than by scientific instruction. For instance, food was commonly mentioned regarding hygiene, while waterborne transmission was largely absent, likely reflecting the fact that Sweden generally has safe drinking water. Quarantine, too, is poorly understood. Paper II documents a shift from collective public health measures to individualised notions of isolation, while pupils demonstrated limited awareness of the historical and societal dimensions of quarantine. The absence of clear definitions in textbooks contributes to this conceptual gap. These findings are consistent with Kafai et al. (2022), who found that educational interventions on infectious disease transmission often neglect population-level concepts and fail to address the broader public health implications of measures (such as how to handle and understand quarantine).

Furthermore, Paper I reveals that quarantine is either omitted or presented in vague terms, often disconnected from biological mechanisms or historical context. This contributes to pupils' limited understanding of how quarantine functions as a public health strategy. The lack of interdisciplinary framing (linkage between biology and civics or history) means that pupils rarely engage with quarantine as a socio-scientific concept in school. This gap stands in contrast to approaches such as those described by Iverson-Cabral (2021), where quarantine and isolation were taught through an integrated lens that included biological rationale, historical examples, and societal implications, demonstrating the value of interdisciplinary science education in supporting deeper understanding.

7.1.3. Hygiene – between informal practice and scientific understanding

Hygiene became a prominent theme during the pandemic, but its treatment in schools was largely informal. Teachers emphasised behavioural routines (e.g., handwashing, cough etiquette) through mentor sessions rather than structured biology instruction (Paper II). Paper III reveals that although pupils generally adhered to hygiene practices, they often lacked insight into the biological rationale behind these behaviours. Hygiene education thus functions more as embodied practice than disciplinary knowledge, underscoring the need to link routines to scientific concepts within contagion literacy. This disconnection between practice and understanding reflects a broader issue. Hygiene is often taught as a behavioural norm rather than a scientific concept (Appiah-Brempong et al., 2018). Paper I reveals that textbooks seldom explain the biological mechanisms underlying hygiene recommendations, particularly the role of handwashing in interrupting transmission routes. These findings are consistent with Simard (2021), who argues that pupils' understandings of microorganisms are shaped more by social messaging than by structured instruction, and with Kilstadius and Gericke (2017), who emphasise the importance of transforming scientific knowledge into accessible and contextually relevant teaching to support health-related decision-making.

7.1.4. Vaccination – between scientific knowledge and societal perceptions

Despite its relevance to public health, vaccination is rarely explored in depth within middle school science education, leaving pupils with limited understanding of its biological basis (Reiss, 2022). The participating teachers reported feeling underprepared to explain vaccine mechanisms and hesitant to engage with the topic due to parental scepticism (Paper II). Textbooks typically present vaccination in a descriptive, functional manner, avoiding deeper engagement with concepts such as herd immunity and immunological responses (Hoffer et al., 2022). This reluctance reflects broader pedagogical challenges in navigating contested knowledge, as also evidenced in Paper II, where teachers expressed uncertainty about how to approach sensitive or controversial health topics within the constraints of the curriculum and community expectations.

A potential omission in current biology education may be a limited attention to the host (that is, the human body) and its biological responses to infectious agents. While infectious agents (such as pathogenic bacteria and viruses) and infectious diseases are occasionally addressed, the immune system and its role in disease prevention and recovery appear to be rarely taught in a structured or conceptually rich manner. This gap could limit pupils' ability to understand how the body interacts with infectious agents and why public health interventions such as vaccination are effective (Ghaddar et al., 2022; Memenga et al., 2022). For a more detailed account of the biological mechanisms involved in host–pathogen interactions and immune responses, see van Seventer and Hochberg (2017).

As shown in Paper III, many pupils were able to describe hygiene routines or symptoms, but few could explain biological mechanisms such as immune responses or the role of vaccination in community protection, indicating a need for more explicit instruction in host-pathogen interactions.

