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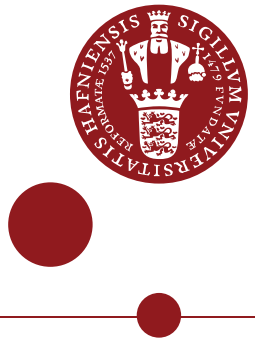

PhD Thesis

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Navigating Curricular Crossroads

Exploring Science Teachers' Enactment of Competence-Oriented Curriculum Reforms

This thesis has been submitted to the PhD School at The Faculty of Science, University of Copenhagen

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Abstract

This thesis examines how a group of lower secondary science teachers in Denmark engage with and navigate a competence-oriented curriculum reform and the factors influencing their abilities to align with intended curriculum goals. As educational policies worldwide increasingly emphasize competence-based education to prepare students for a rapidly changing world, the success of such reforms depends significantly on teachers, who serve as both implementors and interpreters of policy initiatives (Fullan, 2015; Priestley et al., 2015). However, research on how teachers experience, respond to, and navigate such reforms remains limited, especially in authentic contexts. This thesis aims to bridge this gap by exploring Danish science teachers' enactment of a curriculum reform, through four empirical papers addressing the overall research question:

How do science teachers enact and navigate competence-oriented curriculum reforms, and what factors influence their ability to align their practices with the intended curriculum goals?

The question is operationalized through five sub-questions explored in the four papers constituting the thesis. First, the study systematically explored how the implications of curriculum revisions for science teachers have been studied in the past, and what factors that affect their implementations of competence-oriented curriculum revisions. This was explored through a systematic qualitative literature review. Findings show that science teachers' practices are deeply influenced by systemic factors, including assessment frameworks, institutional support, and access to professional development. The review also revealed a dominant reliance on interventionist research approaches that often overlook the contextual factors influencing teachers' approaches to reform implementation. These insights emphasized a need for research that voices teachers' perspectives and experiences within their lived contexts. Second, the study drew on the model of teacher agency (Priestley et al., 2015) to analyze Danish science teachers' construction of agency in their planning and discussions about a key aspect of the competence-oriented curriculum reform: multidisciplinary teaching units. The results highlighted that in their constructions of agency, the teachers drew heavily on their professional horizons by relying on established practices and experiences, which constrained their abilities to fully adopt the objectives of the curriculum. Third, the study applied the Future Workshop method (Jungk &

Müllert, 1987), to explore how the science teachers navigate in the context of the curriculum reform. Findings illuminated the tensions teachers face between the intended goals inherent in the curriculum and the practical difficulties meeting the demands. Furthermore, the results outlined that while teachers often showed a willingness to adapt the curriculum, many felt constrained by organizational factors, which resulted in compromises and reduced ambitions. Fourth, the study explored the teachers' practices in the new oral exam format introduced with the revised curriculum by investigating the types and distributions of questions the teachers and external assessors ask during the exams to elicit information about the students' levels of scientific competence. The results showed that although the curriculum prioritizes development and achievement of scientific competences, assessors often draw on closed, factual questions that fail to effectively assess students' competence levels. Overall, the findings from this thesis indicate a misalignment between curricular intentions and teacher enactment. Teachers adapt and reinterpret reforms based on their professional horizons and contextual realities, often in ways that diverge from policymakers' original intentions. The findings suggest that effective curriculum enactment necessitates both individual and systemic support. This includes recognizing the realities of teachers' curriculum enactment and addressing contextual factors that influence such practices. Such support is critical for empowering teachers to navigate the tensions between existing practices and new requirements.

Resumé

Denne ph.d.-afhandling undersøger, hvordan en gruppe danske naturfagslærere i Folkeskolens udskoling navigerer i arbejdet med at implementere en kompetenceorienteret curriculumreform, samt hvilke faktorer der påvirker deres evne til at tilpasse deres praksis til de tilsigtede læreplansmål. Da der på internationalt plan er et øget fokus på kompetenceorienteret undervisning med det formål at klæde eleverne på til en verden i konstant forandring, afhænger en succesfuld implementering af sådanne reformer i høj grad af lærerne, der fungerer som både oversættere og implementorer af politiske initiativer (Fullan, 2015; Priestley et al., 2015). Imidlertid er forskning i, hvordan lærere oplever, reagerer på og navigerer i konteksten af sådanne reformer begrænset, især i autentiske kontekster. Denne afhandling har til formål at adressere dette videnshul ved at undersøge danske naturfagslæreres implementering af curriculum-reformen, der blev udrullet i skoleåret 2015/2016, gennem fire empiriske artikler, der belyser det overordnede forskningsspørgsmål:

Hvordan implementerer og navigerer naturfagslærere kompetenceorienterede curriculumreformer, og hvilke faktorer påvirker deres evne til at tilpasse deres praksis til de tilsigtede mål?

Dette spørgsmål operationaliseres gennem fem underspørgsmål, der udforskes i de fire artikler, som udgør ph.d.-afhandlingen. Første del af projektet består af en systematisk undersøgelse af, hvordan implikationerne af curriculum-revisioner for naturfagslærere tidligere er blevet undersøgt, og hvilke faktorer, der påvirker læreres implementering af kompetenceorienterede curriculum-revisioner. Dette undersøgte jeg gennem et systematisk kvalitativt litteraturstudie. Resultaterne herfra påpeger, at naturfagslæreres praksis i høj grad er påvirket af systemiske faktorer, herunder rammerne for evaluering, institutionel støtte og lærernes adgang til professionel udvikling. Reviewet viste også, at tidligere studier primært har benyttet sig af interventionistiske forskningsmetoder, der ofte overser de kontekstuelle faktorer, der påvirker lærernes tilgange til reformimplementering. Indsigterne herfra understregede behovet for forskning, der giver stemme til naturfagslærernes perspektiver og levede erfaringer inden for deres givne kontekster. I anden del af projektet benyttede jeg Priestley et al.'s (2015) teori om teacher agency til at analysere danske naturfagslæreres konstruktion af agens i deres planlægning

af, og diskussioner relateret til, et helt centralt aspekt af den kompetenceorienterede curriculumreform: fællesfaglige undervisningsforløb. Resultaterne påpegede, at lærerne i høj grad trak på deres professionelle erfaringshorisonter ved at basere deres praksis på etablerede praksisser og erfaringer, hvilket begrænsede deres evne til fuldt ud at implementere reformens mål efter hensigten. I tredje del af projektet anvendte jeg metoden Fremtidsværksted (Jungk & Müllert, 1987) til at undersøge, hvordan naturfagslærerne navigerer i reformkonteksten. Resultaterne herfra belyste de spændingsfelter, som lærerne møder imellem de tilsigtede mål i læreplanen og de praktiske vanskeligheder forbundet med at imødekomme kravene. Desuden blev det understreget, at selvom lærerne ofte udviste vilje til at implementere curriculum, følte mange sig begrænset af organisatoriske faktorer, hvilket resulterede i kompromiser og nedskalerede ambitioner for praksis. I fjerde del af projektet undersøgte jeg lærernes praksis i den nye mundtlige eksamensform, Naturfagsprøven, der blev introduceret som en del af reformen. Det blev gjort ved at undersøge typerne samt fordelingen af spørgsmål, som lærerne og censorer stillede i løbet af eksamensforløbet med henblik på at danne grundlag for bedømmelse af elevernes niveau af naturfaglig kompetence. Resultaterne herfra viste, at selvom der i målplanerne lægges vægt på elevernes udvikling og tilegnelse af naturfaglige kompetencer, stiller bedømmere oftest lukkede, faktuelle spørgsmål, der ikke tilsigter en vurdering af elevernes kompetenceniveauer. Sammenfattende indikerer resultaterne fra denne ph.d.-afhandling en uoverensstemmelse imellem de tilsigtede mål for undervisningen og lærernes praksis. Lærerne tilpasser og fortolker reformen ud fra deres professionelle erfaringshorisont og kontekstuelle virkelighed, ofte på måder, der afviger fra politiske intentioner. Resultaterne tyder på, at effektiv implementering af nye læreplaner kræver både individuel og systemisk støtte. Dette inkluderer anerkendelse af lærernes realiteter i implementeringen af nye tiltag samt en adressering af de kontekstuelle faktorer, der påvirker deres praksis. En sådan støtte synes afgørende for at styrke lærernes evne til at navigere i spændingsfeltet mellem eksisterende praksis og nye krav.

Contents

Introduction

This thesis investigates how a group of Danish science teachers navigates and implements a competence-oriented curriculum reform, with a specific focus on understanding the factors that influence their abilities to align their practices with the intended curriculum goals. Curriculum reforms, particularly those that emphasize competence-based education, have become a central focus in educational policy and practice globally, aiming to equip students with the skills and knowledge necessary to thrive in an increasingly complex and rapidly changing world (OECD, 2017; OECD, 2019). While these reforms hold transformative potential, their success ultimately depends on teachers, who are both the implementers and mediators of policy mandates (Fullan, 2015; Priestley et al., 2015). Despite the critical role teachers play in the reform process, there remains a notable gap in research on how teachers experience and respond to these reforms. This thesis addresses this gap by exploring the practices and experiences of a group of Danish science teachers as they engage with a competence-oriented curriculum, grounded in empirical data reported in four research papers.

Previous research on science teachers' implementations of competence-oriented curriculum reforms has identified several challenges, particularly in adapting institutional practices to align with reform goals. Teachers often struggle to integrate new pedagogical approaches, facing limitations in their skills and resources (Schneider et al., 2005; Farirah et al., 2021). Moreover, top-down reform processes can overlook the contextual needs and perspectives of teachers, creating further barriers to effective implementation (Priestley et al., 2015). Teachers also face organizational constraints, including inadequate assessment formats and limited time and resources, which hinder their ability to meet curriculum goals (Ling et al., 2021; García Carrillo et al., 2021), highlighting the need for contextualized approaches to teacher support that consider both individual and systemic challenges.

Assessment practices play a crucial role in teachers' abilities to implement competence-oriented curricula effectively. Research has shown that high-stakes assessments often influence teachers' instructional choices and priorities, which can create tensions between reform intentions and classroom practices (Dolin et al., 2018a; Black, 2000; Alderson & Wall, 1993; Cheng, 2014). While competence-based curricula require assessment formats that support students' deeper

reflection and higher-order thinking, such approaches can be challenging to implement in practice.

Despite the recognition of these challenges, studies that offer detailed examinations of teachers' experiences in their lived contexts remain scarce. Much of the existing research treats teachers as "research objects," isolating individual teacher characteristics or external factors, often in interventionist contexts (Tidemand & Tamborg, n.d., under review). This approach, while useful in identifying structural and pedagogical challenges, may miss the contextual perspectives of teachers themselves that seem essential for a thorough understanding of teachers' implementation process. As such, it lacks ecological validity (Roth & McGinn, 1998) as it fails to provide insights into the complex, lived contexts in which teachers operate. Hence, the literature has not sufficiently captured teachers' lived experiences or the contextual factors influencing their responses to reform mandates (Priestley et al., 2015). What is missing is an integrated perspective that explores how teachers navigate such reforms within specific organizational and resource conditions, giving voice to teachers' lived experiences.

In summary, while existing research highlights the challenges teachers face, there is a need for comprehensive studies that explore how teachers work with implementing competence-oriented curricula in their specific contexts. This includes examining how organizational, pedagogical, and structural factors influence teachers' ability to meet reform goals. It is essential to give space to teachers' voices, as much of the current research positions them as passive participants in the reform process, rather than as active agents whose experiences are crucial to understanding the impact of the reforms. This gap in the literature leaves out the nuanced, contextual perspectives of teachers that seems vital for a thorough understanding of teachers' work with curriculum implementation.

In Denmark, the implementation of a competence-oriented curriculum in 2015/2016 reflects broader international educational trends. The curriculum aims to develop students' competences in scientific thinking, problem-solving, and the application of knowledge in real-world contexts (UVM, 2021a). As part of the reform, a new assessment format was introduced to assess students' competences in science. However, traditional single disciplinary content-focused written exams have remained, which creates a dual assessment structure that teachers must navigate. As mentioned, research has shown that high-stakes assessments exert a "backwash effect," influencing teachers' instructional choices and priorities (Dolin et al., 2018a; Black,

2000; Alderson & Wall, 1993; Cheng, 2014), making the Danish context an interesting case to examine how teachers navigate the curriculum reform and this dual assessment structure.

The curriculum reform in Denmark, like in many countries, positions teachers as "agents of change" (Fullan, 2003; Priestley et al., 2015). However, there is limited research on how teachers respond to reforms in practice and whether they have the necessary support, autonomy, and capacity to fulfill this role effectively. This thesis aims to fill this gap by centering teachers' voices and lived experiences. By exploring how teachers navigate the Danish competence-oriented curriculum reform, this research seeks to offer a more interpretive and integrated understanding of the implementation process. It shifts the focus from structural views of curriculum implementation to the lived realities of teachers, providing insights that can inform future support strategies aligned with competence-based education.

By examining how science teachers navigate the competence-oriented curriculum reform and the systemic factors influencing their practices, this thesis provides insights into the relationship between teacher agency in the context of curriculum reforms, curriculum goals, and contextual conditions. It identifies the conditions that enable or hinder teachers from acting as effective change agents, offering a detailed understanding of how curriculum reforms are translated into classroom practices and the challenges teachers face in aligning their work with reform intentions.

The Purpose of the Study

The purpose of this thesis is to elucidate the complexities of science teachers' interactions with competence-oriented curriculum reforms, focusing on how they interpret, work with implementing[1], and sometimes resist the reform mandates, as well as the reasons for this. This purpose is pursued by collecting and analyzing data from teacher planning sessions around

[1] At this point, I use the broader and somewhat colloquial terms "teachers' work" or "teachers' practices" to maintain a general perspective. However, later in the thesis, I will introduce the more specific concept of curriculum enactment (Remillard & Heck, 2014) to provide a more precise framework for separating and communicating the ways teachers engage with and implement curriculum reforms.

multidisciplinary competence-oriented science teaching, teacher group talk-in-interactions about their specific curriculum enactments, workshop data, as well as data collected at oral exams to reflect aspects about their assessment practices.

Specifically, this work aims to uncover the factors that facilitate or hinder science teachers' abilities to align with stipulated goals, thus providing insights into the broader challenges and opportunities inherent in implementing curriculum reforms for teachers. While rooted in a Danish context, the findings carry broader significance. Competence-oriented science curricula and associated teaching practices are global trends, emphasized in educational policy and reform agendas in many countries (Ropohl et al., 2018).

By offering an in-depth analysis of teachers' working conditions, the study amplifies their voices and highlights the contextual factors shaping their agency in the context of the competence-oriented curriculum reform. In doing so, it provides a lens through which to understand how curriculum reforms are translated into practice by teachers, offering insights that are both locally grounded in the Danish context and internationally relevant. By focusing on teachers' agency, this research seeks to bridge the gap between policy aspirations and classroom realities, contributing to a more grounded and contextual approach to educational change, with implications for supporting teachers in similar contexts worldwide.

The aim of the project is realized through the following research question:

How do science teachers enact and navigate competence-oriented curriculum reforms, and what factors influence their ability to align their practices with the intended curriculum goals?

This research question is operationalized through five sub-questions addressed in the four papers included in the thesis, each exploring different aspects related to science teachers' work with implementing competence-oriented curriculum reforms. The studies address the following research questions:

1. *How are the implications of curriculum revisions for science teachers' practices studied?* (Paper 1)
2. *What factors affect science teachers' implementation of competence-oriented curriculum revisions?* (Paper 1)

3. *What characterizes Danish science teachers' construction of agency in their planning of and discussions about multidisciplinary teaching units in the context of adopting the new competence-oriented reform?* (Paper 2)
4. *How do teams of science teachers navigate in the context of a competence-oriented curriculum reform?* (Paper 3)
5. *What are the types and distributions of questions asked by assessors in oral exams that are to elicit information about students' levels of scientific competencies?* (Paper 4)

These research questions set the stage for a detailed insight into teacher practices in the context of a competence-oriented curriculum reform.

Summary of Key Findings

Through the four research papers, this thesis uncovers several critical insights into teachers' work with implementing competence-oriented curriculum reforms in science education. In this section, I will present the main findings from each of the papers that I will discuss later as part of the thesis.

The four papers collectively illuminate the complexities of curriculum reform implementation in science education, offering an exploration of how various aspects associated with curriculum revisions and their contents are practiced, challenged, and assessed in practice. They are interconnected by their shared focus on understanding the multifaceted challenges and contextual dynamics that influence the teachers' work with implementation of competence-oriented curricula in school contexts.

Findings from the literature review (**paper 1)** reveal that science teachers' practices are profoundly shaped by systemic constraints, including assessment constructs, institutional support, and professional development opportunities. The review highlights a trend of interventionist research approaches that often lack ecological validity and do not fully consider the contextual factors that influence teachers' reform implementations. This finding underscores the need for research that values teachers' perspectives and experiences in the context of their given environment, thereby offering a more comprehensive view of the complexities in curriculum enactment.

Drawing on the concept of teacher agency (Priestley et al., 2015), **paper 2** analyzes how a group of Danish science teachers in the lower secondary school construct agency in their planning of multidisciplinary, competence-oriented units; a concept introduced because of the reform that aims to fulfill key aspects related to development and acquisition of student competences. The study finds that teachers' agency is not solely an individual attribute, but an achievement shaped by contextual factors, including prior experiences, school culture, and institutional expectations. Teachers draw heavily on established practices and experiences, which limits their capacities to fully embrace the new reform objectives. These findings suggest that fostering teacher agency in the contexts of curriculum reforms requires both structural and cultural support to reconcile existing teacher practices with new stipulated requirements for practice.

Paper 3 highlights the dissonance teachers experience between the curriculum's aspirations and the practical challenges of adhering to its demands. The study finds that despite teachers' willingness to adapt, many feel limited by organizational constraints, such as time, resources, and institutional expectations. This mismatch often leads to compromises and scaled-down ambitions, indicating a need for policy and instructional support that considers the realities of curriculum implementation. These insights underscore the importance of addressing both individual and systemic, contextual factors in facilitating effective educational curriculum reform.

In **paper 4**, an analysis of assessment practices in competence-oriented oral exams reveals a concerning gap between curriculum goals and actual examination enactment. The study shows that while the curriculum reform emphasizes developing scientific competencies, assessors frequently rely on closed-ended, factual questions that do not adequately assess students' higher-order thinking or competence levels. This misalignment suggests that teachers' current assessment practices may inadvertently reinforce content-focused instruction, rather than fostering the competencies intended by the reform. Enhancing teachers' questioning strategies and aligning all assessment methods with curriculum goals emerge as critical steps toward realizing competence-based education.

Together, the four papers cover key aspects of teachers' implementation of a competence-oriented curriculum for the science disciplines in the Danish context: the challenges and prospects the teachers experience in this regard and the reasons for these. Overall, the key insights are: first, systemic and contextual barriers, such as conflicting demands and limited

support, significantly affect teachers' ability to implement competence-oriented reforms effectively. This insight underscores the risk that, without targeted support and realistic frameworks, reforms may remain largely symbolic and contribute to teacher frustration. Second, teacher agency in the context of competence-oriented curriculum reform emerges as a dynamic process shaped by prior experiences and institutional contexts, suggesting that fostering genuine curriculum change requires policies that both empower and account for teachers' contextual realities. Finally, although assessment formats in the Danish context have been implemented to focus on and embrace competences, results from this project show that teachers continue to predominantly ask content-focused questions during exams. This misalignment suggests that further professional development in assessment practices aiming to assess student competences is necessary to support teachers in fully aligning their practices with the aims and requirements stipulated in the reform. Collectively, the insights from this study indicate that achieving meaningful reform and driving effective change depends on integrated approaches that address contexts, teacher capacity, and assessment alignment.

The thesis contributes to the research on curriculum reforms in science education by centering science teachers' experiences and perspectives within the context of a competence-oriented reform. The findings underscore the complex interplay between teacher agency, systemic constraints, and the curriculum's competence-based aspirations. The insights derived from these studies highlight the need for holistic, contextual approaches to curriculum reform that support teachers both individually and institutionally, facilitating their roles as agents of change in a dynamic educational landscape.

Navigating this Thesis

This thesis reflects the findings of extensive research, presenting four papers that each explore science teachers' work with implementing a competence-oriented curriculum reform. In this wrapping, I will provide an overview of the entire research project undertaken during my PhD studies, along with a discussion of the broader implications derived from these findings. The purpose of the wrapping is to provide an overview of the broader context, theoretical approach, methodological considerations, synthesized findings, and suggestions for future pathways that underpin the research project. While each paper offers detailed insights into specific aspects of

the study, the wrapping serves to expand on areas that could not be thoroughly addressed within the limited scope of each paper.

This wrapping therefore not only integrates and contextualizes the findings from the papers, but also explores additional dimensions of the project, such as a synthesized discussion of the research questions, a critical examination of the methods employed, and a reflection on the implications of this body of work for the fields of research, practice, and policy. In doing so, the aim of the wrapping is to provide a cohesive narrative that links each of the papers into a cohesive contribution, situating the research within the broader landscape of educational research.

The wrapping is structured to guide the reader through the background and context, the methodology, findings, and implications of my study. Below, I provide an overview of the content in each chapter constituting the wrapping.

The background and context chapter introduces the overarching context of the study, with a particular focus on competence-oriented science education and the Danish competence-oriented reform that serves as the context for this study. It provides a definition of the concept of competence, exploring its theoretical and historical development, and distinguishes it from related constructs. Next, the chapter delineates the aspects of competence-orientation in the Danish curriculum reform and describes the multidisciplinary approaches and assessment methods central to the reform. This background sets the stage for understanding the demands placed on the Danish science teachers in their interpretation and enactment of the reform.

Next, I discuss the theoretical and methodological frameworks that shape my study. Drawing on Esmark et al.'s (2005) analytical-strategic approach, I outline how my theoretical perspective influences the lens through which I interpret the empirical material. I specifically elaborate on the concepts of curriculum enactment (Remillard & Heck, 2014) and teacher agency (Priestley et al., 2015) that have been applied in this study.

In the methods chapter, I present the methods employed in my study to collect and analyze data. It describes the instruments and procedures used to capture science teachers' enactment of competence-oriented curriculum reforms. Next, I address the ethical dimensions of the study as a

whole, including considerations related to participant confidentiality, consent, and the ethical implications of my position as a researcher.

Following this, I synthesize the findings from my study. In the discussion, I discuss the broader implications of these findings, then I outline recommendations for practice, research, and policy aimed at fostering more effective enactment of competence-oriented curriculum reforms in science education. I reflect on potential pathways for supporting teachers' professional agency and aligning reform initiatives with the realities of classroom practice. Following this, I discuss the study's limitations, acknowledging constraints related to methodology, scope, and the generalizability of the findings. Finally, I synthesize the key insights from the study and emphasize its contributions to understanding the challenges and opportunities of competence-oriented curriculum reforms. I reiterate the importance of systemic, contextual, and individual factors in shaping teachers' agency in the context of competence-oriented curriculum reforms.

Background and Context of the Study

In this chapter, I will set the stage for the study by situating it within its broader context. The aim is to provide the reader with an understanding of the Danish competence-oriented reform that serves as the context for the research focus. This background not only frames the specific research focus but also lays the groundwork for exploring the opportunities, challenges, and implications of competence-oriented approaches in the context of this thesis.

Competence in Science Education

This section provides a brief historical account of competence-oriented science education, which is a central theme in this thesis and a key framework within the Danish curriculum reform under investigation. My purpose of including this section is to clarify the meaning of "competence" and its educational implications, as well as to highlight its relevance in shaping curriculum goals, teaching practices, and assessment methods and formats. By understanding how competence is conceptualized in science education, I seek to contextualize the demands placed on science teachers who must interpret and enact these competencies in classroom settings. I find a clarification of the concept essential to the focus of the thesis, as it explores how science teachers navigate, interpret and implement competence-oriented mandates in ways that align, diverge, or compromise with reform objectives. This foundation will thus support the broader aim of this

thesis: to investigate teacher enactment of a competence-oriented curriculum reform in the Danish context.

Defining Competence in Science Education

The concept of competence has become central within contemporary educational reforms, including in science education, where it underpins significant shifts in curriculum design, pedagogical strategies, and assessment practices. The concept is not static but one that has evolved in response to changing societal and educational needs, influencing both pedagogical practices and assessment standards globally. Understanding the precise nature of competence, however, is complicated by its multidimensional structure and the lack of a single, universally agreed-upon definition (Rönnebeck et al., 2016). For instance, educational standards in different countries outline specific competences as learning outcomes, yet the exact definitions and scope of these competences vary significantly across educational systems and disciplines (Ropohl et al., 2018; National Research Council, 2013). Consequently, while the concept of competence remains a cornerstone in policy and reform, its practical enactment can vary widely, requiring science teachers to interpret and implement competence-based mandates flexibly within their unique educational settings. Indeed, while traditional science education often focused on delivering content knowledge, a competence-oriented approach encompasses broader skills, including critical thinking, problem-solving, and the capacity to apply scientific knowledge in real-world contexts (Klieme et al., 2008). Competence in education thus encompasses cognitive, interpersonal, and intrapersonal dimensions, enabling students to engage with complex, interdisciplinary problems that mirror those encountered beyond the classroom (Ropohl et al., 2018). Within science education, the concept of competence involves not only understanding scientific principles but also applying them through inquiry, problem-solving, and effective communication (Dolin et al., 2017).

In educational discourse, competence is generally viewed as an integration of knowledge, skills, and attitudes developed through targeted learning experiences – an approach that extends beyond mere factual recall (Klieme et al., 2008). Competence-based learning supports adaptability, preparing students to apply scientific understanding across diverse contexts, fostering scientific literacy, and developing capacities for lifelong learning and civic engagement (Dolin et al., 2017). This foundational shift is crucial for science education, as it not only broadens the scope of learning objectives but also redefines the purpose and outcomes of science curricula.

Theoretical and Historical Shifts in Science Education towards Competence

The shift towards competence-based education in science reflects a broader transformation in educational theory and practice. Science education has undergone significant transformations over time, with changing emphases on why young people should study science, what they should learn, and how the learning should occur (Duit, 2015; Krogh, 2017; Dolin et al., 2017). Early approaches prioritized content delivery over student engagement (Dewey, 1910), and through the 1970s, science classes modeled on academic disciplines, emphasizing textbook-based learning for academic progression (van den Akker, 1998). However, starting in the late 1970s and 1980s, educational theorists began advocating for learning as an active, evolving process (Dolin et al., 2017). Constructivist and sociocultural perspectives, particularly those advanced by Piaget and Vygotsky, redefined knowledge acquisition as a dynamic process influenced by students' prior knowledge and social interactions (Piaget, 1972; Vygotsky, 1978). This shift marked a move toward education that equips students with the competences needed to address complex societal challenges.

This theoretical shift has positioned science education as a means of developing competences essential for addressing complex, real-world challenges, thereby aligning science curricula with holistic educational goals, including critical engagement and lifelong learning (Dolin et al., 2017). Constructivist-inspired methodologies, such as inquiry-based and collaborative learning, have since reframed science education, placing greater emphasis on problem-solving, interdisciplinary application, and scientific literacy (Krogh, 2017). These frameworks have influenced reforms globally, underpinning curriculum designs that prioritize competences necessary for active citizenship and informed decision-making.

Differentiating Competence from Related Constructs

Although closely related to skills, knowledge, and scientific literacy, competence in education encapsulates a broader and more integrated framework that combines content knowledge with context-specific application abilities, critical thinking, and collaborative skills (Klieme et al., 2008). Unlike skills, which may refer to isolated abilities, or knowledge, which pertains to informational content, competences refer to individuals' capacities to *apply* and *adapt* their learning across various contexts. In science education, this means that students are expected not only to understand core scientific concepts but also to *use* these concepts in problem-solving, inquiry, and argumentation (Ropohl et al., 2018).

A related construct, scientific literacy, similarly emphasizes applying science understanding in personal and societal contexts, yet competence frameworks often go further, fostering critical thinking, transferable skills, and adaptability (Ropohl et al., 2018; OECD, 2017; Waddington et al., 2007). For example, the PISA scientific literacy framework emphasizes competences needed for reasoned discourse and evidence-based decision-making, competencies that support both individual development and societal well-being (OECD, 2017). These competencies highlight the role of science education in fostering analytical and reasoning abilities essential for informed citizenship, distinguishing competence from narrower constructs like skills or literacy alone.

Several models of competence have been developed to provide structure to this broad and complex concept, with frameworks such as the PISA model (OECD, 2017) and the National Research Council's (NRC, 2012) standards influencing educational policies internationally. Such models are intended not only to outline learning outcomes but also to guide curriculum design, pedagogical strategies, and assessment methods that support the development of competences.

From Theory to Practice: Competence-Oriented Science Education in Curriculum Reforms

In the previous chapters, I have briefly outlined the concept of competence in the context of science education, tracing its development and theoretical foundations and distinguished it from related constructs. Competence-oriented science education represents a paradigm shift from content delivery to the cultivation of adaptable, transferable skills essential for navigating complex societal issues. As a foundation of curriculum reform, competence-based education aligns science education with broader educational goals, fostering critical thinking, problem-solving, and authentic application abilities essential for active, informed citizenship. In this thesis, these insights provide a contextualization of the demands placed on science teachers who must interpret these competences and implement them into their practice. In the following sections, I will outline the Danish competence-oriented curriculum reform to further frame the demands placed on lower secondary science teachers in Denmark.

Folkeskolen

As my study examines lower secondary school teachers' implementation of the revised curriculum, I will begin this chapter with introducing the Danish public school system, termed Folkeskolen. The chapter follows a structure in which I provide a general introduction to the institution, then an outline of the reform in 2015/2016 as well as the changes in the curriculum.

Next follows a more specific outline of the science disciplines and how these are structured in the lower secondary school as well as the new integrated oral examination format that was introduced in line with the reform, serving as context for this study.

Folkeskolen (the Danish Public School System) is the comprehensive, compulsory school system in Denmark, offering education from grades 0 to 9 with an optional 10th grade, serving students aged 6-16. Established by law in 1814, the *Folkeskole* is governed by *Folkeskoleloven* (can be translated to the Danish Public School Act), which sets out its objectives: to ensure that students acquire knowledge and skills, prepare them for further education, and foster a desire to learn and engage with society as active citizens (Retsinformation, 2020).

Reforming Education

Since its establishment, the Danish Folkeskole has undergone several reforms aimed at improving educational outcomes and adapting to societal changes, each introducing new pedagogical principles, curricular adjustments, and changes to the structure and management of the school system. These reforms have been described as part of a broader global trend, e.g. "Global Educational Reform Movement" (Sahlberg, 2011), characterized by a focus on standardized testing, accountability, and competence-based education. A key turning point for many countries in the context of reforming education, was the "PISA chock" (Rasmussen & Rasch-Christensen, 2015), which reflected disparities in student performance and lead to widespread efforts to rethink and reform national education systems (Rasmussen et al., 2015).

Several factors have driven these radical reforms, particularly in response to the rapid transformations of the job market, globalization, and technological advancements. Environmental challenges, demographic shifts, and increased societal diversity have further underscored the need for schools to prepare students for an increasingly complex world. These forces have heightened the focus on identifying the skills, competencies, and knowledge that students need to become active and engaged citizens, often referred to as 21st century skills (OECD, 2019). These include critical thinking, collaboration, digital literacy, and creativity; skills that are seen as essential for success in a rapidly changing global society. International organizations such as OECD responded to these challenges by developing frameworks which provided guidance to policymakers and educators on how to address these new demands. The European Union also developed the Key Competences for Lifelong Learning framework

(European Commission, 2006) to support member states (including Denmark), in reforming their educational systems to emphasize competencies essential for lifelong learning. Throughout the 2000s, many European countries, inspired by these frameworks, introduced competence-based curricula, shifting from traditional content-based instruction based on learning goals defining what students should *know* to learning goals that define what students should be *able to do* (Dolin et al, 2017).

Denmark followed this trend, and the most recent reform of the Danish Folkeskole (serving as the context for this study) represents the most radical reform in many years. It introduced significant changes, and brought new approaches to teaching and learning. Central to this reform was the emphasis on competence-based education, particularly in subjects like the natural sciences, where learning objectives were reorganized to focus on what students should be able to do, rather than on what they should know. This shift reflects the broader global movement towards preparing students for the demands of a 21st-century society, emphasizing the development of skills and competencies that are crucial for navigating a rapidly evolving world (Retsinformation, 2020).

The following section will delve deeper into the details of this reform, outlining its implications for students and teachers in the Danish context.

The 2015/2016 Reform

The Danish Reform represented a significant shift in the structure and aims of the Danish public school system (Folkeskolen). The reform was widely regarded as the most fundamental educational reform in many decades: The reform was deemed a necessary and radical school transformation project, essential to aligning education with the future demands of the labor market and society (Olsen, 2013a). The reform was seen not just as a set of policy changes but as a reflection of a new vision for education, fundamentally altering the school experience for both teachers and students (Olsen, 2013b; Rasmussen, 2015).

One of the most central aspects of the reform was the introduction of Fælles Mål (can be translated to Common Objectives). These replaced former mandatory objectives and were applied across all subjects in the Danish Curriculum, including the natural sciences. The goal of the new curriculum was to provide clearer, more measurable, and practically applicable learning goals for teachers.

Denmark's adoption of a competence-oriented science curriculum aligns with international educational reforms driven by organizations such as the OECD, which advocates for preparing students to thrive in global, information-rich environments (OECD, 2017; OECD, 2019). The Danish curriculum reform reflects this vision, emphasizing four main competences for lower secondary science education - investigative, modeling, reasoning, and communicative competences (see Table 1) - that extend beyond content knowledge to foster critical engagement with scientific issues (Dolin et al., 2017). Each competence targets a specific domain: for instance, investigative competence emphasizes systematic inquiry, while modeling competence fosters the ability to abstract and simulate scientific phenomena. Collectively, these competences shape the objectives of Danish lower secondary science education, ensuring that students gain skills essential for active, informed participation in societal discourse and decision-making.

The Implications for the Science Disciplines

Following the reform, science teaching in the Danish Folkeskole begins with integrated nature/technology (natur/teknologi in Danish) from 1st to 6th grade and ends with the three disciplines biology, geography, and physics/chemistry from 7th to 9th grade.

For the natural sciences, the reform had several important implications. The focus on competence-based education encouraged the development of students' scientific thinking and problem-solving skills, rather than a mere accumulation of factual knowledge. Following the reform, teachers are expected to prioritize inquiry-based learning and cross-disciplinary approaches, fostering a deeper engagement with scientific concepts. This shift aimed to strengthen the coherence of science education across different grade levels and ensure that students acquired not only foundational scientific knowledge but also the skills to apply in real-world contexts. The reform thus sought to modernize science education and better prepare students for the demands of a knowledge-based society (Rasmussen, 2015).

Problem-based Learning in Science Teaching to Foster Student Competences

For each science discipline, it is stated in the regulations that the students are expected to develop scientific competences and gain insight into how each discipline and related research in interaction with other natural sciences contribute to our understanding of the world (UVM, 2020; UVM, 2019c). To embrace this, students must engage in problem-based learning with the aim of enhancing their perception of nature and the working methods in science, as well as supporting their motivation for each subject.

It is argued in the regulations that a problem-based organization of science teaching significantly contributes to the development of students' scientific competences, as multidisciplinary teaching places students in complex situations where they take part in determining parts of the content and processes in teaching (UVM, 2019a). It is further stated that these complex situations often demand an approach incorporating multiple perspectives from the natural sciences to develop the central and cross-disciplinary dimensions of: i) the educational goals, and ii) the overall purpose of the Danish elementary school. According to the regulations, such problem-based learning provides students with opportunities for decision-making and action related to issues at local and global levels (UVM, 2019a).

Competence-oriented Science Teaching in the Curriculum

Four transversal competence areas are formulated for the science disciplines in the curriculum (UVM, 2019b, translated from Danish):

Competence Area	**When completing 9th grade**
Investigation	The student can make scientific investigations
Modelling	The student can use, assess and create models
Communication	The student can communicate about and with the use of science in a scientific manner
Contextualization	The student can contextualize scientific content and scientific methodology

Table 1 Competence areas for the scientific disciplines, translated from Danish (UVM, 2019b)

These competence areas are emphasized in the reform, and are key in the science subjects, as it is formulated that *"students' development of scientific competence within the four areas of competence is crucial, if the teaching is to contribute to the fulfillment of both the subject's and the school's objectives*" (UVM, 2019b, translated from Danish). In the context of the reform, the formulation of scientific competence is interpreted in continuation of the European Qualification Framework, as the student's ability *"(...) to use scientific knowledge and skills relevant in context of the sciences. However, scientific competence encompasses more than the sum of scientific knowledge and skills being applied. It is also the ability to independently and responsibly reflect on the application of skills and knowledge in specific situations, creating opportunities for critical decision making and action*" (UVM, 2019b, translated from Danish).

In continuation of the competence areas are obligatory competence goals for what students should be able to do at different levels within each competence area. These competence goals

indicate a progression for working with each competence area. According to the curricular guidelines (læseplan in Danish), students' acquisition of the scientific competences presupposes that the students are aware of the specific goal(s) they are working towards and that there is room for reflection in teaching on how the ongoing activity contributes to the development and achievement of the given competence. It is further argued that a fruitful interaction between the scientific competence areas is best achieved when multiple competencies are targeted and explicitly brought into play in educational contexts (UVM, 2019b, translated from Danish).

The revised curriculum "Fælles Mål" (UVM, 2019c) consists of an overarching disciplinary purpose and four competence areas, each with its own associated competence goal. These areas are divided into mandatory skill and knowledge areas. Associated with skill and knowledge domains, teachers can find examples of guiding skill and knowledge goals to use as inspiration for planning their teaching. It is stated in the curriculum guide (faghæfte in Danish) that the competence goals and associated skill and knowledge areas constitute as the overall frame for the teachers' considerations regarding the planning of disciplinary teaching including considerations related to the selections of contents to be unfolded in teaching (UVM, 2019d)[2]. This gives the science teachers autonomy to select contents and formulate learning objectives to use in their teaching.

Multidisciplinary Science Teaching

With the revised curriculum followed an introduction of mandatory multidisciplinary teaching units. Science teachers are obliged to work with the four scientific areas of competence within each science discipline as well as in the interaction between the disciplines, i.e. in the mandatory multidisciplinary teaching units (UVM, 2019b).

There are certain aspects teachers need to consider related to the multidisciplinary units, both with regards to the number and to the format, stipulated in the regulations. Throughout 7th, 8th and 9th grade, at least six multidisciplinary teaching units must be completed. The purpose is to

[2] As the reform was implemented in 2015/2016, knowledge and skill goals were mandatory as part of the curriculum. In 2017, these became guiding (and examples are listed in the guidelines) for the science teachers, and it is within this context of the curriculum that the data was collected.

provide students with the opportunity for immersion and understanding of connections within science, as well as to form opinions and make decisions in complex (real-life) situations. The teaching modules can vary in length and scope but must be based on an interaction between the disciplines and incorporate relevant content from two or all three disciplines. The multidisciplinary teaching should be seen in conjunction with the isolated single disciplinary science teaching, and each multidisciplinary unit must be formulated based on at least two of the following criteria (UVM, 2019b, translated from Danish). It must:

- Involve students' own investigations in the local area.
- Incorporate students' work with technology.
- Involve conflicting interests, allowing students the opportunity for decision-making.

According to the guidelines, the units should be problem-based, encompassing several issues, and provide opportunities for students to work within the four scientific competence areas. According to the curricular guidelines, problem-based teaching is characterized by students' (UVM, 2019b, translated from Danish):

- Participation in the choice of a delimited scientific area
- Addressing one or more problems/issues within the delimited scientific area
- Having the opportunity to independently formulate and investigate selected questions related to the issue.
- Having the opportunity to work on actions or proposals for actions throughout the unit.

The Ministry of Education has proposed six focus areas that the teachers may choose to use (UVM, 2019b, translated from Danish):

- Production with a sustainable utilization of the natural foundation
- Sustainable energy supplies at local and global levels
- Drinking water supplies for future generations
- Individual and societal emissions of substances
- The impact of radiation on living organisms
- The significance of technology for human health and living conditions

In the context of the new science curriculum, the term "multidisciplinary" refers to the students' work with contents and methods from two or all three science subjects in the lower secondary school. Central to the term "multidisciplinary" in the stipulations is that the teaching is planned so that it is experienced as multidisciplinary by the students. It is emphasized in the curricular guidelines that working with the subjects in separate silos in the multidisciplinary teaching does not comply with the intentions in the curriculum, *"(...) since it is impossible for the students to make it multidisciplinary on their own"* (UVM, 2019b, translated from Danish). The teachers are required to explicitly confront the students with multidisciplinary, competence-oriented learning objectives for the unit. Further, students should engage in scientifically integrative experiments, use of models and appropriate terminology.

A new Oral Exam Format

The significance of the role of competence-oriented, multidisciplinary science teaching in the revised curriculum is underlined by the new oral examination format introduced in school year 2016/2017: an examination that includes all three disciplines and is an integrated practical and oral examination to elicit the students' level of competence. The examination is an integrated oral examination, where the students can attend individually or in groups of 2-3 students.

In the exam regulations, it is stated that many of the competence-based skills such as formulating hypotheses, designing experiments, and using, developing and evaluating models can effectively be acquired in the individual science disciplines in a less complex context. According to the regulations, this approach can support the multidisciplinary teaching, where students continue to apply and further develop competence-based skills they have acquired to address their own scientific problems. According to the regulations, this illustrates how disciplinary-specific and multidisciplinary teaching can interact to enhance students' scientific competences (UVM, 2022).

For the multidisciplinary focus areas presented for the exam, students must formulate multiple scientific problems with corresponding research questions from each discipline. To be eligible for the examination, students must submit an approved scientific problem along with relevant research questions in advance. Ideally, the questions incorporate contents from multiple subjects. According to the guidelines, the problem must:

(...) be thoroughly developed to serve both as a guide and a management tool for the students. It is essential for their workflow that the problem statement and the associated guiding questions can provide a coherent "red thread" they can follow as they work to explore the issue. The scientific problem is characterized by one or more questions with scientific content, to which there is no single definitive answer." (UVM, 2020, translated from Danish)

Multidisciplinary unit	Scientific Problem	Operationalizing Questions
A Journey into Space	*What challenges are involved in a future colonization of Mars?*	*How should astronauts train to maintain physical health during space travel? (Biology)* *What is gravity, and what are the potential consequences of altered gravitational forces on the human body? (Physics/Chemistry and Biology)* *How much force is required to escape Earth's gravitational field? (Physics/Chemistry)* *Which locations on Earth are suitable for rocket launches, and why? (Geography)*
Individual and Societal Emissions of Substances	*What societal consequences can arise from climate change caused by CO_2 and other emissions into the atmosphere?*	*What is the greenhouse effect, and is it a new phenomenon? (Physics/Chemistry and Geography)* *What are the causes of rising sea levels, and which areas are particularly vulnerable? (Physics/Chemistry and Geography)* *How does climate change impact different population groups around the world? (Geography)* *How does cattle and pig production contribute to the greenhouse effect? (Biology)* *How can human impact on the greenhouse effect be reduced?*

		(Physics/Chemistry, Geography, and Biology)

Table 2: Excerpt of examples on Focus areas, scientific problems and working questions from the exam guidelines, (Danish: Vejledning til Fælles Prøve) (UVM, 2021b, translated from Danish)

Table 2 is an example from the exam guidelines (UVM, 2021b) of titles for multidisciplinary units and associated problems and questions from each discipline to operationalize the problem. According to the regulations, the students will have developed familiarity with designated multidisciplinary units as well as related scientific problems. However, according to the regulations, the specific problem and guiding questions they will work with during the examination must differ from those addressed in prior work, ensuring that students do not replicate previous work (UVM, 2021b). In the course up until the exam, the teachers support and guide students to refine ideas, while offering feedback on their progress. During the exam, students are encouraged to draw upon experiences and insights from previous teaching to develop a new and distinct scientific issue and associated guiding questions. It is explicitly stated in the regulations for the exams:

"It is important to emphasize that students are being assessed on the extent to which they demonstrate scientific competence. This means that they are not being tested on individual scientific subjects, but rather on their ability to apply relevant aspects of the sciences to address the given scientific problem." (UVM, 2020, translated from Danish)

To ensure that students can demonstrate levels of scientific competence in an unprepared context, students must be asked probing questions that are unknown to them before the exam. According to the regulations *"(...) the probing questions are intended to help students articulate and clarify their work within specific competence areas, enabling them to explain and justify their approach to addressing the scientific problem."* (UVM, 2021b, translated from Danish). The regulations exemplify probing questions:

- You have been provided with two different models that illustrate ... discuss the advantages and disadvantages of each model
- Outline a study based on the following hypothesis: ...
- Using your model, can you formulate a hypothesis and sketch a plan for how it could be tested?