Viewed collectively, the findings from Paper I and Paper II highlight a disconnect between curricular materials and classroom practice as it pertains to vaccination. Paper I reveals that the portrayal of vaccination in textbooks remains largely static and uncritical, even in editions published after the COVID-19 pandemic. This lack of curricular responsiveness places a greater burden on teachers, who may lack the formal training or resources to address these topics comprehensively. Paper II further illustrates how teachers often rely on simplified explanations or choose to avoid the topic altogether. To support both teachers and pupils, textbooks should include structured content on collective strategies for disease prevention, such as vaccination, quarantine, and social distancing. These topics are essential for providing pupils with the knowledge and competencies needed to navigate future public health challenges. This aligns with observations by Reiss (2022), who notes that while science education in many schools covers fundamental biology and immunology, it frequently neglects vaccine hesitancy and fails to situate vaccines within a broader context where moral, social, and ethical dimensions are made explicit. Such tendencies limit pupils' access to powerful knowledge and hinder their ability to engage critically with contemporary scientific challenges.

7.2. Powerful knowledge and pandemic preparedness

Informed by the conceptual challenges identified in section 7.1, this section examines whether pupils are being provided with powerful knowledge that supports contagion literacy and pandemic preparedness. Are pupils being empowered with disciplinary knowledge that enables them to understand infectious diseases and respond to future public health challenges?

Paper III reveals that pupils often hold fragmented understandings of infectious diseases, shaped by media exposure and everyday experiences. This fragmented knowledge can hinder their ability to engage with scientifically grounded explanations. Although many pupils could describe hygiene routines or symptoms, few were able to explain biological mechanisms such as immune responses or the role of vaccination in community protection. These findings align with Simard (2021), who emphasises that pupils' conceptions of microorganisms are frequently influenced by non-scientific sources, leading to oversimplified or inaccurate understandings.

Paper IV further documents persistent misconceptions, including confusion between bacteria and viruses and the belief that common colds are caused by bacteria. Paper II shows that hygiene-related behaviours were often emphasised through informal strategies, such as posters and routines, but these were rarely connected to underlying conceptual content. Similarly, Paper I demonstrates that biological concepts are frequently presented in isolation within textbooks, without being linked to behavioural practices or decision-making processes. These findings suggest that the transformation of disciplinary knowledge into accessible and contextually relevant instruction remains a challenge in current science education.

In the context of this thesis, powerful knowledge refers to structured and conceptually rich instruction that enables pupils to engage with scientific reasoning and participate in public health discourse. As discussed in section 7.3, when powerful knowledge is tethered to contagion literacy, it provides pupils with the tools to move beyond everyday experiences and engage with disciplinary frameworks that support both understanding and action. This is supported by Kilstadius &

Gericke (2017), who argue for the importance of integrating scientific knowledge with societal relevance in science education.

When pupils are taught about pathogens, immunity, and vaccination through interdisciplinary and contextually grounded approaches (as advocated in Papers III and IV), they will probably be better prepared to navigate complex health issues (Ghaddar et al., 2022). Notably, Paper III identified a solidarity-oriented perspective among pupils, many of whom expressed concern about infecting vulnerable family members, particularly grandparents. These findings are consistent with those of Idoiaga et al. (2020), who reported similar sentiments among younger children during the COVID-19 pandemic, illustrating the potential for science education to support empathy and social responsibility.

To conclude, supporting pupils with contagion literacy skills and powerful knowledge about infectious diseases is not only a matter of individual empowerment, but also contributes meaningfully to public understanding and collective well-being. As future pandemics are inevitable, science education must prepare pupils to engage critically with public health challenges and contribute to collective resilience.

7.3. Towards a more powerful contagion literacy framework

The contagion literacy framework, currently conceptualised by Kilstadius and Gericke (2017), provides a valuable structure for exploring how learners engage with infectious disease content. However, according to my findings and previous reasoning I would argue that it lacks sufficient integration of the host's biological role, which limits its explanatory power regarding science education and health literacy. To address this, I propose expanding the framework by incorporating this aspect from the epidemiological triad model (van Seventer & Hochberg, 2017), which conceptualises infectious disease causation through the dynamic interplay between agent, host, and environment. Contagion literacy includes aspects of agent, disease and environment, but neglects the host. As illustrated in Figure 2, the triad model offers a lens for understanding contagion, positioning the host as a central component in both the dissemination and prevention of disease.