- Use the following scientific concepts ... to build an argument for ...
- What potential implications might the conclusion of your scientific investigation have for ...?

The assessors are provided with an outline from each group at the beginning of the exam, which, together with the scientific problem and probing questions serve as the foundation for the examination process and the dialogue. During the exam, 4-6 students are examinated simultaneously in the same room, each working on their problems, while two teachers and one external censor rotate between the groups to engage in dialogues (UVM, 2021b; Nielsen & Nørgaard, 2018).

Assessment Criteria

Each student is assessed individually, and according to the regulations *"(...) it is the examiner and censors' responsibilities to ensure that they acquire a comprehensive and detailed impression of each individual student during the examination"* (UVM, 2021b, translated from Danish).

Each student is assessed according to her level of competence across the four areas of competence. The assessment criteria for the exam are formulated with a clear reference to the areas of competence for the disciplines to ensure that the students are assessed according to their levels of competence. The criteria are (UVM, 2021b, translated from Danish):

- The student can explain and justify the choice of investigations and models
- The student can design, conduct, and draw conclusions from scientific investigations in connection with relevant models and perspectives
- The student can apply, evaluate, and develop models in relation to investigations and perspectives
- The student can argue for scientific concepts and principles
- The student can use relevant terminology from physics/chemistry, biology, and geography
- The student can identify and justify relevant courses of action

Summary: Key Aspects of the Reform

To sum up, the Danish reform introduced a transformative approach to science education, focusing on competence-oriented science teaching, multidisciplinarity, and a new integrated oral exam format designed to assess students' level of competence rather than mere content knowledge. The overall key aspects of the reform that teachers must translate and implement, and which are relevant to the scope of this thesis, are:

Competence-oriented science teaching: Teachers must plan and conduct teaching that goes *beyond* factual knowledge, emphasizing competencies that align with the EU's Key Competences for lifelong learning (European Commission, 2006) emphasizing critical thinking, collaboration, and problem-solving to prepare students for complex, real-world scenarios.

Multidisciplinary teaching units: The reform mandates a number of multidisciplinary teaching units that the science teachers must plan for and conduct in collaboration. The units must be taught in a problem-based manner through an approach that fosters interconnected scientific understanding, allowing students to see science from multiple perspectives within shared contexts. The multidisciplinary approach stipulated in the regulations enhances students' understanding of how knowledge traditionally associated with one discipline can be transferred and expanded when clearly connected to what they are learning in another scientific discipline.

New oral exam format: Two teachers and one external censor assess students' scientific competences, i.e. their abilities to apply knowledge and skills in a multidisciplinary context through dialogue in a dynamic, interactive setting.

Overall, the reform requires science teachers to adopt an integrated, inquiry-based approach that integrates multidisciplinary perspectives and develops transferable scientific competences in students, reflecting modern educational priorities focused on preparing students for societal engagement and lifelong learning culminating with a new oral assessment format. This change stands in stark contrast to previous curricula that contained a heavy focus on knowledge acquisition, both as objectives for science teaching (organized in separate silos) as well as the contents in the exams (Dolin et al., 2017).

Methodological and Theoretical Approach

In the previous chapter, the concept of competence in the context of science education was outlined, followed by an introduction of the Danish competence-oriented curriculum reform with a specific focus on lower secondary education, which serves as the context for this study, including the specific goals and competences that teachers are expected to address and assess. The competence-oriented focus introduced with the reform of 2015/2016 represents a significant shift in the goals and practices of science education. Rather than focusing solely on the transmission of subject knowledge, the reform tasks teachers with designing and implementing learning experiences that develop students' competences in investigation, modeling, reasoning, and communication. This requires teachers to *actively* interpret and implement the competence framework in their teaching practices, translating abstract curricular goals into concrete, classroom-level activities (Priestley et al., 2015; Fullan, 2015). However, the process of engaging with or "enacting" a curriculum is complex and not always straightforward. What does it mean to enact a curriculum? To explore this process, the following section draws on theoretical perspectives from curriculum enactment (Remillard & Heck, 2014) and teacher agency (Priestley et al., 2015), offering a methodological framework for examining how teachers navigate and operationalize these new demands in their unique educational contexts.

In my work with this thesis, I commit to a conception of methodology grounded in an analytical-strategic approach as developed by Esmark et al. (2005). Here, methodology is understood as the set of reflections and considerations belonging to the choice of a theoretical framework, along with the implications that this framework brings to the researcher's perspective on a segment of social reality (Esmark et al., 2005). In this chapter, I will first outline the specific - the frameworks of curriculum enactment (Remillard & Heck, 2014) and an ecological approach to teacher agency (Priestley et al., 2015) - explaining their definitions and interrelations. In the latter part, I will discuss the ways in which my theoretical framework shapes my analytical lens, exploring how these choices impact my interpretation and understanding of a distinct aspect of the social world (Esmark et al., 2005).

My aim with this chapter is thus to make explicit the methodological commitments that underpin this research, recognizing that the theoretical approach I employ does not merely structure my inquiry but also inherently informs what aspects of social phenomena came to the fore.

Delineating the Concept of Curriculum Enactment in the Context of this Study

In this thesis, I draw on the concept of curriculum enactment, as articulated by Remillard and Heck (2014), to develop a lens through which I understand what it means to enact a curriculum, as well as how Danish science teachers engage with the competence-oriented curriculum. Rather than viewing the curriculum as a static set of predefined objectives to be uniformly implemented, curriculum enactment as articulated by Remillard and Heck (2014) emphasizes that teachers are *active* participants in bringing curriculum to life through a process of interpretation, adaptation, and decision-making in their specific contexts. This perspective positions teachers as mediators who translate policy intentions into classroom practices, influenced by a complex interplay of individual, organizational, and cultural factors.

Central to the conceptualization is the idea that teachers are not passive implementers of curricular policy, but instead engage as *agents* whose professional judgments, creative adaptations, and situational responses shape the curriculum in practice. Remillard and Heck (2014) highlight that curriculum enactment is an inherently dynamic and context-bound process, where teachers' prior knowledge, beliefs, institutional constraints, and local contexts all contribute to how official curriculum goals are realized. This notion is especially pertinent in the context of competence-oriented curriculum reforms, where curricular aims extend beyond traditional content knowledge to include multifaceted competencies, such as critical thinking, problem-solving and collaborative skills (Ropohl et al., 2018). Indeed, the realization of these curricular objectives is heavily contingent upon teachers' capacities to interpret, adapt and integrate such competencies into their instructional routine and assessment practices.

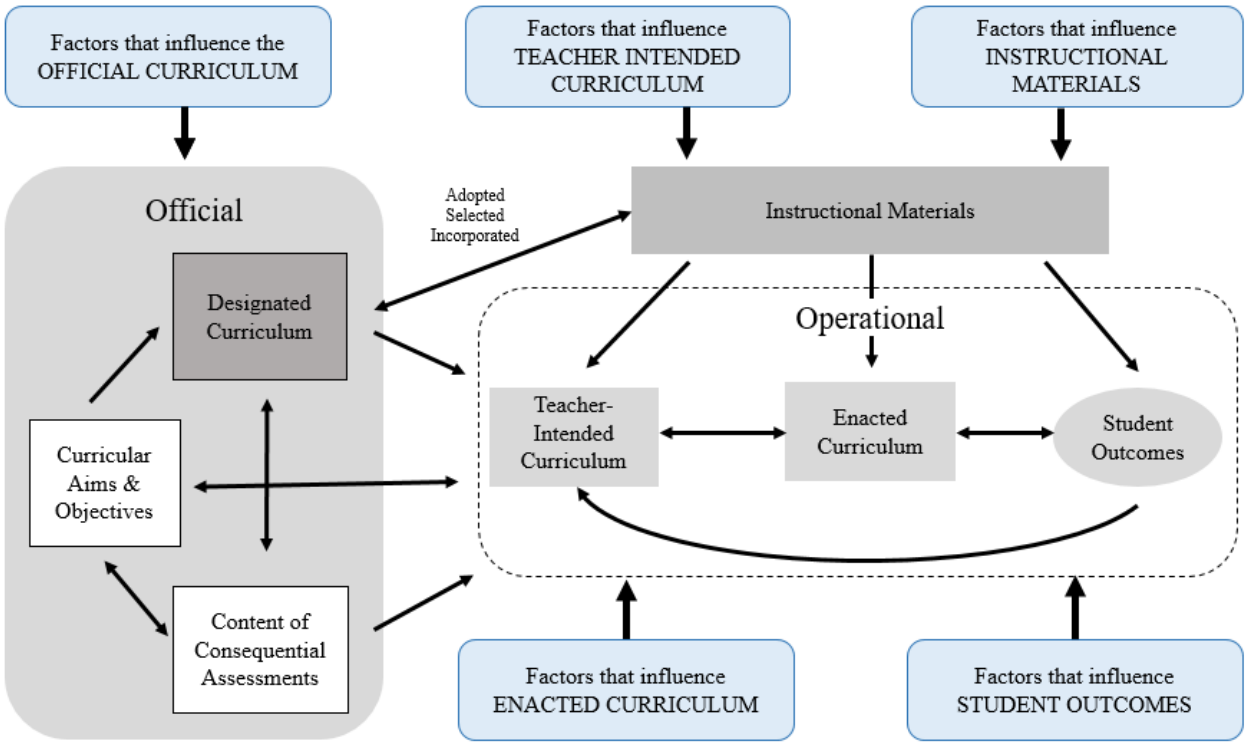

Figure 1. Visual model of the curriculum policy, design, and enactment system, adopted from Remillard & Heck (2014). The arrows in the diagram signify paths of likely influence in the U.S. school system (Remillard & Heck, 2014).

In their description of the enactment process, Remillard and Heck (2014) expand upon the distinctions between the *official* curriculum and the *operational* curriculum, building on the work of Goodlad et al. (1979) and Schmidt et al. (1996). As such, an essential insight from Remillard and Heck's framework (2014) is their distinction between the intended (official) curriculum as defined by policymakers, and the *enacted* curriculum that emerges in classroom settings.

The *official* curriculum (Figure 1) comprises the learning goals, performance expectations, and sometimes instructional resources designated by governing agencies. In this context, the official curriculum represents the policy structure within a school system including i) national, state and local policies, ii) curricular aims and objectives; the specified learning expectations and outcomes set by policy, and iii) assessment content. In Remillard and Heck's (2014) framework, the *designated* curriculum is part of the official curriculum. They argue that this component may vary in form and specificity across educational contexts: it may consist of instructional materials, approved textbooks, or other resources intended to structure the content, pacing, and sometimes the instructional processes and tools (Remillard & Heck, 2014). In the *official* curriculum, curricular aims and objectives outline the intended learning goals and outcomes set by

educational authorities at various levels, defining the knowledge and skills that students should ideally acquire through instruction and sometimes explaining the rationale behind these goals. Additionally, in Remillard and Heck's (2014) model, the curriculum is influenced by the content of official assessments, which hold significance for students, educators, and schools. These assessments are aligned with the specified curricular objectives and are crafted to evaluate students' achievements relative to these established goals.

Remillard and Heck (2014) describe the *operational* curriculum as the practical implementation process, i.e. what occurs in practice *through the enactment process* encompassing three components: the teacher-intended curriculum, the enacted curriculum, and student outcomes:

> *"When put in the hands of teachers, the official curriculum, conveyed through curricular objectives, content of assessments and the designated curriculum, begins to change form, moving from descriptions of instructional objectives and means for achieving them toward actual classroom enactments." (Remillard and Heck, 2014, p. 6)*

Remillard and Heck (2014) term these components *operational* because they reflect the transformations that occur during curriculum enactment. Drawing on McLaughlin (1990) and Stein and Coburn (2008), they argue that enactment involves an interpretative, meaning-making process in which both the innovation and the local context adapt to each other, with local factors and actors influencing outcomes. As mentioned above, within their framework, Remillard and Heck (2014) define the *operational* curriculum as comprising the teacher-intended curriculum, the enacted curriculum, and student outcomes. The *teacher-intended* curriculum refers to the curriculum shaped by teachers, including the interpretations, adaptations, and decisions about instructional strategies. Drawing on Gueudet and Trouche (2009), they describe this process as "documental genesis" - teachers' meaning making of instructional resources and development of new documents, including lesson plans tailored for their specific student group. Thus, the teacher-intended curriculum is a unique adaptation designed for a specific classroom context. To emphasize the process of interpretation and adaptation in the context of curriculum enactment, Remillard and Heck (2014) describe the difference between the designated and the teacher-intended curriculum as "*(...) the difference between a script of a play and each scene as conceived by the director,"* (Remillard & Heck, 2014 p. 7).

By incorporating the *teacher-intended* curriculum, Remillard and Heck (2014) acknowledge at least two active phases of the operational curriculum: 1) teachers *transforming* the designated curriculum into plans for instruction and 2) the *enactment* of those plans in the classrooms. A third phase emphasized by other researchers, such as Gueudet and Trouche (2012), but not represented in Remillard and Heck's (2014) model, involves collaborative planning and interpretation of the official curriculum by groups of teachers.

According to Remillard and Heck (2014), the *enacted* curriculum is the curriculum as delivered in the classroom, encompassing decisions and modifications teachers make as they adapt to student needs, classroom dynamics, and situational constraints or opportunities. This dimension emphasizes the responsive and evolving nature of teaching, where teachers' intentions and plans may shift due to e.g. student questions, responses, or time limitations. Originally developed within the context of U.S. mathematics education, Remillard and Heck's (2014) framework outlines five key aspects of the *enacted* curriculum: i) the mathematics (i.e. the contents and nature of the discipline, including the particular disciplinary ideas that are addressed and how they are represented and engaged with), ii) instructional interactions and norms (i.e. the interactions that take place between students, the teacher, the tasks and tools, as well as the norms and particular routines of practice that govern them), iii) teacher pedagogical moves (i.e. the actions that shape how the discipline is addressed, including how it is represented and investigated, which subsequently influences how interactions are structured, the kinds of interactions that are valued, and tools used), and iv) tools and resources (i.e. physical, technological, linguistic, and cognitive tools utilized by teachers and students). According to Remillard and Heck (2014), tools are often introduced through teachers' actions and shape how the discipline is represented and engaged as well as the dynamics of interactions.

The third component of the *operational* curriculum is student outcomes, representing the knowledge, skills, and attitudes that students retain following their engagement with the enacted curriculum. Referred to by Hiebert (1997) as the "residue," student outcomes encompass a range of results, from academic achievement to students' attitudes toward learning and perceptions of themselves as thinkers. Outcomes can include students' understanding of the discipline (Ruthven, 2011), their views of the subject (Boaler & Staples, 2008), their self-concept as learners (Boaler & Greeno, 2000), and their engagement in classroom discourse (Herbel-

Eisenmann & Otten, 2011). Remillard and Heck (2014) argue that these outcomes are closely linked to the enacted curriculum and that instructional materials play a central role.

According to Remillard and Heck (2014), curriculum enactment occurs in a sociopolitical context, influenced by various "mediating factors", which impact both the *operational* and *official* curriculum These mediating factors - social, political, cultural, structural, and cognitive - can affect curriculum enactment through policy influences, collectively shared perspectives, institutional constraints or supports, and the capacities of individuals involved in the process.

I find the distinction between the *official* and the *operational* curriculum particularly relevant in the context of competence-oriented science education of two reasons: First, previous research has pointed to the fact that ambitious goals for teaching often do not fully align with existing teaching practices, available resources, or assessment systems (Dolin et al., 2018a; Fullan, 2015). Second, while the curriculum reform in Denmark aspires to foster students' abilities to apply scientific knowledge in real-world contexts, teachers face the challenge of *translating* these complex goals into practical, classroom level and assessment strategies. In this thesis, I therefore adopt an understanding of curriculum enactment that foregrounds these tensions, exploring the scope and limitations teachers encounter as they attempt to align their practices – transform, translate and interact (Remillard and Heck, 2014) - with the intended goals of the reform.

In the context of the competence-oriented curriculum reform in Denmark, the process of aligning practices with reform goals represents a significant and complex task for teachers. This alignment requires what Remillard and Heck (2014) describe as *translation* and *adaptation*: teachers must not only *interpret* broad curriculum objectives but also *reshape* and *adapt* them to the realities of their everyday classroom practice. This involves deep, multifaceted work to operationalize abstract competencies in the Danish context - such as scientific modeling, investigation, and contextualization - to concrete learning activities, assessments, and teaching strategies. However, previous research has shown that Danish science teachers have received limited guidance and support in this translation process (Nielsen & Nielsen, 2021). The official curriculum documents offer few practical resources and structured frameworks to support teachers' adaptation efforts, leaving them without instructional materials aligned to these competence goals or any formal support for implementing such practices, as they are given autonomy to translate the curriculum into their practices. As a result, the work of *interpreting,*

adapting, and implementing competence-oriented goals relies heavily on teachers, making the enactment of the curriculum both demanding and resource-intensive.

In the work with this thesis, Remillard and Heck's (2014) framework serves primarily as a classificatory system that enables me to differentiate between the roles of teachers and the curriculum. It provides a detailed view of enactment as a layered, dynamic process, thereby allowing me to depict how various elements – such as instructional materials, teacher decisions, or contextual influences – interact with the with the broader curriculum enactment process. By disaggregating these layers, I can clarify the structural and functional distinctions inherent in enactment without conflating them with interpretive or agentic dimensions. Furthermore, I can utilize Remillard and Heck's (2014) curriculum enactment model to outline the specific aspects of the curriculum enactment process I focus on methodologically – as well as those that are out of scope for this thesis. Their model allows me to articulate the segments of the enactment process that my chosen methods aim to examine, such as teacher interactions in planning sessions, decision-making processes, thoughts about enactment, or the adaptation of curriculum elements in response to dynamics in their given contexts. This approach enables a structured methodological focus, as I can identify and prioritize the specific layers of enactment that are central to my analysis, rather than treating the enactment process as a uniform entity.

However, while the enactment framework aids in isolating and categorizing these aspects, it lacks the analytical power needed to explain the motivations, choices, interactions, and adaptations teachers make within and across these layers, i.e. the explanatory depth for the arrows visualized in Figure 1 - or, as framed by Remillard and Heck (2014) - the "hand-off" that occurs between the dimensions in their model. This is where the concept of teacher agency, as formulated by Priestley et al. (2015), becomes essential in the work with this thesis.

The Concept of Teacher Agency

Teacher agency refers to the idea that teachers have *"(...) the power to act, to affect matters, to make decisions and choices, and take stances"* (Vähäsantanen, 2015, p. 1). Research on human agency across various professional and personal contexts has resulted in diverse perspectives, and the concept of agency in education has been widely discussed (Priestley et al., 2015).

According to Eteläpelto et al., (2013), the concept of agency is grounded in various academic fields, such as psychology, sociology, philosophy, economics, and anthropology. Additionally,

agency has been explored through various intellectual frameworks, including as postmodern, post-structural, sociocultural, identity and life-course perspectives (Eteläpelto et al., 2013). Scholars from these traditions often perceive agency differently, for instance psychological traditions tend to view agency as a person (e.g. Bandura, 2009), while other scholars emphasize the relationship between the person and the environment (e.g. Lasky, 2005; Wertsch, 1991). These diverse interpretations illustrate the complexity of agency as a concept used for analysis and study, with a key challenge being the lack of a clear conceptualization of agency in much of the literature (Priestley et al. 2015).

Teacher Agency – an Ecological Approach

This thesis is anchored in the theoretical concept of teacher agency as formulated by Priestley et al. (2015). Their framework not only provides a theoretical lens through which the thesis is understood but has also directly informed my research design, shaping how I collected data, and has served as an analytical foundation for my exploration of teacher actions and decision-making processes in two of the papers that constitute part of the thesis (**papers 2 and 3**). Thus, by applying teacher agency – the ecological approach – by Priestley et al. (2015), I can explore how teachers act - both problematically and productively - within their professional contexts: how they navigate structural constraints and enact in response to their specific educational contexts.

Importantly, Priestley et al. (2015) do not conceptualize agency as an individual capacity or something one possesses, but as a possible achievement (Biesta & Tedder, 2006). In practice, agency can lead to both effective and counterproductive outcomes, as teachers navigate systemic pressures that may conflict with their professional values and aspirations (Vähäsantanen & Eteläpelto, 2011; Lasky, 2005; Emirbayer & Mische, 1998). Priestley et al.'s (2015) model does not assume agency to be inherently positive or effective; rather, it highlights the complexities and potential pitfalls within teachers' actions as they draw on past experiences, make present evaluations, and envision future possibilities (Priestley et al., 2021).

Priestley et al. (2015) define teacher agency as the capacity to act purposefully and reflectively within one's socio-material context. Here, agency is not seen as a fixed attribute but rather as an emergent and context-dependent phenomenon shaped by teachers' past experiences, current contextual evaluations, and future aspirations. Viewing agency in such terms can, according to Priestley et al. (2015), help us understand not only how humans can exhibit reflexivity and

creativity, defying societal constraints, but also how social and material environments both can empower and restrict individuals.

Their approach to teacher agency builds on Emirbayer and Mische's (1998) temporal-relational framework, which positions agency as a complex interplay across three dimensions: iterational (influences from the past), practical-evaluative (the engagement with the here and now), and projective (the orientation toward the future). The close alignment with Emirbayer and Mische (1998) is particularly evident in terms of how past achievements, understandings and patterns of action influence present and future practices. According to Emirbayer and Mische (1998), actors actively recognize and reconfigure past patterns of behavior to navigate current dilemmas, drawing upon a repertoire of prior experiences, both professional and personal experience. This process allows them to maneuver among various repertoires of action, thereby adapting their responses to the demands of their immediate context while maintaining a future-oriented perspective. Thus, the interplay between the three temporal dimensions enables actors to use past knowledge and accomplishments to inform their present and future actions. Indeed, this underscores the significance of accumulated experience as a foundation for decision-making and adaptability in educational settings.

Priestley et al. (2015) argue that all three dimensions influence concrete actions, but their contribution varies depending on the situation. Each dimension offers insights into how agency is exercised within specific contexts and timeframes in a concrete situation – constrained and supported by discursive, material, and relational resources - as teachers draw on prior knowledge, make situational decisions, and envision potential futures, balancing short-term and long-term goals, values and aspirations. The model below illustrates the key dimensions of the teacher agency model, showing how the dimensions are separated and interact, according to Priestley et al., (2015):

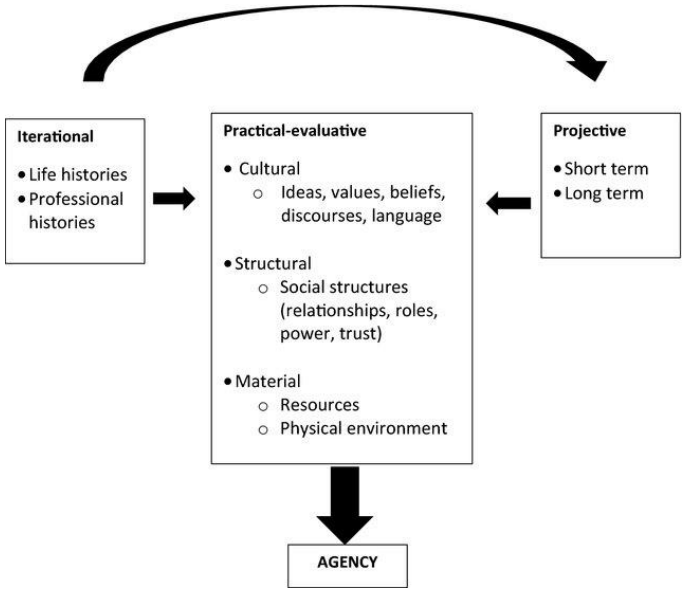

Figure 2 Teacher Agency, adopted from Priestley et al., (2015)

The iterational dimension of teachers' work: Priestley et al. (2015) emphasize various factors that influence teacher agency, such as personal capacity (skills and knowledge), beliefs (both professional and personal), and values - all rooted in teachers' past experiences. In their model, Priestley et al. (2015) differentiate between broader life histories and more focused professional histories, encompassing education and the collective experiences the individual gained through teaching. The iterational dimension of teacher agency, which draws on Bourdieu's (1977) concept of habitus, encompasses the established practices, routines, and cognitive schemas that teachers have developed over time. It captures the stability and continuity of teachers' practices showing how they bring coherence to their work by drawing on personal histories, institutional norms, and ingrained professional practices. Thus, it encapsulates how teachers bring continuity to their practice by drawing on accumulated experiences, established norms, and professional memories. For example, a teacher may apply classroom management strategies refined through years of experience when facing new classroom challenges, demonstrating how past knowledge shapes current actions. The iterational dimension of teacher agency thus provides a foundation for agency, enabling teachers to rely on familiar strategies and knowledge, which helps maintain coherence and consistency in their practice. However, it can also constrain agency when teachers for example become overly reliant on past practices that may no longer be effective in new or changing contexts. Thus, this dimension can reveal both the strengths and limitations of habitual

practices, highlighting how past experiences perpetuate rigidity or inhibit adaptation (Priestley et al., 2015).

The practical-evaluative dimension of teachers' work: Priestley et al. (2015) assert that while agency is connected to both the past and the future, it can only be enacted in the present, as reflected in this dimension of the framework: The practical-evaluative dimension is situated in the present and involves teachers' abilities to make contextual judgments, evaluate options, and adjust practices in real-time. In this dimension, Priestley et al. (2015) differentiate between cultural aspects (ways of speaking and thinking, of values beliefs and aspirations, including both internal and external dialogue), material aspects (resources that facilitate or constrain agency and the broader physical environment in and through which agency is possibly achieved), and structural aspects (social structures and relational resources that facilitate (or hinder) the realization of achieving agency) (Priestley et al., 2015).

Priestley et al., (2015) highlight that teachers face challenging daily decisions, often requiring compromises and sometimes clashing with their goals. These challenges can leave teachers with a sense of being pressured by what they perceive as arbitrary or unwarranted interference in their work. This highlights the importance of teachers' abilities to navigate complex and evolving situations, demonstrating adaptability and responsiveness to the specific demands and opportunities of their given contexts (Priestley et al., 2015). In addition, it can expose flaws or biases in judgments. For example, a teacher's situational response might be influenced by unconscious biases from their iterational experiences or by future aspirations (projective) that are not feasible in the present context. Practical-evaluative actions may also lead to ineffective or unintended outcomes, revealing the complexities and potential for error in teal-time decision-making. Thus, according to Priestley et al. (2015), the practical-evaluative dimension of the model has a significant impact on teacher agency, as it influences decision-making and actions, providing both opportunities for achieving agency and inhibiting it. This dimension is essential for understanding how teachers exercise agency within often complex and unpredictable environments, as it captures the adaptability and critical thinking teachers apply to their practices in the moment.

The projective dimension of teachers' work: the projective dimension looks toward the future and is associated with teachers' goals, aspirations and visions for change. It captures the aspirational and imaginative aspects of teacher agency, where teachers not only envision possible

futures, but actively strive to realize them within their professional contexts. In the projective dimension of the model, they distinguish between short-term and long(er)-term orientations of action, and argue that the aspirations are deeply rooted in teachers' prior experiences (exemplified by the arrow from the iterative dimension to the projective dimension of the model).

Drawing on Archer's (2003) *internal conversation* concept and Bourdieu's theory of *field* (Bourdieu, 1977), Priestley et al. (2015) underscore how the projective dimension of agency involves a forward-looking orientation that drives teachers to innovate or reform aspects of their practice. For instance, a teacher might engage in inclusive teaching practices to build a more equitable classroom environment, reflecting a broader commitment to future-oriented educational values. However, it can also lead to frustration or misalignment when future-oriented aspirations are unrealistic or are in tension with institutional constraints, e.g. if a teacher wishes to implement inclusive teaching practices but find that structural limitations, such as lack of support or resources make the goals difficult to realize. Thus, this dimension can highlight the tensions between idealism and practicality, showing how aspirations can, for example, encounter barriers that limit teacher enactment. The projective dimension is where agency intersects with teachers' capacity to act as "agents of change", as they pursue goals that may challenge or reshape existing structures.

The three dimensions in the model (figure 2) are deeply interconnected, forming a temporal-relational process that enables teachers to dynamically navigate their environments. The model can also help indicate how agency can be constrained, and sometimes misdirected (Priestley et al., 2015). As such, Priestley et al.'s (2015) model of teacher agency consists of a triad – a framework where in teacher agency can emerge at the intersection of the iterational, the practical-evaluative, and the projective dimensions. This triad achieves harmony when these dimensions are in balance, enabling teachers to act effectively and with coherence. However, at times, one dimension may dominate, disrupt this harmony, and influence the exercise of agency: For example, iterational dominance may lead to a reliance on past routines and experiences, potentially stifling innovation or adaptability to novel situations. Practical-evaluative dominance may reflect an overemphasis on immediate constraints and decision-making, limiting the integration of long-term vision or reflective use of past insights. Projective dominance may involve a strong focus on future aspirations, which could overlook the practical realities or the

lessons of past experiences. Understanding how these dimensions interact - whether in harmony or imbalance - offers valuable insight into the conditions that enable or constrain teacher agency in practice (Priestley et al., 2015)

The ecological approach to agency is emergent and contingent on the relationship between individual capacity and external conditions. Thus, in this framework, teacher agency is not solely an individual endeavor; it is *shaped by* the broader social, institutional, and material contexts in which teachers operate. This approach acknowledges the constraints imposed by educational structures yet highlights how teachers actively negotiate these structures through the interplay of past experiences, current context, and future aspirations. Priestley et al. (2015) stress that agency should be understood as the result of the *interplay* between individuals' capacities and the conditions within their environment. According to Priestley et al., (2015), this highlights the importance of considering not only what individuals are capable or incapable of doing, but also the broader contexts, including cultures, structures, resources, and relationships that shape the specific environments in which they work. According to Priestley et al. (2015), it is the interaction between these capacities and conditions that is key to teacher agency. This implies that efforts to foster and enhance teacher agency should not only focus on improving teachers' capacities, such as through professional learning and development programs, but also address the factors and dimensions that influence the contexts in which teachers work (Priestley et al., 2015).

As previously mentioned, teachers play a central role in the implementation of educational reforms (Fullan, 2003), yet their agency is not exercised in isolation or independently of the organizational conditions within which they work (Priestley et al., 2015). Research has shown that institutional structures, policies, and cultural norms significantly shape and, at times, limit teachers' actions and decision-making processes (Priestley et al., 2015). Consequently, there is a need for analytical perspectives that avoid granting primacy to *either* teachers *or* their organizational contexts. Instead, an integrated approach is required: one that acknowledges the dynamic interplay between individual agency and structural conditions. Such a perspective allows for a contextualized understanding of teachers' practices; one that recognizes *both* their capacity for active, reflective engagement *and* the powerful influence of the organizational settings in which this engagement unfolds. This approach positions teacher agency as a lens, offering insights into how teachers navigate and respond to the opportunities and constraints inherent in reform contexts.

The teacher agency framework as articulated by Priestley et al. (2015) has assisted me in the exploration of the ways in which teachers actively shape, modify, and at times resist the revised curriculum based on personal, institutional, and contextual influences. Thus, the framework provides the interpretive and explanatory depth that supplements the structural insights provided by Remillard and Heck (2014), enabling a more comprehensive understanding of curriculum enactment not merely as a procedural, dynamic phenomenon, but as a complex, agentic activity, driven by individual and collective agency within specific socio-cultural contexts. In the following section, I will turn to the philosophical framework underpinning this thesis.

The Philosophical Framework of this Thesis

In my work with this thesis, I have adopted an approach known as *analytical strategy* (Esmark et al., 2005), which addresses questions related to the philosophy of science by starting from the theories and concepts employed in a given study. This approach emphasizes examining the premises and conditions under which the use of specific theories or concepts enables the study of an empirical object. Positioned within a constructivist paradigm, analytical strategy conceptualizes "theory" not as a hypothesis predicting cause-effect relationships, but as a set of tools that facilitate the production of scientific knowledge (Esmark et al., 2005).
A key constructivist principle of analytical strategy is the recognition that empirical objects do not exist independently of the ways in which they are described and observed (Andersen, 1999). Instead, empirical observations and descriptions are understood as products shaped by the theoretical and conceptual frameworks employed by the researcher. Accordingly, analytical strategy requires that researchers carefully articulate how their chosen concepts and theories shape the ways in which empirical objects are observed, described, and analyzed. In this sense, the term "strategy" underscores that the observation and description of an object result from deliberate conceptual choices (Andersen, 1999).

An analytical strategic approach differentiates between methodology and method. Methodology pertains to a researcher's examination of the ontological and epistemological implications of using specific concepts. Method, on the other hand, refers to the practical techniques used to collect, format, and analyze data (Esmark et al., 2005). Although methodology and method are interconnected as such, they serve distinct purposes.

Below, I will discuss matters of methodology in the context of my study, while the methods employed in the study will be outlined in a later chapter.

Analytical Strategy in the Context of this Study: Enacting a Competence-oriented Curriculum Reform in Science Education in an Agency Perspective

The analytical strategy underpinning this study is situated within a constructivist paradigm, which shapes both the theoretical and methodological approach. This paradigm recognizes that knowledge is socially and contextually constructed rather than discovered as an objective reality (Guba & Lincoln, 1994). Accordingly, the practices of science teachers as they enact a competence-oriented curriculum reform are not treated as fixed entities but as dynamic phenomena *shaped by* interactions, interpretations, and contextual factors. In this sense, the empirical object of the study – the science teachers' enactment – *emerges* through the interplay of the specific theoretical frameworks, methodologies, and empirical observations employed. I will unfold this in the sections below.

The theoretical framework and concepts employed in this study – curriculum enactment (Remillard & Heck, 2014) and teacher agency (Priestley et al., 2015) - serve as the foundation for describing, understanding, and analyzing how teachers navigate the competence-oriented reform. The frameworks help "make practice visible" by providing me with concepts and language to interpret teachers' actions, decisions, and interactions with the curriculum:

The curriculum enactment framework (Remillard and Heck, 2014) highlights the active role of teachers in interpreting and implementing the Danish competence-oriented curriculum reform. Rather than viewing teachers as passive recipients of reform mandates, enactment theory emphasizes their agency in adapting, negotiating, and, at times, transforming curricular expectations to align with their professional judgments, classroom contexts, and student needs. This lens enables me to explore the complexities of Danish science teachers' *sense-making* in the context of the competence-oriented curriculum reform: the stages and the complexities of their work, including how they balance competing demands and priorities. Complementing curriculum enactment, the model of teacher agency (Priestley et al., 2015) allows examinations of how teachers' capacity to act is shaped by a complex interplay of influences from the past, the teachers' engagement with the present, and orientations toward the future. This framework foregrounds the interplay between context and agency, emphasizing that the science teachers'

enactment of the competence-oriented curriculum is influenced by both their professional autonomy and the systemic conditions under which they work. The framework by Priestley et al., (2015) has been instrumental in analyzing the Danish teachers' curriculum enactment, as I have explored the teachers' planning practices, their thoughts about rationales and prospects related to their specific curriculum enactment, and their assessment practice in the context of the new oral exam format, focusing specifically on how they engage with, interpret the curriculum, and enact agency in these varied contexts as well as the reasons for this.

While these theories illuminate critical aspects of teachers' enactment practices, they also shape the study's trajectory. Drawing on the curriculum enactment (Remillard and Heck, 2014) and teacher agency (Priestley et al., 2015) frameworks, this thesis foregrounds the processes by which Danish science teachers enact the competence-oriented curriculum reform, implying that the key questions in relation to teacher enactment of a competence-oriented curriculum reform are such as the following:

- *How do the teachers interpret and navigate competence-oriented mandates?*
- *How do the teachers enact the competence-oriented reform in ways that reflect their professional values and classroom realities?*
- *What is the status of the teachers' experiences from the previous curriculum? Are these experiences, grounded in previous traditional knowledge- and skills-oriented education, conducive or obstructive to implementing the reform?*
- *Can their experiences be utilized as they are? Or do they need to be reworked to hold value in the new context? How do the teachers approach this in practice?*
- *How effectively can teachers enact competence-oriented goals within the contexts of lesson planning and assessment, particularly when limited structural support is provided?*
- *What strategies do the teachers use to navigate challenges that arise if their experiences and knowledge are insufficient to address reform demands?*
- *Do the teachers genuinely subscribe to the competence-based visions inherent in the new curriculum, or, alternatively, do they perceive it as a policy imposition at odds with their educational policies or practical realities?*

Hence, examining competence-oriented curriculum enactment from an agency perspective raises numerous questions. Addressing all of these within a single PhD thesis is not feasible. Therefore, I have chosen to focus on a subset of these questions, systematically prioritizing and narrowing them down through the overall research question for the thesis and the operationalizing research questions also outlined previously, in the chapter on the purpose of the study:

1. *How are the implications of curriculum revisions for science teachers' practices studied?*
2. *What factors affect science teachers' implementation of competence-oriented curriculum revisions?*
3. *What characterizes Danish science teachers' construction of agency in their planning of and discussions about multidisciplinary teaching units in the context of adopting the new competence-oriented reform?*
4. *How do teams of science teachers navigate in the context of a competence-oriented curriculum reform?*
5. *What are the types and distributions of questions asked by assessors in oral exams that are to elicit information about students' levels of scientific competencies?*

Building on the research questions for this thesis, the included papers collectively explore how science teachers enact and navigate competence-oriented curriculum reforms and the factors that mediate their enactment. Each paper addresses specific aspects of this overarching focus. In the following, I will outline how the focus and empirical scope of the individual papers are interrelated and how these relationships are reflected in the overall methodological approach of the thesis.

Paper 1 establishes the conceptual and methodological foundation of the thesis by systematically mapping the existing research landscape on how curriculum reforms influence science teachers' practices. Its primary focus is to identify knowledge gaps and characterize the field's insights. The paper highlights significant knowledge gaps, particularly the lack of studies adopting a teacher-centered perspective and considering the interplay between teacher enactment and organizational contexts. Its empirical scope is a systematic literature review, which uncovers systemic contradictions shaping teachers' practices and the prevalence of interventionist study designs. These findings underscore the need for research that explores how teachers navigate

curriculum reforms, drawing on theoretical frameworks to address the complexities of their professional experiences: frameworks that can unpack – and provide explanatory power to - the complexities of teachers' lived professional experiences as they enact competence-oriented curriculum reforms. Insights from this review inform the theoretical framing and methodological design of the subsequent empirical studies.

Paper 2 applies the insights from **paper 1** to an empirical investigation. Its focus is on exploring how Danish lower secondary science teachers collaboratively navigate the demands of a competence-oriented curriculum reform in their planning practices. Drawing on the ecological model of teacher agency (Priestley et al., 2015), this paper analyzes how teachers construct agency in response to the reform and how their actions are shaped by structural and cultural constraints. The empirical scope consists of data from collaborative teacher planning sessions as well as data from group talk-in-interactions about their practices, analyzed to illuminate the interplay between agency and context. The paper uses qualitative methods to trace how teachers' planning practices reflect both opportunities and barriers in their enactment of the revised curriculum.

Paper 3 complements **Paper 2** by focusing on individual and contextual factors influencing teachers' enactment of the competence-oriented reform. The Future Workshop method (Jungk & Müllert, 1987) is employed to explore how teachers make sense of and respond to reform demands, highlighting the tensions between their professional aspirations and systemic barriers. This paper's empirical scope is workshop data that captures teachers' reflections and proposed solutions to reform-related challenges. It emphasizes the tensions between aspirations and constraints, contributing to a deeper understanding of how teachers navigate practical realities while seeking to align with curriculum goals.

Paper 4 shifts focus to another part of curriculum enactment in the Danish context: the assessment dimension, addressing a critical but underexplored aspect: oral examination practices within the framework of competence-oriented curricula. The empirical scope includes assessors' questioning techniques in oral exams, analyzed to explore whether the assessors' questioning techniques align with the reform's emphasis on competence development and to identify gaps that may hinder students' opportunities to demonstrate their skills. Methodologically, as the area is underexplored, the paper adopts an exploratory and empirically driven approach (rather than being framed by a teacher agency perspective approach to analysis), revealing a gap between

reform intentions and actual assessment practices. Thus, unlike **paper 2 and 3**, **paper 4** does not explicitly draw on the teacher agency or curriculum enactment theories (Priestley et al., 2015; Remillard and Heck, 2014), but the study addresses a key dimension of enactment in the Danish context: how assessment practices serve as an integral part of teachers' interpretation and implementation of curricular goals. To be sure, it remains informed by the overarching constructivist paradigm, positioning assessment practices as an integral part of teachers' curriculum enactment.

In combination, the four papers seek to provide a nuanced and layered understanding of curriculum enactment. **Paper 1** establishes the conceptual and methodological terrain by identifying key challenges and pointing to theoretical tools, while **paper 2 and 3** apply these insights to empirical data, seeking a deeper understanding of the challenges and agency involved in teachers' work with competence-oriented curriculum reforms. **Paper 4** extends the discourse to assessment practice as a part of teacher curriculum enactment in the Danish context, offering an empirical lens on an area that remains insufficiently explored.

Together, the papers form an examination of curriculum enactment as a dynamic and context-dependent process. The choice of emphasizing curriculum enactment and teacher agency directs attention to the dynamic and contextual aspects of teacher practice. Methodologically, this means that I investigate not only *what* this group of teachers do, but also *why* and *how* they navigate in their specific contexts. For instance, focusing on teacher agency necessitates exploring the structural and cultural affordances/constraints that shape their actions. On a practical level, I employed a range of methods to capture various nuances and contexts of the teachers' curriculum enactment. The methods employed align with the theoretical focus, aiming to ensure coherence between the aim of this study and its empirical approaches. In the following chapter, I will describe the empirical foundation of this thesis and how I collected data.

Methods

As outlined above, the research object of this thesis – teacher enactment of competence-oriented curriculum reforms – is not a fixed entity but is constructed through the theoretical and methodological lenses applied in the study. By adopting a teacher-centered perspective, the study

explores how teachers enact competence-oriented frameworks within their unique contexts. This involves examining:

- How teachers perceive and respond to competence-oriented mandates.
- The strategies they employ to integrate these reforms into their practices.
- The ways in which structural constraints and institutional supports influence their actions.

This focus acknowledges that the various aspects of their enactment that I explore within the scope of this thesis is inherently situated and shaped by a multitude of interacting factors, including teachers' beliefs, professional identities, and the practical realities of their work environments.