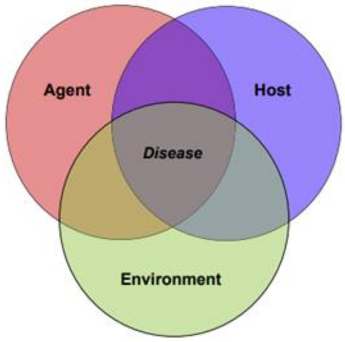

Figure 2. The epidemiological triad model of infectious disease causation (reproduced from van Seeventer & Hochberg, 2017).

The host (defined as the human body with its varying immune responses, vulnerabilities, and capacities for resistance) plays a critical role in determining whether exposure to an infectious agent results in illness (van Seventer & Hochberg, 2017). Integrating host-related concepts such as immunity, and susceptibility into the contagion literacy framework would allow learners to better understand why some individuals develop illness while others do not, even when exposed to the same pathogen. Hence, this addition would support the transformation of everyday knowledge into powerful disciplinary understanding, as discussed in section 7.2.

In the sense articulated by Young and Müller (2013), powerful knowledge refers to specialised, systematic knowledge that enables learners to go beyond their everyday experiences and engage with abstract concepts and explanatory models. By embedding the host dimension into the contagion literacy framework, the model becomes more aligned with this epistemic aim. It allows learners not only to describe observable phenomena but also to understand underlying biological mechanisms in which the contagion and the host interact, thereby bridging informal knowledge with disciplinary reasoning.

To further strengthen the curricular and pedagogical utility of the contagion literacy framework, I propose the addition of a host (the human potentially becoming ill) with an immune system. This theme would address how the human body interacts with infectious agents, including behavioural factors, immune responses, and susceptibility. It would help learners conceptualise the role of the host in disease transmission and prevention. The immune system would be central to focus on the biological mechanisms of defense, including innate and adaptive immunity and immune memory. It would provide a foundation for understanding how immunity develops and how it can be supported or compromised.

This revision of the contagion literacy framework also responds to gaps identified in Paper III, where participants demonstrated limited knowledge of immune responses and host-pathogen interactions. By integrating these dimensions, the contagion literacy framework would have a greater potential of supporting powerful knowledge in biology and health education.

7.4. Implications

Drawing on the conceptual and pedagogical challenges identified in the previous sections, this part of the analysis outlines key implications for biology teaching and learning in the context of infectious disease education.

7.4.1. Implications for practice

The findings from this thesis point to several important implications for biology and health education practice, particularly regarding how disciplinary knowledge about infectious diseases is transformed into teachable content.

Firstly, Paper II demonstrates that teachers require sustained professional development to strengthen both subject-matter expertise and pedagogical content knowledge. Teaching complex biological phenomena such as microbial behaviour, immune responses, and vaccination, requires not only scientific accuracy but also the ability to transform disciplinary knowledge into age-appropriate and interdisciplinary instruction. This is consistent with Simard (2021), who emphasises the importance of bridging scientific knowledge and pupils' lived experiences in ways that support conceptual clarity.

Secondly, instructional transformation must be supported at the institutional level. Teachers often lack the frameworks and resources needed to adapt their teaching practices in response to evolving public health contexts. This includes the capacity to connect biological content to behavioural and societal dimensions, which are frequently underrepresented in existing teaching materials (Paper I, Hoffer et al., 2022). Targeted training and school-level support can play a key role in enabling these pedagogical shifts and in supporting the transformation of knowledge into meaningful classroom practice.

Thirdly, Papers III and IV reveal that primary science teacher education must be strengthened to better prepare educators to teach foundational concepts related to infectious diseases. Pupils' misconceptions and limited understanding of microbial biology suggest that early and explicit instruction in pathogen-related content is necessary. This includes distinguishing between pathogenic and beneficial microorganisms and linkage of specific pathogens to specific diseases, an approach that supports the transformation of everyday knowledge into powerful disciplinary understanding.