In this chapter, I will outline the methods employed to investigate how science teachers enact competence-oriented curriculum reforms within their specific contexts. Building on the analytical strategy and the theoretical frameworks discussed in the previous chapters, I will provide an account of the empirical approaches used to capture the nuances of teachers' practices, interpretations and decision-making processes. My choice of methods reflects the study's commitment to explore the complex interplay between teacher agency, contextual matters, and the enactment of curriculum mandates. I have chosen qualitative approaches to illuminate the situated and dynamic nature of teacher practice, and in this chapter, I aim to demonstrate how this aligns with the study's overarching aim: to construct a rich understanding of science teachers' enactment processes.

The thesis consists of four individual papers that examine different aspects of teacher enactment of competence-oriented curriculum reforms in science education. These studies utilize diverse approaches, including a qualitative literature review, observation methods, and a workshop. As previously mentioned, guided by an analytical strategic approach in my work with this thesis, I distinguish between methodology, which pertains to the fundamental philosophical foundations of a research project, and method, which encompasses the specific, practical techniques used to gather, organize, and analyze data (Esmark et al., 2005). In the following sections, I will outline the methods applied in my work with this thesis and account for the data collection.

The Qualitative Literature Review

In my work with this thesis, **Paper 1** employed a qualitative systematic literature review as one of the methods for collecting data. While the primary methodological aspects related to the analytical process of the review are presented in details in **paper 1,** this section focuses on methodological decisions which were crucial to addressing the research question of the thesis comprehensively. These details, omitted from **paper 1** due to space limitations, provide insights into the systematic approach and its alignment with the broader objectives of this thesis.

I chose to conduct a qualitative systematic literature review as it allowed me for an interpretive synthesis of existing research to uncover patterns, themes and theoretical insights from studies within the field of educational research on teachers' work with implementing competence-oriented curriculum reforms. Unlike traditional narrative reviews, which may present an overview of research findings, a qualitative systematic review systematically organizes and evaluates qualitative evidence, focusing on understanding the underlying concepts and meanings described in the literature (Grant & Booth, 2009). This method was particularly valuable for this study, as it allowed me to identify key gaps in the existing literature on teachers' work with implementing competence-oriented curriculum reforms in science.

The qualitative systematic review was conducted through a structured process including the following distinct steps to ensure transparency and rigor: The process began with defining the research questions followed by a search in three databases, which yielded a total of 765 peer-reviewed papers.

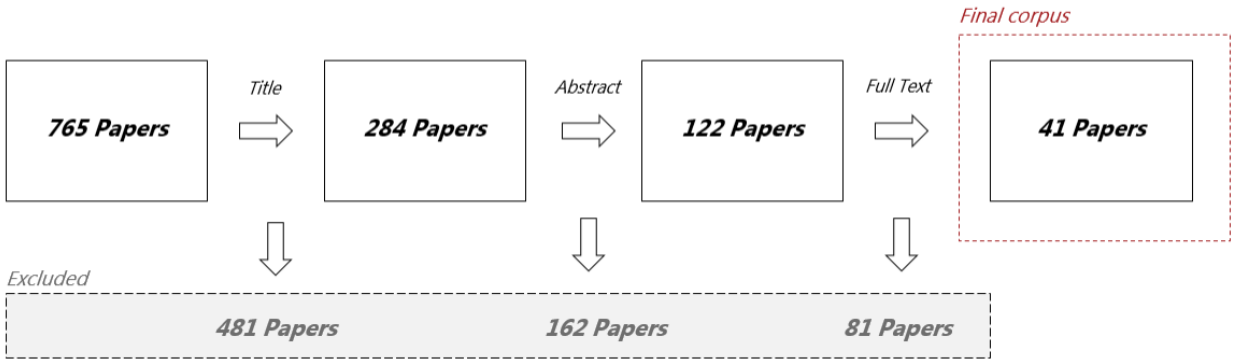

Figure 3 The Process of Screening the Papers. Image copied from Paper 1.

As reported in **Paper 1**, we[3] exported the data generated by our search into an Excel sheet and initiated our analytical process. Following the approach suggested by Higgins et al. (2017), we screened the data sequentially at the title, abstract, and full-text levels. The inclusion and exclusion criteria applied during the screening process are summarized in Table 3 below:

Inclusion Criteria	**Exclusion Criteria**
Studies focusing on **curriculum change** and **reform-based changes**	Studies focusing on **upper secondary** or **tertiary education levels**.
Research examining **teacher beliefs, perspectives, attitudes** and **practice**	Research involving **pre-service teachers**
Studies related to **STEM education,** including the introduction of **STEM units** in the context of competence-oriented reform changes.	Studies primarily addressing **technology education, language teaching**, **medical science** or **gender-focused topics**.
Research on **competence-oriented reforms**	Research with a focus on **students' attitudes towards science**, **motivation,** or **perceptions**.
Teacher perspectives on the introduction of **Inquiry-Based Science Education (IBSE)** and/or **IBSE units**	Studies without a focus on teachers (e.g., **student-centered studies, student knowledge,** or **misconceptions**).
Studies addressing **Socio-Scientific Issues (SSI)** or **Science-Technology-Engineering-Society (STES)** from a teacher's perspective, in the context of competence-oriented reform changes.	Analyses of **textbooks, learning materials,** or **tests of instruments**.
Investigations exploring the implementation of a **new curriculum.**	Studies with a focus on **science careers** or **science capital**.
	Research on **digitalization** or **topics unrelated to science education**.
	Studies that **lack an emphasis on curriculum reforms**.

Table 3 Inclusion and exclusion criteria

Table 3 presents the inclusion and exclusion criteria that were used in the literature review in the initial screening of the papers (here, they are presented in a readable form). These inclusion and exclusion criteria play a central role in addressing the research question of this thesis and were applied to ensure that the systematic literature review focused on studies directly relevant to understanding teachers' practices and experiences in the context of competence-oriented curriculum reforms. By focusing on studies that explore teacher perspectives, practices, and

[3] Paper 1 is co-authored. The list of authors is included in the paper.

attitudes, as well as the systemic and contextual factors shaping their enactment of reforms, the literature review provided a foundational framework for the thesis.

These criteria guided the identification of relevant literature that highlighted gaps in existing research, such as the tendency to overlook teachers' lived experiences or to separate their enactment from the organizational and systemic contexts in which they operate. As previously mentioned, these insights are critical for framing the subsequent empirical studies, which explore the practical realities and complexities of teacher agency and reform implementation in the Danish context. By explicitly excluding studies focused on students, pre-service teachers, or unrelated curricular contexts, the criteria ensured that the review maintained a sharp focus on in-service teacher-centered perspectives.

The subsequent step involved screening the remaining 122 papers at the full-text level. As elaborated in **Paper 1**, we did a systematic deductive coding (Braun & Clarke, 2006) of each paper in an Excel spreadsheet using the following categories: i) purpose, ii) research method/design, iii) study location (geographically), iv) educational level, v) theoretical frameworks applied, and vi) focus area of teacher practice in the studies. Along with the exclusion criteria outlined in Table 3, we also excluded papers during the full-text examination if they were not written in English or if it became clear that the study did not address teachers' practices within the context of curriculum revisions.

As a result, we ended up with 41 papers that constituted the final corpus of the review. The approach to analysis is described in detail in **paper 1.**

The insights from this review (**Paper 1**) informed the focus of the subsequent empirical work involving teachers. In the following sections, I will elaborate on the methods employed for data collection.

The Collection of Empirical Material Involving Teachers

In this section, I will provide an overview of the empirical material that I have collected in various sites/contexts with the teachers that were a part of this study. Table 4 below provides an overview of the data collected, over the course of one school year in one municipality, involving 18 science teachers:

Site/Context	Method	Data Collected[4]	Amount/duration/minutes of presence
Initial meeting with teachers from the 3 schools	Participant observation	Audio recording and field notes	1,5 hours
Planning sessions about multidisciplinary, competence-oriented science teaching on all 3 schools	Non-participant Observation	Audio recording and field notes	8 hours
Mixed groups talk-in-interactions about competence-oriented science teaching and curriculum mandates	Non-participant observation	Audio recordings	3,75 hours
Future Workshop: critique phase, group discussions in 3 mixed groups	Non-participant observation	Audio recordings + visual products produced by teachers (post-it overviews)	3 hours
Future Workshop: critique phase, follow-up plenary discussion	Participant observation	Audio recordings	30 minutes
Future Workshop: fantasy phase, group discussions in 3 mixed groups	Non-participant observation	Audio recordings + visual products produced by teachers (post-it overviews)	3 hours

[4] In addition to the data reported here, I conducted a pilot study where the teachers sat in groups and worked on operationalizing the competence goals for use in future planning and teaching, comprising 1 hour of data for each team. This turned out to be a dead end that I decided not to pursue further.

Future Workshop: fantasy phase, follow-up plenary discussion	Participant observation	Audio recordings	30 minutes
Future Workshop: implementation phase, group discussions in school groups	Non-participant observation	Audio recordings + visual products produced by teachers (post-it overviews)	3 hours
Future Workshop: implementation phase, follow-up plenary discussion	Participant observation	Audio recordings	30 minutes
Oral examinations on all 3 schools	Non-Participant observation	Field notes	6 hours

Table 4 The empirical data collected involving teachers

Entering the Field and Recruiting Informants

The recruitment of informants in this study was guided by the intent to develop an in-depth understanding of a phenomenon – Danish science teachers' enactment of a competence-oriented curriculum reform – rather than to generalize findings to a broader population (Creswell, 2015). In my search for participants, I sought to ensure that the selected informants and contexts would offer me diverse yet pertinent perspectives that contribute to a comprehensive understanding of the phenomenon under investigation. In this case, a peripheral contact informed me of a municipality interested in increasing its focus on the reform and its implications for science education and teacher practice. This municipality was identified as an ideal context for my study due to its seemingly pre-established proactive approach to addressing reform-related challenges and opportunities and to the diverse contexts apparent in each school (please consult **paper 2** for an elaborate description of the schools).

The municipality consisted of three schools, each with distinct conditions and characteristics regarding collaboration among science teachers (please see **paper 2** for a more elaborate description of these differences). These variations provided a valuable opportunity to investigate how differing school environments and teacher dynamics shaped the enactment of the curriculum reform. By focusing on this municipality, the study gained access to a diverse yet

thematically cohesive setting, enabling an exploration of the interplay between policy, teachers' agency, and institutional contexts. This sampling approach was chosen to facilitate a nuanced understanding of the enactment processes central to my research. The data was collected over the course of one school year.

Entering the field required careful consideration of my role as a researcher and the ways my presence and actions might shape the contexts I observed. Before initiating data collection, I contacted the schools through a municipal gatekeeper, ensuring the teachers were fully informed about the study's aims, scope, and ethical considerations (Creswell & Poth, 2016). I briefed the teachers about the project in a way that emphasized my role as a non-judgmental observer with a genuine curiosity about their practices. I chose to explicitly communicate that the study focused on understanding their experiences and strategies in enacting the competence-oriented curriculum reform, aiming to build trust and encourage open participation (Kawulich, 2005).

My positioning as a researcher recognized that my presence and interpretations are inevitably part of the research process (Esmark et al., 2005). As such, I approached the field with an awareness of my dual role as both an outsider observing the teachers' practices, and an insider temporarily embedded in their professional environments. As I strived to minimize the potential for power imbalances or disruptions, I presented myself as a collaborator at the initial meeting (Table 4), emphasized that I was interested in insights rather than being viewed as an external evaluator (DeWalt & DeWalt, 2011). In my opinion, this approach seemed crucial in shaping my engagement with the teachers throughout the process of data collection in the various contexts.

Contexts for Data Collection

As outlined in the chapter on the methodological and theoretical approach, Remillard and Hecks (2014) model for curriculum enactment has provided a framework for communicating specific segments of the enactment process that my chosen methods aim to investigate. These segments include teacher interactions in planning sessions, decision-making processes, teachers' reflections on their enactment, and the adaptation of curriculum elements in response to the dynamics of their specific contexts. In this wrapping, the model has been instrumental in isolating and categorizing these various aspects of the enactment process throughout the empirical studies in my thesis as a whole, to provide an overarching account of my data collection which not

necessarily can be inferred from reading the four research papers which are disseminated as individual research outputs.

Now, I will extend this model by applying it specifically to the Danish context, which allows for an exploration of how the enactment process is shaped by the local conditions of Danish schools. By doing so, I aim to articulate the segments of the enactment process that my chosen methods are designed to examine in the Danish educational system, building on the broader conceptual framework established by Remillard and Heck (2014).

As outlined previously, Remillard and Heck (2014) distinguish between the official curriculum (i.e., curricular elements that are officially sanctioned by policy) and the operational curriculum (i.e., how curricular elements are enacted in practice). To recall, the operational curriculum includes the teacher-intended curriculum, the enacted curriculum, (i.e. the curriculum that is *actually* enacted with the students), and student outcomes (Remillard & Heck, 2014). In their separation of the official and operational curriculum, Remillard and Heck (2014) argue that despite variations in the official curriculum across national settings, the three components of the operational curriculum can be found in some form in most school systems. This is also the case in the Danish context. However, it is possible to emphasize three additional components to the model. As such, in the context of this study, there are three modifications to Remillard and Heck's model of the curriculum policy, design and enactment system in terms of the curricular reform context in Denmark (Remillard & Heck, 2014).

First, the official curriculum in Denmark is communicated through curricular aims and objectives (see the chapter on background and context in this thesis) as well as the scope and content defined in the assessment guidelines. However, in the Danish context, municipalities, schools, and teacher teams are given autonomy to select the resources that are encapsulated in what Remillard and Heck (2014) term the designated curriculum - a key point in curriculum enactment in the context of this study. As such, textbooks and other resources are not explicitly part of the official curriculum. This approach stands in contrast to systems with more rigidly defined, official curricular materials.

Second, while Remillard and Heck's (2014) model incorporates assessment and its associated contents as part of the official curriculum (and implicitly in the operational curriculum through student outcomes), the situation in Denmark is somewhat different. As mentioned in the

background chapter, the curriculum reform altered the assessment, with the inclusion of an integrated competence-oriented oral science exam for the lower secondary school. While written science examinations remain part of the officially sanctioned curriculum, oral examinations have become a key component of the operational curriculum, as the oral assessment process is dynamic and teacher-involved: it is based on the multidisciplinary teaching units that may vary across school, and up until the exam, teachers collaborate with students to refine ideas and provide feedback, illustrating a more interactive and teacher-mediated form of assessment compared to the more passive, written examination. In addition, it is the teachers who frame the assessment by engaging in dialogue with student. Thus, in the Danish context, the operationalization (Remillard & Heck, 2014) of the curriculum extends to the oral assessment.

Third, an additional active phase of the official curriculum can be identified in the Danish context, which is not represented in Remillard and Heck's (2014) model but is emphasized by Gueudet and Trouche (2012). This phase involves collaborative planning and interpretation of the official curriculum by groups of science teachers. As outlined in the background chapter of this thesis, this collaborative aspect of curriculum enactment is crucial in Danish science education, particularly when it comes to teachers' collective interpretation and planning of the multidisciplinary units in science. In this context, teachers work together to interpret, adapt, and implement curricular aims in ways that reflect their local teaching contexts and resources.

The contexts for data collection that will be delineated below are contexts in which the teachers engage with the curriculum in one way or another in their enactments – or reflections about their enactments – in their specific contexts. As mentioned in the methods chapter, my study adopts a teacher-centered perspective and explores how teachers enact the competence-oriented framework within their unique contexts. As such, the contexts for data collection allowed me to closely examine how the teachers perceive and responded to competence-oriented mandates, the strategies they employ to navigate the reform, and the ways in which various mediating factors (Remillard & Heck, 2014) influence their actions.

The Future Workshop

The Future Workshop is a participatory method designed to engage stakeholders in envisioning and co-creating future possibilities. Originally developed by Jungk and Müllert (1987), the method is particularly well suited for exploring complex, multifaceted issues that require collective input and creativity. The Future Workshop is structured into three distinct phases: i)

the Critique Phase, where participants identify and discuss existing problems, ii) the Fantasy Phase, which encourages participants to generate innovative and unrestrained ideas for the future, and iii) the Implementation Phase, in which the participants evaluate, refine, and plan actionable steps based on the ideas generated in the Fantasy Phase (Jungk & Müllert, 1987).

The division into phases fosters a balance between critical reflection, imaginative thinking and pragmatic planning, making the Future Workshop an effective tool for collaborative problem-solving and innovation.

The Future Workshop as a Site for Data Collection

The choice of Future Workshop as a method for data collection reflects a deliberate alignment with the epistemological commitments of this thesis and the theoretical framework. The selection of the Future Workshop as a site for data collection is grounded in its capacity to engage teachers in a reflective and participatory process that aligns with the constructivist understanding of agency and context. In the context of this study, the Future Workshop was designed to elicit both critical reflection and visionary thinking by creating structured opportunities for teachers to articulate their experiences, challenges, and aspirations. As such, the method was employed as a site for data collection to explore how teams of science teachers navigate within the context of a competence-oriented curriculum reform.

Photo 1 Teachers Participating in the Future Workshop

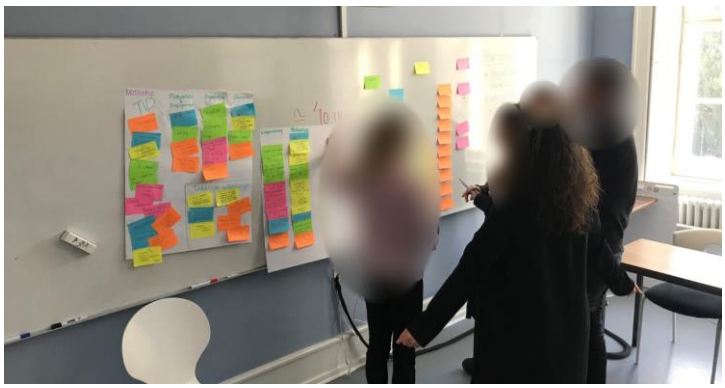

Photo 2 Teachers participating in the Future Workshop

The workshop, which is described in greater detail in **paper 3**, was used to facilitate a structured and participatory process in which the teachers critically reflected on their experiences and challenges, developed visions for an ideal future, and formulated concrete action plans: The teachers first articulated their essential critiques of reform mandates and their own practices. Next, they went on to describe their visions for an improved future, imagining ideal scenarios free from current constraints. Lastly, they discussed concrete action plans related to their practices, to transform fantasies into concrete action plans. This approach enabled an in-depth examination of the teachers' experiences and practices in the context of enacting the competence-oriented curriculum, while supporting a theoretically grounded understanding of their agency and context within the framework of curriculum reform.

Teacher Planning Sessions

Another key context for data collection in this study was the science teachers' planning meetings held at their respective schools. These meetings provided a setting where science teacher teams collaboratively sat down to plan the multidisciplinary, competence-oriented science teaching as depicted in the curriculum. Taking place within the everyday routine of the schools, these meetings served as moments for negotiating shared goals, addressing challenges, and coordinating instructional strategies to align with the stipulations of the curriculum. By focusing on these planning sessions, I sought to capture teacher interactions, decision-making processes, and information about how they interpret and operationalize reform demands in practice. As such, the meetings not only reflected the immediate institutional and collaborative contexts but also revealed their work with the complexities and the nuances of translating policy into actionable plans.

Group Talk-in-interactions

Group talk-in-interactions served as a context for data collection to explore teachers' reflections on their curriculum enactment processes. These sessions were designed to foster reflective and generative dialogues among teachers by creating a space for open and honest discussions about their practices and experiences. Mixed groups of teachers were intentionally formed to encourage diverse perspectives and facilitate discussions that extended beyond the dynamics of pre-existing teams or close colleagues (Hennink et al., 2020; Bryman, 2016).

The rationale behind mixing the groups was twofold: first, to encourage the exchange of varied viewpoints and experiences, and second, to create a neutral setting where teachers might feel more comfortable expressing their thoughts freely without the constraints of familiar work relationships. This approach was guided by the understanding that group composition can significantly influence the dynamics of dialogue, with mixed groups often enabling richer and more balanced discussions (Bryman, 2016).

To structure and guide the conversations, I provided teachers with written prompts and questions designed to elicit detailed reflections on their curriculum practices and experiences with reform implementation. These prompts, described in detail in **Paper 2**, served as a framework for the sessions, ensuring that discussions remained focused while leaving room for participants to explore topics they deemed significant.

Oral Examinations

The oral examinations served as a site for data collection to investigate how the teachers enact the revised curriculum. With the exams' inherent coupling to the multidisciplinary science teaching, as outlined in the background chapter, these examinations provided a structured setting to observe teachers' roles in guiding and assessing students' levels of competence. The procedures at the exam are described in detail in **Paper 4**. Below are photos of the students' setups that they used as part of their presentations and which were referred to and elaborated during the discussions with the assessors.

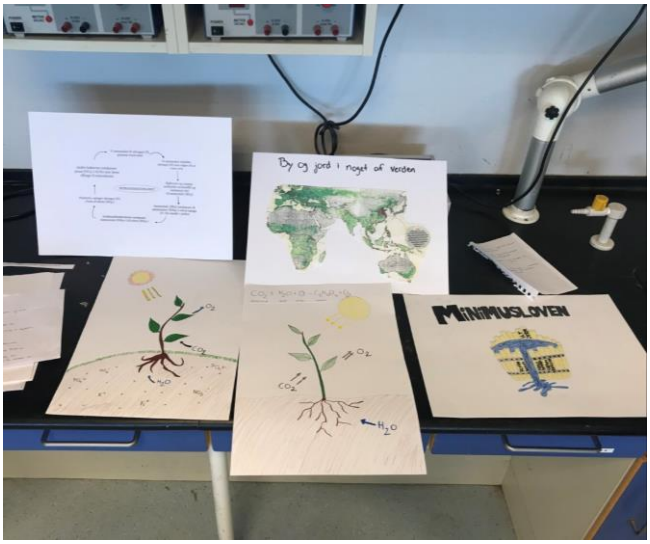

Photo 3 Student setup at the oral examination

As a formalized and high-stakes setting, the examinations highlighted teachers' practices and decision-making in real-time, particularly through their interactions with students and the questions they posed. Drawing on Remillard and Hecks (2014) framework for curriculum enactment, the teachers' actions during the examinations were understood as reflective of their interpretations and implementation of the curriculum. This context was especially valuable for examining how teachers navigated the expectations of the reform, as their practices during the examinations illustrate how policy intentions were translated into pedagogical strategies and assessment approaches.