Finally, interdisciplinary collaboration may offer valuable opportunities for strengthening science education. As discussed in Paper II and supported by Paper I, collaboration between biology and social science teachers, as well as school health teams, can help integrate scientific knowledge into broader societal contexts. Such collaborative efforts have the potential to support the development of interactive and critical health literacy, enabling pupils to connect biological concepts with real-world decision-making. By supporting dialogue across disciplines, educators may be better positioned to transform scientific content into meaningful and contextually relevant learning experiences. Wang et al. (2021) demonstrate that interdisciplinary programs involving natural science and social studies, teachers can enhance pupils' ability to engage critically with complex societal issues, including public health.

7.4.2. Implications for syllabus and textbook development

In addition to its pedagogical implications, the findings from Paper I highlights the need for reform of both syllabus and textbook content. In spite of the global impact of the COVID-19 pandemic, the representation of infectious diseases in Swedish middle school biology textbooks has remained largely unchanged. This lack of revision suggests a gap between significant societal events and educational content and

illustrates the limitations of relying solely on textbooks to convey critical health-related knowledge.
Paper I demonstrates that textbook content is often fragmented, with biological concepts presented in isolation from behavioural, societal, and ethical dimensions. This disjointed approach limits pupils' ability to understand the mechanisms of disease transmission, the role of vaccination, and the importance of hygiene from both scientific and socio-scientific perspectives. Moreover, the absence of interactive and critical perspectives restricts opportunities for pupils to engage meaningfully with public health issues, an essential component of contagion literacy.

Given that pupils' knowledge of infectious diseases is shaped by both teacher competence and formal instructional materials, the absence of structured, contemporary, and pedagogically grounded content in textbooks presents a challenge, particularly for teachers with limited training in biology. To support educators in delivering accurate and meaningful instruction, developers of teaching materials and publishers should consider how content on infectious diseases can be systematically organised, scientifically robust, and accessible to pupils at different developmental stages. Milgroom (2023) emphasises the importance of presenting infectious disease content in a structured and conceptually coherent manner, making it accessible to learners and supportive of teachers' instructional goals.

Future middle school curriculum revisions ought to include infectious diseases explicitly in the biology syllabus. As demonstrated in Papers III and IV, to make a distinction from non-infectious diseases is pedagogically significant. It helps pupils differentiate between communicable and non-communicable conditions and supports a more nuanced and accurate understanding of public health. Integrating such content would also support the development of powerful knowledge by enabling pupils to move beyond everyday experiences and engage critically with complex health-related phenomena.

7.4.3. Limitations and future research suggestions

This thesis focused on Swedish biology textbooks, teachers' instructional practices, and pupils' understanding of infectious diseases. Future research could usefully examine how infectious disease education is approached in other national contexts. Comparative studies may offer valuable insights into how different educational systems respond to global health crises and contribute to a more comprehensive understanding of contagion literacy in science education. Also, as three of the included studies (Papers II–IV) are case studies, the number of participants was small and selected based on convenience. More large-scale and generalisable studies reinforcing this thesis would be of great importance.

Expanding upon the findings of this thesis, further research might also explore how the contagion literacy framework could be expanded to include additional biological dimensions, particularly the human immune system. Understanding the immune response is central to grasping how the body interacts with pathogens, and its inclusion could enhance the explanatory power and pedagogical relevance of the framework. While the concept of the host is important in infectious disease biology, referring specifically to the human host and its physiological responses may offer a more accessible and educationally meaningful focus for middle school pupils.

Moreover, there is a need for continued empirical research to investigate what constitutes powerful knowledge within the domain of infectious disease education. Such studies may assist in identifying which concepts and competencies are most critical for preparing pupils to engage with public health issues in scientifically informed and socially responsible ways. This includes exploring how disciplinary knowledge is transformed into teachable content and how pupils' access to such knowledge is supported via curriculum design, teacher education, and instructional materials.