Photo 4 Student setup at the oral examination

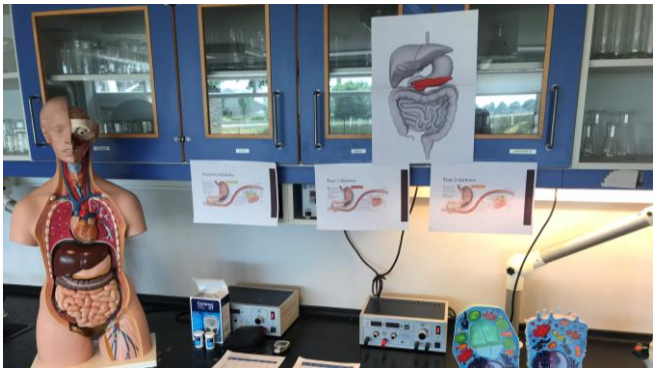

Photo 5 Student setup at the oral examination

Observation

Observation is a foundational method for exploring social and professional practices within their natural contexts (Creswell, 2015; Bryman, 2016). For this study, I employed a combination of participant observation, non-participant observation, and remote observation via audio recording. These methods allowed for an understanding of the teachers' practices, interactions, and reflections while minimizing disruptions to their collaborative processes. Below, I outline the foundations of these methods and their specific application in this study.

Observation as a research method is central to qualitative inquiry, offering insights into the lived experiences and situated practices of individuals and groups (Creswell & Poth, 2016). Participant observation involves the researcher's physical presence and engagement in the observed setting, either as a passive observer or an active participant (DeWalt & DeWalt, 2011). Non-participant observation, on the other hand, entails observing without direct interaction, allowing for a less obtrusive data collection (Kawulich, 2005). Remote observation through audio recording extends this principle by enabling researchers to gather data without being physically present, thereby reducing observer effects and preserving the authenticity of interactions (Creswell, 2015).

These approaches were selected to align with the study's aim of exploring teacher practices across various contexts while accounting for ethical considerations, logistical constraints, and the need to capture both individual and collective dynamics. Furthermore, triangulating multiple observational methods enhances the validity of qualitative findings by reducing potential biases and providing a multidimensional perspective on the phenomena under investigation (Denzin, 2017).

Application in this Study

As an observer, I adopted a nuanced approach to balance immersion and objectivity. My role shifted depending on the context for data collection: at times, I participated more actively in discussions to clarify points or respond to queries (e.g. at the plenary discussions during the Future Workshop asking clarifying questions to deepen my understanding of the teachers' perspectives), while at other times, I deliberately maintained a passive, unobtrusive presence (Creswell, 2015). This flexibility allowed me to align with the nature of the activities being observed while respecting participants' autonomy.

The observational methods were applied across various contexts to capture the complexity of science teachers' practices and interactions. The settings and methods are detailed below:

I conducted participant observation during an initial meeting with teachers from the three participating schools. These meetings were guided by a set of predefined questions, which were asked by a teacher acting as a gatekeeper (Creswell, 2015). The questions prompted discussions about their existing practices and organizational structures, providing insights into their initial sense-making processes regarding the curriculum reform (DeWalt & DeWalt, 2011). My role was to observe the discussions, audio record them, and take notes to capture key themes. Participant observation was also employed during the plenary discussions of the Future Workshop. These discussions occurred during the critique, fantasy, and implementation phases and involved all participating teachers. My role included observing, audio recording, and occasionally asking clarifying questions to ensure an accurate understanding of the teachers' points. These sessions provided rich data on collective sense-making and the negotiation of strategies for enacting curriculum reforms.

During team planning sessions focused on multidisciplinary science teaching, I employed non-participant observation while being physically present. My presence was limited to observing the teachers' collaborative processes and capturing their discussions through audio recording, ensuring minimal interference with their planning practices. This approach, akin to fly-on-the-wall observation (Cohen et al., 2002; Creswell, 2015), allowed me to document how teachers negotiated and implemented strategies aligned with the curriculum reform.

In various contexts, such as mixed-group discussions on curriculum mandates and competence-oriented teaching, I utilized remote observation by placing audio recorders in the room while not

being physically present. Both for practical reasons, as I could not be present in five places at the same time, but also to minimize observer influence and to enable an authentic data collection on teachers' reflections and shared strategies (Kawulich, 2005). Group discussions conducted during the critique, fantasy, and implementation phases of the Future Workshop were also captured through audio recordings in a similar manner.

To explore assessment practices, I conducted non-participant observation during oral examinations at all three schools. Here, I adopted a fly-on-the-wall approach (Creswell, 2015; Cohen et al., 2002), taking detailed field notes to document the interactions between assessors and students. It was not possible to get consent to audio record the examinations; instead, field notes captured the dialogues (Emerson et al., 2011).

By employing a combination of participant, non-participant, and remote observation methods, I captured diverse dimensions of teacher practice and interaction. By triangulating these approaches (Creswell & Poth, 2016; Denzin, 2017) I sought to enhance the study's validity by capturing multiple dimensions of teacher enactment and reducing potential biases associated with one single observational method.

Data processing and Approach to Analysis

The data collected that involved the participating teachers consisted of audio recordings, which were transcribed verbatim to create a textual dataset suitable for detailed analysis. This step was essential for ensuring accuracy in capturing the teachers' verbal interactions and facilitating a thorough examination of the data (Braun & Clarke, 2006). In addition to audio transcriptions, extensive field notes were taken during instances where audio recording was not permitted, i.e. during the oral examinations. These notes were written in real-time and included observations and verbatim dialogues. Immediately following each examination session, these handwritten notes were transcribed into a digital format, with annotations that detailed the school, date, and roles of the speakers (teachers, students, external assessor).

The analytical approach employed were designed to suit the specific research questions and contexts of each paper. One key focus throughout the analyses was the concept of teacher agency (Priestley et al., 2015), which played a central role in shaping the approach to data analysis, particularly in **Papers 2 and 3**. This theoretical lens guided the identification and coding of data points that could provide insights into the three dimensions of teacher agency as outlined in the

chapter on methodology and theoretical approach. These dimensions were crucial for understanding how teachers navigated and enacted the reform within their professional contexts. The analyses involved searching for patterns and themes that reflected the teachers' decision-making processes and responsive actions in relation to curriculum mandates.

In **paper 4**, the data analysis followed an abductive approach (Timmermans & Tavory, 2012), blending deductive and inductive elements to examine assessor questioning practices. A coding scheme was developed to categorize different question types and their cognitive demands, informed by the PISA competence framework (OECD, 2017; OECD, 2019). This scheme facilitated the identification of patterns in questioning practices and the distribution of different question types across contexts. The data were then quantified to understand the frequency and variation of these practices.

The specific analytical approaches and procedures used for data interpretation are elaborated in the individual papers. I used the analytical methods with a strong awareness of the ethical principles guiding my research. I prioritized participant trust, transparency, and respect, ensuring that the analyses were conducted with due consideration for the teachers' perspectives and the integrity of their professional practices. These ethical considerations are fundamental to the responsible handling of data and analysis and will be further elaborated below.

Ethical Considerations

Qualitative research encompasses a range of ethical considerations that span from the design phase to the presentation of findings. According to Harper (2014), ethics entails careful reflection on our relationships and obligations, both to participants and to the wider community. This ethical responsibility seems particularly significant in qualitative research, which delves into individuals' personal experiences and lives (Brinkman, 2020). Consequently, ethical challenges can potentially arise during several stages of the research process. This study of science teachers' enactment of the Danish competence-oriented curriculum reform involved careful attention to maintaining ethical integrity and protecting the teachers' well-being. In this chapter, I will outline the ethical considerations that have guided my research.

One of the primary ethical commitments in this research was ensuring that all informants were fully aware of their involvement and purpose of the study. As previously mentioned, I ensured at the primary stage of the project that the participating teachers were informed about the

objectives, procedures and the teachers' rights as participants. I told the teachers that their participation was voluntary and that they could choose to withdraw at any time. This transparency helped build trust and encouraged an open exchange of information, aligning with ethical principles of respect and honesty (Creswell & Poth, 2016; Harper, 2014).

To safeguard participants' privacy, all data collected was anonymized and stored securely. I removed all identifiable information from transcripts and reports to protect the identities of the teachers and their schools. This practice aligns with ethical guidelines that stress the importance of protecting participants' confidentiality and maintaining their trust throughout the research process (Brinkmann, 2020).

Ensuring ethical integrity also applied to how I handled and analyzed data. I thoughtfully considered the ethical responsibility of sharing findings that may have implications for the teachers' professional practices. My use of audio recordings was performed with the consent of teachers, and all collected data was securely stored and handled according to data protection standards. Throughout the process, I have been mindful to present findings that accurately represented the participants' perspectives, avoiding selective reporting or misrepresentation of the teachers' practices and views (Creswell & Poth, 2016).

Results: Explaining the Discrepancy between the Official and the Enacted Curriculum in the Danish Context

In this chapter, I will synthesize the findings across the four papers included in this thesis. While each paper provides its own detailed analysis and insights into specific issues related to the overall research question of this thesis, this chapter zooms out to integrate the findings into a cohesive narrative to allow for a broader reflection on the systemic, contextual, and individual professional factors shaping teacher enactment of curriculum reforms. By synthesizing these findings, this section highlights not only the key areas where the gap between policy and practice becomes most evident, but also the broader implications for understanding and addressing this discrepancy.

The first key finding from this research, based on the systematic literature review conducted in **Paper 1**, reveals a notable gap in the existing literature: teachers' voices are rarely heard in studies related to competence-oriented reforms in science education, particularly in authentic settings. Despite their central role in bridging the gap between curriculum policy and classroom practice, teachers have remained an underrepresented group in curriculum research on the matter. Much of the existing research is dominated by intervention studies that focus on pre-designed implementations rather than the lived realities of science teachers navigating the reform. As the results from **Paper 1** highlights, these interventionist contexts often fail to capture the systemic contradictions that may hinder teachers in aligning with competence-oriented goals, thereby underestimating the complex interplay between the curriculum intentions and the realities of the teachers' professional lives. In my work with this thesis, I have addressed these issues by foregrounding the perspectives of science teachers as they engage with a competence-oriented curriculum in their everyday contexts, highlighting the challenges they face and the systemic barriers that shape their work. As such, by amplifying the teachers' voices and providing a platform for them to articulate their experiences, this study examines how they enact the curriculum in various settings. It highlights the persistent discrepancy between what Remillard and Heck (2014) term the official curriculum, i.e. the competence-oriented aspirations articulated in policy for the science disciplines in the lower secondary school in Denmark, and the enacted curriculum, i.e. the practices that unfold in the teachers' daily professional lives.

The Nature of the Discrepancy

The research I have conducted in my work with this thesis demonstrates a significant and systemic divergence between the official curriculum and the enacted curriculum. While the official curriculum aspires to foster multidisciplinarity and student development and acquisition of scientific competences, the results from my research highlight that the enacted curriculum often falls short of these goals. This discrepancy is not attributable to teacher resistance or lack of effort: rather, it stems from a constellation of structural, professional, and curricular factors that limit the teachers' abilities to implement the reform as intended. The discrepancy becomes apparent in the following key areas: i) the gap between teachers' professional experiences and the competence-oriented goals inherent in the revised curriculum ii) contextual barriers, such as disciplines divided into silos and time constraints, which seems to inhibit multidisciplinary collaboration among the teachers and an integration of the disciplines, and iii) ambiguities

inherent in the official curriculum that leave teachers without proper guidance on how to operationalize competence-oriented objectives.

Teacher Agency and Professional Horizons

My use of teacher agency has been a key factor in understanding the discrepancy between the official and the enacted curriculum. Drawing on Priestley et al. (2015), this study highlights how the teachers' professional horizons – shaped by their prior experiences and pedagogical knowledge – influence their abilities to engage with the curriculum in a way that complies with the stipulations. As **Paper 2** underscores, teachers construct agency by relying on their past patterns of thought and action, yet these fail to align with the curriculum's intentions. I found that the teachers constructed agency in a manner that, following the terminology from the teacher agency framework (Priestley et al., 2015), was heavily anchored in the iterational dimension, influenced by the context that guided their practice, but in a way that did not comply with the stipulations. This was reflected in how they approached their planning of the contents in the multidisciplinary units as well as how they planned to conduct the actual teaching in practice. In addition, assessment practices, as highlighted in **Paper 4**, represent a bottleneck in the implementation of a competence-oriented curriculum. The findings highlighted teachers' prioritization of content mastery in high-stakes settings at the expense of the broader competences. While the new oral assessment format itself is designed to support and foster competence-oriented education, teachers' practices were still rooted in traditional, content-focused approaches due to their professional experiences, pedagogical habits, and lack of support in transitioning to new teaching methods.

The competence-oriented curriculum represents unfamiliar territory for the teachers in this study, whose established practices, often rooted in content transmission and discipline-specific methodologies, clash with the emphasis on transversal scientific competences inherent in the revised curriculum. This lack of familiarity with competence-oriented approaches creates significant challenges for the teachers, as they struggle to reinterpret their practices to align with the visions inherent in the curriculum, and their accumulated experiences and expertise seem redundant within the framework of the new curriculum. The findings suggest that without targeted professional development and support, as also emphasized in **Paper 3**, teachers are left to navigate the challenges they encounter alone, potentially further widening the gap between policy and enactment.

Organizational and Contextual Constraints

The findings from this study also point to the critical role of organizational and contextual factors in shaping the teachers' curriculum enactment. Even when teachers are motivated to buy in on competence-oriented visions or embrace competence-oriented practices, structural barriers and systemic constraints within the schools limit their abilities to do so. A recurring theme in **Paper 2** and **Paper 3** was the persistence of discipline specific silos, which limit opportunities for multidisciplinary collaboration (a key aspect of the competence-oriented curriculum). Furthermore, this siloed approach to disciplinary organization, where the students are expected to connect the dots themselves, places an undue burden on the science teachers to shoulder the consequences. It seems neither fair nor justified to attribute these outcomes to the teachers, as the root of the issue lies elsewhere. The teachers are placed in a situation where they are tasked with implementing a curriculum for which they are poorly equipped to fully understand or enact effectively. Furthermore, my research revealed how rigid scheduling and the compartmentalization of disciplines create logistic challenges. Time constraints further complicate these challenges, undermining collaborative planning and experimentation necessary for implementing the revised curriculum.

Ambiguity in the Official Curriculum

The teachers in this study find that the rather vague and open-ended nature of the curriculum's objectives leaves them without clear direction. In **Paper 3**, the teachers highlighted how the transversal scientific competences were challenging to translate into their own practice. This ambiguity places an interpretive burden on the teachers, requiring them to independently determine how to enact the curriculum's vision. At the same time, overly prescriptive curricula risk undermining teachers' professional autonomy and their abilities to adapt practices to their own professional contexts. The findings from this study suggest that achieving a balance between guidance and prescriptive support is essential for supporting meaningful curriculum enactment.

Teacher Voices as a Window into the Discrepancy

By centering teachers' perspectives and enactment in various contexts in my work with **papers 2, 3 and 4**, my study provides insights into the practical challenges associated with science teachers' enactment of a competence-oriented curriculum reform. The findings underscore the

systemic nature of the discrepancy between the official and the enacted curriculum (Remillard & Heck, 2014). Teachers are not merely passive recipients of policy but active agents navigating a complex and often contradictory landscape of curriculum requirements as they seek to interpret, adapt and implement revised curricula. The teachers emphasized that the challenges they face are not necessarily due to a lack of willingness to engage with the reform, but to the contextual factors that shape their professional environments. The results from **paper 3** highlight that even when ideal conditions are established to enable teachers to improve their situation, they did not succeed: When the teachers aspired to exercise agency in shaping their professional practices, their abilities to do so seemed heavily dependent on contextual factors beyond their control. As such, the tasks they are required to undertake demand greater mandate than what is readily available to them. This highlights the need for a greater alignment between policy objectives, institutional structures in school contexts, and the resources provided to the teachers.

Enacting a Competence-oriented Curriculum through the Lens of Teacher Agency

The teachers' enactment of the competence-oriented curriculum reform hinges on three interconnected critical dimensions of teacher agency: their professional horizons, vision buy-in, and supportive structures to successfully enact the curriculum. These findings underline persistent challenges in aligning teachers' established practices with curriculum aspirations, particularly when teachers' prior experiences, institutional conditions, and pedagogical support systems fail to align. Addressing these barriers in the future will require a coherent approach that bridges curriculum design, professional development, and organizational support tailored to the context in which teachers operate, ensuring that teachers are empowered to navigate reforms effectively.

Discussion

Bridging Policy and Practice: Teacher Agency and Contextual Realities

Besides answering the research questions, the results presented above provide new perspectives on an under-studied phenomenon, which I believe will bring both practical implications and lead to new questions. In the following chapter, I will discuss the key contributions from my thesis and conclude with reflections on new ways of practicing, researching, and shaping policy for competence-oriented curriculum reforms in science education

This study underscores a discrepancy between the official curriculum and the operational curriculum (Remillard & Heck, 2014) in the Danish context, aligning with the findings of previous research that highlights some of the complexities that teachers face in adapting to competence-oriented reforms (e.g. Schneider et al., 2005; Farirah et al., 2021). These reforms often aim to equip students with broader competencies, such as problem-solving, critical thinking, and collaboration, yet they provide limited operational guidance for teachers on how to embed these goals into their daily practices (Nielsen & Nielsen, 2021). As the results from my study demonstrate, the gap between policy and practice is not merely a logistical challenge but a systemic issue rooted in structural, institutional, and cultural dynamics.

One of the primary contributions of my work with this thesis lies in foregrounding teachers' voices, which are often overlooked in research on and discussions about competence-oriented curriculum reforms. The findings reveal that the Danish teachers navigate a complex web of constraints, including time pressures, resource limitations, and ambiguous curriculum objectives. Importantly, these challenges intersect with the teachers' professional experiences and pedagogical beliefs, shaping their capacities to implement the reform in a meaningful way. Whereas previous research approaches predominantly have contributed in identifying challenges associated with reform implementation (Crujeiras & Jiménez-Aleixandre 2013; Nielsen & Dolin 2016; Schneider et al., 2005), my study offers broader and more contextualized insights on *how* these systemic issues interact to influence the teachers' curriculum enactment.

The findings highlight how teachers adapt and reinterpret reform initiatives based on their professional horizons and contextual realities, often in ways that diverge from policymakers' original intentions. By situating teacher agency within broader systemic contexts, this research contributes to a contextual understanding of teachers' responses to curriculum reforms and their room for acting as agents of change in this context. Rather than merely studying what challenges teachers encounter in their attempts to adhere to new curricular requirements, an essential contribution of my thesis is to provide empirical insights into *why* and *how* these challenges emerge.

Teacher Agency: Beyond Personal Determinants

A key contribution of my study is the application of teacher agency (Priestley et al., 2015) as a lens to explore how science teachers enact competence-oriented curriculum reforms. While

previous research has highlighted the role of individual factors such as teacher experiences and pedagogical beliefs (e.g. Kruger et al., 2013; Nielsen & Nielsen, 2021) in the context of curriculum implementation, the perspective in this study moves beyond individualistic interpretations of teacher capacity and positions teachers as embedded within and shaped by their professional contexts as they enact the curriculum. By exploring the interplay between personal, institutional, and systemic factors, the study highlights how teacher agency serves as a critical framework for understanding both the challenges and opportunities associated with teacher enactment of a competence-oriented curriculum change. This approach integrates teachers' voices and experiences as central to understanding how competence-oriented curriculum reforms in science education are navigated, treating teachers and their organizational contexts as an integrated unit. It also underscores the importance of creating structures that enable teachers to draw on their prior experiences and collaborative practices to work toward meaningful and sustainable educational change. By situating teacher agency at the heart of this research, the results from my study identify structural barriers that limit teacher agency in the context of teacher enactment of competence-oriented science curricula, such as disciplinary silos, high-stakes assessments, and limited collaborative opportunities. At the same time, it demonstrates how teachers navigate these barriers in ways that reveal the contextual and dynamic nature of their agency. This dual focus not only offers a contextual understanding of the enactment process but also suggests actionable pathways for creating future environments that empower teachers to lead and sustain curriculum innovations.

While my study does not offer a definitive solution to the challenge of striking a balance between specificity and flexibility in curriculum design, the findings suggest that achieving this balance is essential for supporting meaningful curriculum enactment. In this regard, the theoretical framework of teacher agency (Priestley et al., 2015) provides a valuable lens for exploring how teachers can navigate and potentially resolve this tension. Although my study does not prescribe a single pathway for achieving balance, it emphasizes the importance of creating *opportunities* for teachers to connect curricular objectives to their professional experiences and specific contexts. The findings from my study indicate that fostering continuity and relevance between the revised curriculum and teachers' professional horizons is a critical step to effective curriculum enactment and thereby curriculum implementation. Ensuring this continuity allows teachers to maintain their footing amidst the demands of the reform, potentially

avoiding scenarios where the curriculum's alienation and detachment pulls the rug out from under them, leaving them without the necessary support to adapt reforms to their given contexts.

By using the framework of teacher agency (Priestley et al., 2015) as a guiding principle, policymakers and educational leaders can explore ways to create *spaces* where teachers can collaboratively interpret curriculum goals and translate them into their contexts. Such spaces would allow teachers to draw on their professional experiences while also engaging critically with curriculum reforms. This approach not only supports meaningful curriculum enactment, as the teachers would be provided with opportunities to develop shared languages for both the official curriculum as well as curricular translations into arenas of the operational curriculum (Remillard & Heck, 2014), but also potentially reinforces teachers' professional autonomy and capacities for innovation.