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Previous publications

Doctoral and licentiate theses in Biology produced at the Department of Environmental and Life Sciences, Karlstad University

1. Ivan C. Olsson. Influence on migration in brown trout, *Salmo trutta* L. Licentiate thesis, 19 May 2003.
2. Ivan C. Olsson. Migration by brown trout (*Salmo trutta* L.) and the effect of environmental factors. Doctoral thesis, 17 December 2004.
3. Amra Hadzihaliovic-Numanovic. Genetic variation and relatedness of fresh water pearl mussels *Margaritifera margaritifera* L. populations. Licentiate thesis, 19 January 2006.
4. Olle Calles. Re-establishment of connectivity for fish populations in regulated rivers. Doctoral thesis, 27 January 2006.
5. Martin Österling. Ecology of freshwater mussels in disturbed environments. Doctoral thesis, 8 December 2006.
6. Mattias Olsson. The use of highway crossing structure to maintain landscape connectivity for moose and roe deer. Doctoral thesis, 8 June 2007.
7. Arne N. Linløkken. Population ecology of perch (*Perca fluviatilis*) in boreal lakes. Doctoral thesis, 13 June 2008.
8. Pär Gustafsson. Forest-stream linkages: experimental studies of foraging and growth of brown trout (*Salmo trutta* L.). Licentiate thesis, 18 June 2008.
9. Niklas Gericke. Science versus school-science: multiple models in genetics – the depiction of gene function in upper secondary textbooks and its influence on students' understanding. Doctoral thesis, 6 February 2009.
10. Gunilla Cassing. Deciduous species occurrence and large herbivore browsing in multiscale perspectives. Licentiate thesis, 12 June 2009.
11. Jan-Olov Andersson. A GIS-based landscape analysis of dissolved organic carbon in boreal headwater streams. Doctoral thesis, 2 October 2009.
12. Linnea Lans. Relations between metabolic rate, migration and behaviour in Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*). Licentiate thesis, 3 June 2010.
13. Pär Gustafsson. Forest-stream linkages: Brown trout (*Salmo trutta*) responses to woody debris, terrestrial invertebrates and light. Doctoral thesis, 25 February 2011.
14. Nina Christenson. Knowledge, value and personal experience: upper secondary students' use of resources when arguing socioscientific issues. Licentiate thesis, 11 March 2011.
15. Carola Borg. Utbildning för hållbar utveckling ur ett lärarperspektiv: ämnesbundna skillnader i gymnasieskolan. Licentiate thesis, 30 September 2011.
16. Johnny R. Norrgård. Landlocked Atlantic salmon *Salmo salar* L. and trout *Salmo trutta* L. in the regulated River Klarälven, Sweden: implications for conservation and management. Licentiate thesis, 25 November 2011.