The Role of Future Workshops in Supporting Teacher Agency

In my study, I have chosen to conduct a future workshop as a method to operationalize and support teacher agency. This approach proved to provide a structured yet flexible framework that enabled teachers to reflect on their experiences, identify shared challenges and visions for a desirable future, as well as co-create solutions (Jungk & Müllert, 1987). Unlike traditional professional development programs, which may adopt top-down approaches, the Future Workshop is a democratic method that *actively* empowers teachers to take role in shaping reform implementation processes.

The integration of the Future Workshop method (Jungk & Müllert, 1987) with the theoretical framework of teacher agency is a significant contribution of my study. This dual approach shows that Future Workshops can be used both as a tool for investigating teacher agency and as a way of fostering it. The method has the potential to enable teachers to translate possibly abstract curricular objectives into actionable strategies grounded in their professional contexts. Moreover, the collective nature of the method can foster a sense of professional solidarity and teacher team spirit, which can mitigate feelings of isolation and frustration. In sum, by creating a democratic and participatory space, the method allows teachers to engage meaningfully with both individual and contextual factors influencing their agency. This aligns with the understanding that teacher agency is not confined to personal attributes but is shaped by systemic and organizational dynamics (Priestley et al., 2015). However, the results from this study highlight that many of the

barriers to curriculum enactment cannot be resolved by teachers alone. As such, fostering teacher agency in the context of competence-oriented curriculum reforms requires a broader involvement and support from other levels of the educational system, including for example school leadership and policy makers.

A key question emerging from this synthesis is whether the Future Workshop method could transcend the boundaries of the immediate teacher group and associated contexts to include broader institutional and policy levels. By involving additional stakeholders – such as school and/or municipal leaders or even policy makers – the use of Future Workshops could potentially enable a more comprehensive examination of how various layers of the educational system intersect to shape teachers' curriculum enactment, providing opportunities to align reform goals with practical realities across multiple arenas.

This proposition connects directly to the enactment model (Remillard & Heck, 2014), Figure 1, which conceptualizes curriculum enactment as a layered, dynamic process that unfolds across several interconnected arenas. While my study primarily focuses on the operational curriculum and the associated mediating factors in the Danish context, the Future Workshop method holds the potential to extend its influence into other dimensions and mediating factors, e.g. factors that influence the official curriculum, by engaging a wider spectrum of actors. By doing so, this would facilitate a dialogue that not only addresses localized challenges but also potentially informs broader policy discourses.

In summary, the integration of Future Workshops with the theoretical framework of teacher agency represents an innovative approach to addressing teachers' curriculum enactment. Future research could explore the scalability of this approach, examining its potential to include additional levels within the enactment model and contribute to systemic changes across educational contexts.

Towards New Ways of Practicing, Researching, and Shaping Policy for Competence-Oriented Curriculum Reforms in Science Education

The findings from my study highlight how the teacher agency framework has foregrounded specific questions about the teachers' enactment of the curriculum reform, emphasizing the interplay between individual, institutional, and systemic factors. As such, by examining teachers' work with implementing the competence-oriented curriculum reform through the teacher agency

(Priestley et al., 2015) lens, my study foregrounded a range of questions related to exploring teacher enactment of the curriculum. My study identifies not only the challenges teachers face in enacting reforms but also potential pathways for action available to a variety of stakeholders, including policymakers, educational leaders, and teachers themselves. Building on the findings of this study, I will outline the key opportunities and considerations for educational practice, research and policy arising from my work. Specifically, initiatives that create collaborative spaces for teachers to share experiences, develop solutions, and translate policy into enactment are essential. This could involve establishing professional learning communities, organizing workshops, and integrating participatory methods such as Future Workshops into professional development initiatives. Such aspects not only empower teachers but also potentially help align curriculum reforms with teacher contexts.

Opportunities for Educational Practice

My study highlights the potential for rethinking how teachers engage with curriculum reforms. One insight is the importance of creating collaborative spaces where science teachers can exchange experiences, strategies and discuss challenges. Participatory methods like the Future Workshop model can offer valuable opportunities for teachers to develop a shared understanding of curriculum goals, reflect on their practices, and collaboratively develop solutions that align with their professional experiences and the needs of their students, integrating their professional experiences into their enactment. This approach fosters professional agency, enabling teachers to potentially better navigate the complexities of curriculum reforms and adapt them in ways that enhance student learning outcomes. Furthermore, engaging in such reflective practices can help reduce feelings of isolation and frustration, reinforcing teachers' professional autonomy.

For educators and school leaders, the findings suggest that fostering teacher agency related to a successful enactment of the curriculum involves recognizing it as a product of personal experiences, institutional structures, and broader systemic dynamics. Professional development programs should, therefore, address these multiple dimensions, by offering collaborative opportunities for teachers to build networks and share insights, advocating for flexible curriculum structures that allow adaptations, and ensuring that professional support systems align with teachers' needs. This approach can foster an environment where teachers feel competent and confident in enacting reforms.

Teacher education programs also play a crucial role in fostering teacher agency among preservice teachers. To prepare teachers of tomorrow for the complexities of competence-oriented curricula, programs could benefit from integrating aspects of theoretical frameworks such as teacher agency (Priestley et al., 2015) to help future teachers engage in discussions about and understand that agency is influenced not only by personal attributes, but by professional environments and systemic factors. This could potentially instill a foundational awareness of how personal and systemic factors may intersect, equipping future teachers to critically meet, analyze and adapt reforms in their future classrooms. Additionally, teacher educators could consider facilitating discussions that highlight the importance of institutional and policy-level support, ensuring that future teachers understand the broader context in which they will work.

Rethinking Policy

Fostering teacher agency in the context of enacting a competence-oriented curriculum involves more than enhancing (pre- and in-service) teachers' skills and professional capacities through education and training. It also necessitates a focus on the broader cultural and structural environments within which teachers work, and the factors that mediate them. Without efforts to address these systemic dimensions, calls for teachers to act as agents of change are unlikely to result in meaningful or lasting transformations in educational practices and processes. To be sure, to effectively promote teacher agency in the context of competence-oriented science curriculum revisions, policy initiatives must go *beyond* targeting individual teacher competences.

Policymakers could benefit from prioritizing mechanisms that strike a balance between curricular specificity and adaptability, enabling teachers to tailor reforms to their professional knowledge and local contexts. In the Danish context, this is particularly relevant, as an ongoing curriculum renewal process (fagfornyelse in Danish) that is currently under construction aims to revise and simplify the national curriculum for primary and lower secondary school education (Ministry of Education, n.d.). The findings from my research underscore the importance of understanding how curricula are *translated* and *enacted* in practice.

My study offers relevant information for the contents and design of curriculum renewals. While simplification and modernization are essential goals for the renewal in the Danish context (Ministry of Education, n.d.), it seems equally important to ensure that the curriculum supports teachers in adapting and enacting reforms effectively. Simplified curricula should not just be clearer in their objectives but also supply room for teachers to connect these objectives to their

existing professional knowledge, pedagogical practices, and contextual realities. The results from my study suggest that future curriculum reforms could be developed with mechanisms that allow teachers to engage *actively* in the interpretation and translation of curriculum goals. In addition, ensuring that the curriculum is not only simplified but also relevant to the teachers' professional contexts can potentially prevent potential gaps between policy intentions and teacher enactment in the future. This alignment would facilitate a more effective and meaningful curriculum enactment that truly enhances student learning outcomes. Moreover, involving a range of stakeholders in the development phase of a curriculum renewal, including school leaders, policymakers and teachers, could facilitate a cross-level dialogue that addresses challenges more holistically.

Considerations for Future Research

The findings from my research open several avenues for further research into science teacher enactment of competence-oriented curriculum reforms. Future studies could explore the following:

1. Studies across Municipal and/or Organizational Contexts: My study was conducted within a single municipality, which provided a focused yet localized perspective on how competence-oriented curriculum reforms are enacted. Future research could extend this work by examining curriculum enactment across multiple municipalities or organizational contexts. Such studies could reveal the influence of varying policy structures, cultural expectations, and institutional support on teachers' agency and curriculum implementation. By identifying commonalities and contextual differences across municipal contexts, this research could enhance the robustness and generalizability of findings, offering deeper insights into the factors that shape the implementation of competence-oriented curriculum reforms.

2. Studies on Teacher Agency Development: Future research should consider longitudinal studies that track the development of teacher agency over time as they engage with competence-oriented curriculum reforms. Such studies could investigate how teachers' professional horizons evolve and adapt as they gain experience with the reform and the types of professional development that most effectively support this growth.

Understanding this adaptability can highlight the ways teachers' professional outlooks shift to meet emerging demands and opportunities within their contexts.

3. The Impact of Participatory Methods on Curriculum Enactment: Building on the innovative integration of Future Workshops in this study, future research should further explore how participatory methods can be used to facilitate and support teacher agency and curriculum enactment. Studies could assess the effectiveness of these workshops in supporting teachers' abilities to interpret and translate abstract curricular goals into practice, as well as their potential scalability and adaptability across different educational contexts and levels of policy engagement.

Limitations of my Study

As with any study, this research has limitations to consider. These limitations pertain to the theoretical framing, methodological choices, and the specific contexts in which I conducted the research. While these choices were made to align with the research questions and objectives of the thesis, they also scope the findings and their generalizability.

In this study, I draw on Remillard and Heck's (2014) model of curriculum enactment. While the model has proven effective in delineating the enactment process, related to the operational curriculum and the factors that mediate it, my study does not explicitly address the contents in the official curriculum itself (Figure 1). My study has therefore not challenged whether the goals inherent in the curriculum are aligned with insights from the international research literature. This means that I have treated and discussed the observed discrepancies between the official curriculum and the teachers' enactment as challenges to be resolved, thus emphasizing alignment between the official and the operational curriculum over a potential critique of the contents in the official curriculum (and the factors that mediate it). An examination of the official curriculum could for example explore how closely the stipulated competence goals in the revised curriculum align with state-of-the-art research on effective science education practices related to achievement of transversal scientific competences. I imagine such research could focus on what constitutes an ideal definition of competence-oriented science education, and how this aligns with the directives in the official curriculum. While my study focuses on the teachers'

enactment, future research could dive into the relationship between the patchwork of the official curriculum and broader educational or scientific research.

Another limitation pertains to the fact that my study was conducted within the context of a single municipality, encompassing all schools and science teachers within that locality. While this approach has provided an in-depth view of science teachers' curriculum enactment in the specific context, it has limited the study's generalizability. Other municipalities may differ in their organizational structures, policy implementations, and/or resource allocations, which could potentially influence how teachers enact competence-oriented curriculum reforms. To address this limitation, future studies could compare multiple municipalities to identify contextual commonalities and differences. This could enable a more comprehensive understanding of how contextual factors shape curriculum enactment across diverse settings, thereby enhancing the generalizability of findings.

A central focus of this study has been on understanding the Danish group of science teachers' perspectives on their enactment of the competence-oriented curriculum reform. In this regard, qualitative methods were employed, to provide insights into teachers' experiences, challenges, and reflections. However, the empirical material of my study does not include direct observations of the teachers' classroom practices. While this methodological choice aligns with my study's objective of exploring the teachers' experiences, it limits the study's ability to comment on their actual enactment inside the classroom. Although their practice in the integrated oral exam is one window into their curriculum enactment, observations of their classroom practices could have provided a complementary perspective, offering a more detailed understanding of how the teachers operationalize the competence-oriented reform in their specific teaching contexts. To follow the terminology of the teacher agency framework (Priestley et al., 2015) the practical-evaluative dimension of the teacher agency model (Figure 2) is explored through teacher dialogues, but not through observable actions and decisions made in real-time teaching. My study relies on teachers' descriptions of their actions and experiences. While these narratives are valuable for understanding how teachers perceive and navigate their roles, they may not fully capture the complexities of classroom dynamics. The methodological choices I made in this study reflect an alignment between the research object and the chosen methods. By focusing on teachers' perspectives in parts of the study, it sheds light on their

thoughts, challenges, and sense-making processes. Future research could incorporate classroom observations to provide a more comprehensive understanding of teacher enactment of a competence-oriented curriculum, encompassing both their reflections and observable teaching practices.

While these limitations delineate the boundaries of my study, they also suggest valuable directions for future research. By addressing the contextual, theoretical, and methodological aspects highlighted above, future studies could build on this work to further deepen our understanding of teacher agency in the context of competence-oriented curriculum reforms.

Conclusion

In this thesis, my purpose has been to explore how science teachers navigate the complexities of competence-oriented curriculum reforms and the factors that mediate their curriculum enactment. In particular, I have sought to uncover the factors that facilitate or hinder teachers' abilities to align with stipulated reform expectations and goals. This aim has been pursued through the collection and analyses of multifaceted data from teacher planning sessions around multidisciplinary competence-oriented science teaching, teacher group talk-in-interactions about their specific curriculum enactments, workshop data, as well as data from oral exams. I have examined the interplay between science teachers' professional identities and horizons, institutional contexts, and broader systemic factors. The findings provide insights into how science teachers construct agency as they enact competence-oriented curriculum reforms and how various personal, contextual, and systemic conditions shape their actions, decisions, and reflections.

The findings highlight that teacher agency in the context of enacting a competence-oriented curriculum reform is not an individual attribute, but emerges dynamically, and is highly influenced by specific organizational and systemic contexts. In this study, the Danish teachers' enactment of the competence-oriented science curriculum was significantly influenced by institutional structures, (lack of) collaborative opportunities, and the ambiguity seemingly inherent in the curriculum. Structural barriers such as the organization of teaching into disciplinary silos, assessment formats and practices, as well as a lack of professional support and

development constrained the teachers' abilities to meaningfully adapt and implement the reform. In addition, the findings shed light on how the teachers worked to translate reform initiatives into their lived contexts drawing on their professional horizons and contextual realities, often in ways that diverged from the stipulated curricular intentions. By identifying these barriers and the agentic configurations teachers employed to navigate them, my study sheds light on the complexities of enacting a competence-oriented curriculum reform.

The Danish reform was characterized by various stakeholders as a radical and necessary educational policy project, aiming to transform the schools into fundamentally different spaces for both teachers and students (Rasmussen, 2015). However, shortly after its implementation, teachers working within the schools pointed out that the reform was to be built on a school day and teacher practices that already existed; involving the same teachers with the same knowledge, values, competences, and attitudes as before the reform (Rasmussen, 2015). My study illustrates how teachers navigate this tension between continuity and change, revealing that the balance between preserving existing practices and adapting to new curricular demands can be challenging. Particularly, it highlights how teachers struggle to find space for their pre-existing expertise within the framework of new curricular expectations.

This tension underscores the importance of considering teachers' lived contexts when designing and implementing reforms. It is one thing to anticipate that teachers will serve as agents of change in implementing curriculum reforms; it seems quite another to establish the systemic and contextual conditions that foster their agency (Priestley et al., 2015). Curriculum reforms inherently intervene in teachers' existing practices and routines. As this study highlights, teachers interpret, enact, and sometimes resist reform mandates.

A key contribution of my thesis is the application of Priestley et al.'s (2015) framework for teacher agency, utilizing it to explore teachers' construction of agency as they enact a competence-oriented curriculum reform. This approach foregrounded critical questions about how systemic and contextual factors influence the teachers' agency and their curriculum enactment. Specifically, my study highlights the challenges posed by the specific organization of teaching, which hinders the integration of competence-oriented approaches emphasized in the curriculum and explores the complex relationship between the teachers' enactment and the

expectations put forth by the curriculum. As such, the work advances research on teachers' work with implementing competence-oriented curriculum reforms in science education by applying Priestley et al.'s (2015) theoretical understanding of teacher agency and demonstrating how the framework can be used to illuminate the complex interactions between individual, institutional, and systemic factors. Empirically, it provides insights into the challenges and opportunities teachers face when navigating reforms, offering a clearer picture of the conditions that support or constrain their professional agency.

The findings suggest pathways for future research, practice, and policy. For the sake of future science teachers and students, and if teacher agency is regarded key to effective curriculum enactment, then policymakers, educators, and researchers ought to carefully examine and support the conditions that make it possible for teachers to achieve such agency in their given contexts. Reforms that aspire to transform teaching and learning must balance ambition with realism; acknowledge and build upon the existing realities of teacher practices rather than imposing prescriptive changes that fail to resonate properly with their contexts and professional horizons.

Ultimately, this thesis contributes to a deeper understanding of the challenges and opportunities inherent in enacting competence-oriented curriculum reforms in science education. By foregrounding the interplay between systemic, contextual, and individual factors, it offers empirical insights and practical recommendations. The study highlights that teachers approach curriculum enactment from diverse professional backgrounds, experiences, as well as working conditions and constraints, necessitating adaptable strategies rather than universal solutions to bridge the gap between official and enacted curricula. Future efforts to support teachers' curriculum implementation could benefit from prioritizing systemic conditions that align with teachers' lived realities, enabling them to translate curricular intentions into meaningful practices. As such, this thesis provides a foundation for further exploration into the conditions that enable teacher agency in the contexts of school reforms, offering insights that inform both practice, educational research, and policy development aimed at supporting effective curriculum reform in the future.

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Included Papers

Paper 1

Title: Navigating Change: A Review of the Literature on How Competency-oriented Curriculum Revisions Affect Science Teachers' Practices

Abstract

This study reports on a qualitative, systematic review on how competency-oriented curriculum revisions affect science teachers' practices. The study is guided by two research questions: How are the implications of curriculum revisions on science teachers' practices studied? What factors affect science teachers' implementation of competency-oriented curriculum revisions? Our study reveals a diverse range of methods used to investigate teacher practices in the context of curriculum revisions. Furthermore, the findings present both hindrances to the implementation of curriculum revisions and conditions that support it. Our study illuminates and discusses the implications of the interventionist contexts in which most studies have been conducted to investigate how teachers navigate curriculum revisions, as well as the systemic contradictions that seem to hinder science teachers in complying with the requirements of a competency-oriented science curriculum.

Keywords: curriculum reform, competency-oriented science education,

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Introduction

Curriculum revisions are often considered the go-to instrument for changing practices in science education, since curricula define the guidelines of what should be taught and how. While such revisions may be guided by various support strategies such as professional development, curriculum materials and the like, changing practices through curricular reforms relies on the assumption that curriculum revisions in fact are an effective means of changing science teachers' practices[1].

During the past decade, there has been an international tendency in curriculum revisions to adopt competency-oriented approaches, emphasizing students' *application* of knowledge (OECD, 2017, 2019; Crujeiras & Jiménez-Aleixandre, 2013; Berland et al., 2016; Ropohl et al. 2018).

In science education, a competency-oriented approach refers to the development of scientific competencies or skills that students need to acquire, typically encompassing a combination of scientific knowledge, inquiry, and problem-solving skills, critical thinking, and laboratory skills (OECD, 2017). Examples of recent competency-oriented curriculum reforms are found in Finland's national Core Curriculum, that promotes multidisciplinary learning and project-based activities (Sahlberg, 2011), the Australian Curriculum that has integrated more real-world applications and inquiry based learning approaches, particularly in STEM education (Fensham, 2013), or in Canada, where various provinces have revised their curricula to incorporate experiential learning and skill development to prepare students for future work (Hargreaves and Shirley, 2012).

A key driver for this competency-orientation has been the ambition to train students to meet complex demands by mobilizing knowledge, skills, and attitudes (OECD, 2017) to support students in succeeding in their careers, communities, and personal lives (Kelly, 2008). Previous research has indicated that it is a challenging task for teachers to change their practices and perceptions of school science in the shift towards such competence-oriented curricula (Crujeiras & Jiménez-Aleixandre 2013; Nielsen & Dolin 2016). Studies have identified various reasons for these difficulties, including teachers' lack of well-suited pedagogical skills (Schneider et al., 2005) and top-down approaches to implementation that fail to accommodate the perspectives and needs of teachers (Haney, 1996). Currently, we,

[1] In this paper, we understand teaching practice as the ways in which teachers understand and implement curriculum and instruction under the influence of beliefs and ethics about the process of teaching and learning (Hunter & Rasmussen, 2018)

however, only have a scattered overview of these difficulties, and of which circumstances that support teachers in implementing such curricula. Previous reviews in this area have focused on competing visions of science and the influences on science teachers (Haglund & Hultén, 2017), the implementation of competency-oriented curricula with a specific focus on learner-centered pedagogies (Nsengimana et al., 2020), and the intrinsic challenges associated with designing and implementing inquiry-based practical work (Callaghan, 2019). What is missing is a review on how science teachers' practices are affected by curriculum revisions, and through what research methodologies these findings have been generated (Van Driel et al., 2001; Fullan, 2001; Mangiante, 2018). This paper fills this gap by answering the following research questions:

1. How are the implications of curriculum revisions for science teachers' practices studied?
2. What factors affect science teachers' implementation of competency-oriented curriculum revisions?

Answering these questions can contribute to constructing an overview of how future curriculum revisions may be informed by insights derived from research in science education. Such insights elucidate how curriculum revisions can serve as a mechanism for altering the practices of science teachers.

Method

To elucidate the research questions, we conducted a qualitative systematic literature review (Grant and Booth, 2009). A qualitative systematic literature review is a research method used to systematically collect, analyze and synthesize a body of qualitative research studies on a particular topic or research question. The primary objective of such a review is to provide a comprehensive overview of the existing literature related to a specific area of interest; it looks for "themes" or "constructs" in or across a corpus of individual qualitative studies (Grant and Booth, 2009). We find this method relevant in the context of our study, as we seek to broaden our understanding of the factors that affect science teachers' implementation of competency-oriented curriculum revisions.

Search and screening process

This review aims to investigate how educational research literature describes the factors that affect how compulsory school science teachers (students aged 6-16) implement competency-oriented curriculum revisions. We chose to focus on this group of teachers as they often are

generalists without a master's degree within the science subject(s) they teach and are therefore likely to experience particular challenges and opportunities in relation to a curriculum reform that can be different from those experienced by e.g. high-school teachers. To address our research question, we initiated searches for peer-reviewed papers in the databases Web of Science, ERIC and ProQuest, yielding a total of 765 papers. We conducted the search on July 3rd 2023, using the following query: ("science teaching") AND ("competenc*") AND ("planning") OR ("teacher practice") AND ("compulsory school") OR ("lower secondary school") OR ("K-9") OR ("elementary school") AND ("curriculum reform") AND ("science teachers"). We restricted the search to include papers published in the period after 2011, partly to ensure that studies were conducted after the implementation of the European Qualification Framework (European Parliament and European Council, 2008), which required European curricula to be described according to competencies, and partly to generate a manageable number of articles to process. Although our search string was restricted to science education contexts, we have chosen to include papers that focus on STEM, as many recent competency-oriented reforms concern STEM.