17. Linnea Lans. Behaviour and metabolic rates of brown trout and Atlantic salmon: influence of food, environment and social interactions. Doctoral thesis, 24 February 2012.
18. Maria Pettersson. Lärares beskrivningar av evolution som undervisningsinnehåll i biologi på gymnasiet. Doctoral thesis, 16 November 2012.
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20. Stina Gustafsson. The macroinvertebrate community in a nature-like fishway with habitat compensation properties. Licentiate thesis, 20 December 2012.
21. Johan Watz. Winter behaviour of stream salmonids: effects of temperature, light, and ice cover. Licentiate thesis, 27 May 2013.
22. Åsa Enefalk. Effects of fine woody debris on juvenile brown trout (*Salmo trutta*) and drifting invertebrates. Licentiate thesis, 29 April 2014.
23. Johnny R. Norrgård. Migration and quality of landlocked Atlantic salmon smolt: implications for conservation and management. Doctoral thesis, 5 June 2014.
24. Daniel Olsson. Young people's 'sustainability consciousness': effects of ESD implementation in Swedish schools. Licentiate thesis, 14 November 2014.
25. Teresa Berglund. Student 'sustainability consciousness' and decision-making on sustainability dilemmas: investigating effects of implementing education for sustainable development in Swedish upper secondary schools. Licentiate thesis, 28 November 2014.
26. Nina Christenson. Socioscientific argumentation: aspects of content and structure. Doctoral thesis, 5 June 2015.
27. Johan Watz. Salmonid behaviour under winter conditions. Doctoral thesis, 22 January 2016.
28. Susanne Walan. From doing to learning: Inquiry- and context-based science education in primary school. Doctoral thesis, 20 May 2016.
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34. Stina Gustafsson. Habitat compensation in nature-like fishways: effects on benthos and fish. Doctoral thesis, 15 December 2017.
35. Karin Thörne. Linguistic challenges in science education: a classroom study of teachers' and students' use of central concepts in genetics. Doctoral thesis, 8 June 2018.
36. Daniel Olsson. Student sustainability consciousness: Investigating effects of education for sustainable development in Sweden and beyond. Doctoral thesis, 14 December 2018.
37. Anna Hagelin. Conservation of landlocked Atlantic salmon in a regulated river: behaviour of migratory spawners and juveniles. Doctoral thesis, 12 April 2019.
38. Anna Mogren. Guiding principles of transformative education for sustainable development in local school organizations: Investigating whole school approaches through a school improvement lens. Doctoral thesis, 20 December 2019.
39. Karl Filipsson. From behaviour to genes: anti-predator responses of brown trout (*Salmo trutta*) under winter conditions. Licentiate thesis, 13 March 2020.
40. Kristine Lund Bjørnås. Modeling Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) responses to river habitat alteration. Licentiate thesis, 26 March 2020.
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44. Jeffery Marker. Forests, Functions, and Food Webs: Riparian processes through an ecological and molecular lens. Doctoral thesis, 8 December 2023.
45. Annika Thyberg. Students' meaning-making of epigenetic visual representations: An exploration within and between levels of biological organization. Licentiate thesis, 8 March 2024.
46. Henry Hansen. A Spatial Scale Approach to Fish Habitat Ecology and Impacted Rivers. Doctoral thesis, 25 April 2024.
47. Jacqueline H.T. Hoppenreijs. Rooting for riparian vegetation: processes underlying community composition in boreal ecosystems. Doctoral thesis, 13 September 2024.

48. Annika Forsler. The Role of Pedagogical Content Knowledge When Teaching Sustainable Development in Science Education. Doctoral thesis, 29 November 2024.
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51. Elin Blomqvist. Paving the way for evidence-based control of Garden lupine (Lupinus polyphyllus). Doctoral thesis, 28 May, 2025.
52. Velizara Stoilova. Helping Fish Pass Dams – Is Behavioural Guidance the Solution? Doctoral thesis, 14 November, 2025.
53. Stina Eriksson. Analogy competence for science teachers – The development and validation of the ACT framework. Licentiate thesis, 21 November, 2025.
54. Anna-Clara Rönner. Teaching and Learning about Infectious Diseases in the Aftermath of COVID-19. Doctoral thesis, 5 December, 2025.

Teaching and Learning about Infectious Diseases in the Aftermath of COVID-19

The COVID-19 pandemic profoundly affected children's everyday experiences, highlighting the importance of infectious diseases in science education. As future outbreaks are inevitable, it is essential to understand how teaching and learning about diseases was shaped by the pandemic, in order to develop biology education to meet the needs for future epidemic-prone diseases. This thesis explores how knowledge about infectious diseases is transformed from external sources into content taught and understood in Swedish middle school. The central research question is: How is the portrayal of knowledge about infectious diseases reflected in textbooks, teachers' practices, and pupils' understanding in the aftermath of COVID-19?

The thesis includes 4 empirical studies examining different stages of this transformation. A comparative textbook analysis (Paper I) shows that representations of infectious diseases remained largely unchanged post-pandemic. Teaching (Paper II) was shaped by pupil-driven discussions rather than curriculum expansion. Studies of pupils' understanding (Papers III–IV) reveal limited conceptual grasp, with informal sources outweighing formal instruction. Interpreted through the lens of contagion literacy and powerful knowledge, the thesis argues for integrating the contagion literacy framework including immune response into science education.

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