Next, we exported the data generated by the search into an Excel sheet. We then processed the data by following steps suggested by Higgins et al. (2017): First, we screened data on title and abstract level, excluding papers conducted in other contexts than compulsory school and papers that did not focus on in-service science teachers, but for example focused on pre-service teachers or students. Additionally, we excluded papers which focused on textbooks, or which were unrelated to science education. 481 studies were excluded in this step, leaving 284 papers for subsequent screening. We conducted a similar process based on reading the abstracts, in which we excluded 162 papers.

We then carried out a deductive coding process guided by our research question as described in Braun and Clarke (2006). In this process, we coded together and in parallel to ensure reliability and validity of our findings (Creswell, 2009). We codified the remaining 122 papers in an Excel spreadsheet according to the following codes: purpose of paper, method/research design, geography of study, school level, theories applied, and area of teacher practice studied. This led us to exclude another 81 papers. In addition to the exclusion criteria used in the title and abstract level, we excluded papers based on full-text screening if they were not written in English or if it became evident that the study did not focus on teachers' practice in the context of a curriculum revision. In addition, a criterion for including papers was that the reported study concerned a curriculum reform aiming to build students'

competencies in the sense of how they are described in (OECD, 2017) as mentioned in the introduction.

This left us with a final corpus consisting of 41 papers. The screening process described above is visualized in figure 1 below.

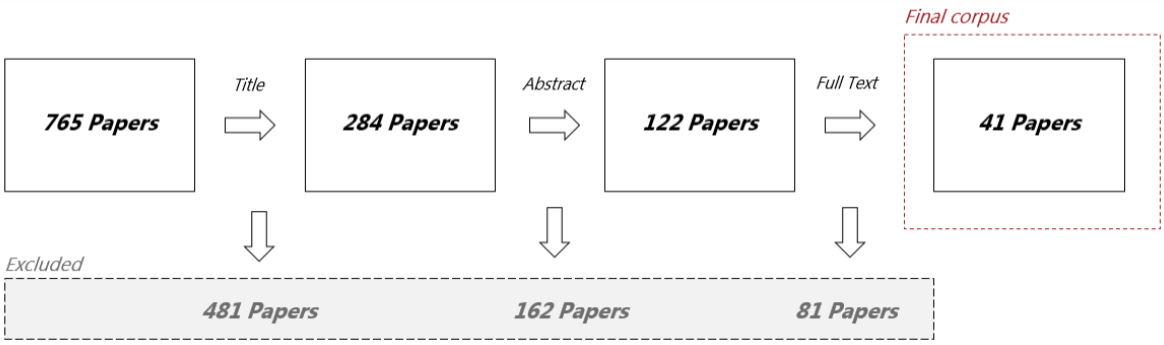

Figure 1: The process of screening papers

Approach to Analysis

To elucidate the research questions, we initially grouped the 41 papers into categories based on the methodology used. We then synthesized the studies according to the following guiding questions:

- What curriculum change does the study concern? (e.g., a change from content-based to competence-based science curriculum)
- What part(s) of science teachers' practice(s) is/are studied? (e.g., their planning of science teaching)
- What is studied in the paper and how? (e.g., teacher beliefs using semi-structured interviews)
- What are the results?

To address the first research question (*how are the implications of curriculum revisions for science teachers' practices studied?*), we categorized the studies into four methodological categories based on the synthesis described above. These categories included: case studies, intervention studies, surveys and reviews. Next, we grouped the studies within each category to identify trends in *contexts* for (e.g. PD contexts) and *aspects* of teachers' practices that were studied (e.g. teachers' perceptions contrary to teachers' practices).

To address the second research question (*what factors affect science teachers' implementation of competency-oriented curriculum revisions?*), we revisited the synthesis of

papers and further condensed it to identify patterns and themes in the studies' findings. This process was guided by the following questions:

- What themes do the findings concern? (e.g., the integration of STEM depends on teacher knowledge.)
- What are the findings? (e.g., teachers find it difficult to balance the requirements of mono-disciplinary teaching and integrated STEM.)

We then made a visual representation, i.e. a visual step of the data analysis and thus not a part of this paper, for each bullet to help us sort them, move them around as part of our process with data analysis, discuss the possible relationship between them, and arrange each of them into themes. Next, we discussed, reviewed, and refined the themes as described in Braun and Clarke (2006). Through this process, two overall themes emerged: factors that hinder implementation of curriculum revisions and factors that support it.

Results

How are the Implications of Curriculum Revisions on Teachers' Practices Studied?

Our analysis found that the following methods are deployed in the papers to study the effects of curriculum reforms on teachers' practices:

Methodology	**n**
Case studies	22
Surveys	9
Intervention studies	7
Reviews	3
Total	41

Table 1 Methodologies deployed in corpus papers

Of the 22 case studies, 8 of the studies were conducted in professional development (PD) in the sense of processes and activities designed to enhance in-service teachers' professional knowledge, skills, and attitudes to support them in improving student learning (Guskey, 2000). The case studies conducted in PD contexts roughly fall into two categories. The first category primarily focuses on studying what teachers *do* (e.g. how they implement a curriculum revision after PD participation as in the case of (Arias, Bismack et al., 2016)) and the *factors that influence* science teachers' practices (e.g. teacher support networks Herman et al. (2019)). The second category primarily focuses on science teachers' beliefs, attitudes, and

beliefs of what has been adopted in a new curriculum revision, and the extent which these beliefs have changed due to PD participation. For example, Rinehart et al. (2022), studied how teachers' epistemic cognition, aims and ideals impact their dialogic processes as they engage in argument-based inquiry in a PD-context. The case studies conducted in non-PD contexts fall into 4 categories characterized by a focus on 1) knowledge of and experience with concepts in curriculum revisions (e.g. Ling et al., 2021), 2) practices and reasoning about own practices (e.g. Nielsen and Nielsen, 2021a), 3) perceptions and beliefs about concepts in curriculum changes (e.g. Kruger et al., 2013) and 4) conditions for curriculum implementation (e.g. Mkimbili et al., 2017).

The survey studies in the corpus generally focus on teachers' *perceptions*, e.g. their level of perceived competence to teach new curriculum. For example, Uitto and Saloranta (2017) investigated Finish science teachers' perceived level of competence related to their implementation of sustainability education. Also, Nielsen and Nielsen (2021b) investigated science teachers' perceived practices of, rationales behind, and possibilities for working with models and modelling. The survey studies also included investigations of factors that affect attitudes, and teachers' levels of implementation, e.g. Hackman et al. (2021). Only a few survey studies focus on uncovering changes in teachers' practices caused by curriculum revisions (e.g. O'Grady et al., 2014).

The intervention studies in our corpus are approximately equally distributed between studies of PD-programs and of science teachers' implementation of curriculum materials or similar developed by the researchers. The intervention studies are distinct from PD-context case studies in that the former primarily focus on studying properties or areas of improvement of the *innovation*, whereas the PD-context case studies have a primary focus on studying *the effect of the innovation on teachers' practice*[2]. The corpus included three literature reviews: Haglund and Hultén (2017) examined the treatment of energy in Swedish secondary curricula in the period 1962-2011 through the lens of two competing visions of science characterized by 1) a focus on products and processes of science, and a focus on 2) science in relation to society and students' everyday life. The review does not focus on teacher practice, but the

[2] e.g. the intervention study conducted by Vasconcelos (2012) that used teachers' reflection diaries to assess and refine some concerns in their interventions whereas the PD-context case study conducted by Dare et al. (2018), they used an engineering design-based approach for integrated STEM instruction to guide professional development and curricular design. The study by Dare et al. (2018) reports on teacher perspectives on the factors, techniques, and approaches that were most important to them during an integrated STEM unit in a PD-context.

authors argue how science teachers' practices may be shaped and challenged by the competing visions. Nsengimana et al. (2020) examines empirical and theoretical literature about competency-oriented curriculum in general, particularly focusing on its implementation with an emphasis on learner-centered pedagogy in science subjects and the challenges associated with the implementation. Last, Akuma and Callaghan (2019a) characterize the intrinsic challenges related to the design and implementation of inquiry-based practical work.

What Factors Affect Science Teachers' Implementation of Competency-oriented Curriculum Revisions?

Most studies in our corpus considered changes in teachers' practices in the light of conditions that either hinder or support curriculum implementation. To answer our second research question, we therefore present our synthesis of the factors that studies found to *hinder* or *support* the implementation of curriculum revisions.

Hindrances

The findings regarding hindrances can be divided into challenges at the "system level" and challenges at the "teacher level". The system level refers to factors external to the teacher, e.g. teaching resources and administrative/organizational policies. Hindrances at the teacher level refer to teacher-dependent factors such as knowledge required to adopt a new curriculum, existing practices/beliefs that hinder curriculum implementation.

System Level

Competency-oriented curriculum revisions can take many forms but typically call for a close collaboration between two or more science subjects and often comes with new pedagogical approaches with which teachers may not be familiar with. Our analysis revealed that these features brought systems-level hindrances of curriculum implementation in particular with relation to time and resources, mono-disciplinary organization of science education and exam-driven teaching.

Time and resources

Several of the studies identify lack of teacher resources, insufficient teaching resources, and limited time allocated to science teaching as heavy hindrances to the implementation of competency-oriented curriculum revisions. Farirah et al. (2021) found that while many teachers agree with the pedagogical approaches outlined in a curriculum revision, the lack of resources, supportive materials and allocated time hindered teachers in implementing the new curriculum. Similarly, García-Carrillo et al. (2021) found that lack of time and organizational

difficulties (e.g. onerous teamwork) hindered teachers in implementing an integrated, competency-oriented STEM curriculum. Braskén and Pörn (2021) also argue that integrating competencies in science teaching curricula is time consuming, as it takes time to develop themes and well-suited assessment criteria.

Mono-disciplinary and Content-specific Organization of Science Education

Competency-oriented curriculum revisions often concern concepts or approaches that exceed a mono-disciplinary divide and bring a shift in focus from content to competencies. In our corpus, curriculum revisions were often implemented in contexts where science education is organized in mono-disciplinary silos with a focus on content, which several studies find problematic. For example, Nsengimana et al. (2023) examined teachers' knowledge, understandings, and perceptions of a competence-based curriculum revision that addressed multidisciplinary issues. This study found that teachers' focus on content contrary to competencies made it unclear for them how to apply multidisciplinary competences in their teaching. Similarly, Dare et al. (2018) found that a key hindrance for teachers in implementing the concept of integrated STEM was that the teachers' practical teaching of STEM subjects often is organized in isolated disciplines. The teachers struggled in integrating engineering into their mono-disciplinary teaching and felt an obligation to commit to a specific focus instead of integrating them (Dare et al., 2018). Ling et al. (2021) found that teachers tended to teach a new STEM education curriculum in isolated subjects, and that the teachers were not able to mention integrated STEM projects within their teaching.

The Effect of High-Stake Testing

Although curricula are revised, high-stakes national or international tests are not necessarily changed in accordance with new curricular guidelines or requirements (Au, 2007). Several studies in our corpus identify such tests to be a hindrance for teachers' curriculum implementation. Nielsen and Nielsen (2021) focused on a curriculum revision in which models and modelling competency became part of the curriculum and examined how science teachers perceived their practices, rationales behind, and the possibilities for working with models and modeling. Their study showed that, despite curricular revisions that concerned multidisciplinary competences, teachers still faced content-heavy exams with tasks reliant on recall and memorization. This was described as counterproductive to teachers' efforts to implement a more competence-oriented approach.

Similarly, Park et al. (2022) found that despite supporting curriculum changes, teachers tend to shape their practices according to national tests. Also, Ling et al. (2021) and Zhan et al. (2021) found that high stakes standardized exams had a different focus than curriculum revisions, and that teachers prioritized preparing students for the test higher than complying with the curriculum.

Teacher Level

Another hindrance in our corpus relates to the teacher, who often is emphasized as an instrumental agent in enacting curriculum revision. Our corpus reveals that hindrances particularly relate to teacher's beliefs and knowledge.

Teacher Beliefs

Teacher beliefs can be defined as professional viewpoints that are static, emotionally bound, organized into systems, and developed episodically (Gess-Newsome, 1999). Teacher beliefs are significant in relation to teachers' implementation of curriculum revisions in that they guide decisions behind instructional strategies, classroom management and assessment methods (Haney et al., 1996). One example of how teacher beliefs hinder curriculum implementation is found in the study by Kruger et al. (2013). This study found teachers' pedagogical beliefs to have a substantial impact on how they interpret and implement curriculum. If teachers' beliefs conflict with ideas embedded in curriculum revisions "(...) *one cannot expect successful implementation of it."* (p. 43). Similarly, Nielsen and Nielsen (2021) investigated science teachers in the context of a newly implemented competency-oriented curriculum that emphasized models and modelling. While teachers in this study taught models and modelling, their rationales for doing so were product- and content oriented rather process- and competency-oriented as emphasized in the curriculum revision. Hence, the teachers' beliefs about why and how to teach models and modelling constituted a hindrance to curriculum implementation.

While the two above-mentioned studies mainly focused on teachers' pedagogical beliefs, Haglund and Hultén (2017) argue that same issue applies to content: if the content of new curriculum revisions do not align with science teacher beliefs, they will not prioritize the changes. Further, the study by Arias, Bismack et al. (2016) found beliefs to play a role in how teachers use resources developed to support implementation of curriculum revisions. While a wide range of resources were developed to support teachers in adopting reform-based science

teaching, the teachers in this study only used materials characterized by a style of teaching that resembled their own.

According to Rinehart et al. (2022), beliefs are not changed easily. This study explored how teachers' epistemic cognition, aims and ideals impact their dialogic processes in argument-based inquiry. The teachers in this study participated in a PD program designed to develop foundational skills and dispositions to promote argument-based inquiry in their classrooms. Despite careful and deliberate PD efforts, the teachers' orientations and beliefs remained stable, and their practices did not change significantly. However, Mangiante (2018) showed how science teachers' implementation of reform-based teaching was influenced by their beliefs about their students' needs depending on their socio-economic and cultural backgrounds.

Teacher Knowledge

Several studies in the corpus identify various aspects of teacher knowledge to challenge curriculum implementation. One of these aspects concerns teachers' knowledge about the content embedded in a curriculum revision. An example is the study by Diehl (2016) who investigated science teachers' implementation of curriculum revisions concerning entrepreneurship. The study found that teachers held various understandings of entrepreneurship and expressed uncertainty in translating entrepreneurship into their science teaching practice. Another example is Archer-Bradshaw (2017), who argue that teachers' lack of knowledge of science concepts such as scientific literacy to be a key reason for the gap between research-based knowledge of best practices and actual teaching practices in the classroom.

Lack of knowledge of pedagogical approaches and strategies to accompany the teaching of new science contents also emerged as a hindrance (e.g. Nsengimana et al., 2020). Mkimbili et al. (2017) explored the levels of inquiry-based science teaching (IBST) among teachers and the contextual factors that influenced it. This study found that teachers' limited understanding of and knowledge about IBST led to lower levels of implementation. Similarly, Chadwick et al. (2023) identified that teachers need knowledge about suitable pedagogical approaches to teach new content. Further, Sherwood et al. (2020) found that even if science teachers *want* to change their classroom according to curricular revisions, it cannot be taken for granted that they know *how* to do it, and that this hindrance should be addressed by providing authentic examples that illustrate what real-life implementation could look like.

Knowledge can lower *the extent* of curriculum implementation, but it can also influence the *ways in which* teachers implement curriculum revisions. A study by Smith et al. (2018) found that teachers tended to deviate from curriculum guidance in cases where they had only limited knowledge about the topic. This implied that teachers left things out because they did not acknowledge its importance and therefore missed opportunities to address core aspects of the curriculum revision (Smith et al. 2018). Likewise, Bismack et al. (2014) found that teachers adapt resources developed to support a curriculum revision based on their knowledge, and less knowledgeable teachers tended to rely on content-focused curriculum materials and were less prone to use materials developed to support inquiry-based science teaching (Bismack et al. 2014). De Landazábal et al. (2012) found that lack of knowledge also affects science teachers' assessment of their students in competencies. The teachers preferred assessing lower levels of complexity in students' learning. The authors argue this tendency to be due to the teachers' lack of knowledge of the cognitive processes involved in more complex levels. A similar result is found in Vasconcelos (2012). Akuma and Callaghan (2019b) found that teachers' prioritization of what to teach often is defined by what they know the most about. If efforts are made to build a solid knowledge foundation among science teachers about new content embedded in curriculum revisions, their practices are likely to change accordingly. According to Granger et al. (2019), such knowledge should be built on the basis of teachers' existing knowledge.

Supportive Factors

Our corpus also includes studies on what supports competency-oriented curriculum implementation. Below, we report on these findings.

Key Elements and Pedagogical Approaches in PD

Only two studies report on advantageous ways of organizing PD to support competency-oriented curriculum implementation. The PD approaches in these studies are of various extent in terms of time spent by teachers, but nonetheless point to valuable insights when preparing teachers for curriculum implementation.

Active learning and "expert" feedback appear as crucial components in effective PD (Maeng et al. 2020). Maeng et. Al. investigated teachers' understandings, confidence, and classroom implementation of PBL, inquiry, and nature of science (NOS) instruction following a PD. The PD program consisted of a combination of inactive content-focus lectures on NOS and inquiry within PBL, and active exercises where they were to develop PBL-based teaching units for 5th graders. The PD included 4 weeks of training, 22,5 hours of coaching were

coaches co-taught, observed, promoted reflection, and provided feedback on teachers' science instruction, and a minimum of 14 hours follow-up sessions. The study found that teachers who underwent the PD improved their understanding and confidence in implementing the reform-based practices compared to a control group. A significantly greater number of teachers from the treatment group implemented PBL, inquiry and NOS compared to the control group teachers. The treatment teachers ascribed the PD's focus on active learning, practice, collaboration, and valuable feedback from coaches and instructors to the main reason for this effect.

Another crucial aspect of PD organization is the incorporation of teachers' prior knowledge and experiences and guidance for teachers' continuous support of students' learning processes. A study by Bowers et al. (2020) illustrated this by examining teachers engaging in a four-day PD, coaching sessions, and a classroom visit by an expert. This study found that PD should dedicate time to help teachers to recognize and scaffold students' emergent understanding and sense-making. They recommended that PDs should create a "safe space" for teachers to integrate curriculum revisions , and Bowers et al. (2020) argue that rehearsal is a promising format for PD. .Although only two studies in our corpus provide insights into how PD could be designed effectively, other studies report on what could be gained when such criteria are met. Kang and Keinonen (2016) investigated factors that influence teachers' work with implementing competency-oriented curricula, and argue that PD can build teacher confidence. Furthermore, PD can support teachers in using new curriculum materials that can be key in implementing competency-oriented curricula. This was demonstrated in the study by Arias, Davis et al. (2016), who through a three-day PD program supported teachers in using educative features to support the implementation of new science units. Lastly, Paige et al. (2016) investigated teachers' participation in a two-year professional PD aligned with components of a new national competency-oriented curriculum and found that PD can improve science teachers' understandings of multidisciplinarity and its potential connection to students' everyday lives.

Key Factors Supporting Curriculum Integration

Integrating curriculum revisions hinges on the supportive organizational context in which science teachers work, and several studies focus on this matter. A study conducted by Hackman et al. (2021) investigated contextual factors and their impact on science teachers' attitudes toward a new integrated STEM curriculum. They identified several positive

influential factors, including PD, access to suitable STEM resources, sufficient preparation time and time allocated for teaching, as well as administrative support. Similarly, Herman et al (2019) highlighted the role of collegial support. Their results demonstrated that teachers who engaged in support networks were more likely to adopt more sophisticated forms of teacher decision-making. Other contextual factors with a positive impact are multi-institutional partnerships and instructional support (Cottone et al., 2021).

Discussion

26 of the studies in our corpus were conducted in a PD or intervention setting, indicating that it is common to investigate how teacher practices are influenced by curriculum revisions in interventionist contexts. On the one side, this could reflect an acknowledgement of the difficulties of implementation competency-oriented curriculum revisions and a commitment of researchers to develop ways of aiding teachers in this work. The studies in our corpus research provide suggestions of different types of such support, including development of teaching resources, PD formats, and workshops, which teachers then implement or apply with varying success. Despite these contributions, we however believe that the seeming trend of interventionist research designs is associated with a number of implications. First, the level of control embedded in the nature of an intervention or a PD program is rarely present in everyday teaching environments, thus making it an artificial setting. There is a risk that teachers' awareness of the artificial setting may lead to altered behaviors, practices, and even perceptions about own practice. Further, intervention studies often have a short-term focus, which does not necessarily align with an ongoing and evolving process of teacher practice and professional growth.

Second, it is evident that the intervention/PD studies predominantly focus on the *construct* of the intervention/PD rather than on teachers' *actual* practices. Hence, the knowledge we acquire from studying reforms in such contexts primarily stems from studies emphasizing the characteristics of *the construct* rather than addressing the teachers' needs and experiences. This leads to a potential risk that our knowledge base shifts from insights on how teachers implement curriculum revisions to insights about how they interact with the construct. There are also studies in our corpus conducted in non-interventionist contexts. However, these studies seldom emphasize *changes* in teacher practices but focus on teacher *perceptions* or *perspectives* regarding curriculum revisions. While teacher beliefs are important, they cannot

stand alone; real life teacher practices are equally important. Yet, it appears that these are underrepresented in educational research on competency-oriented curriculum reforms.

Taking the points mentioned above into account, we risk overlooking that curriculum revisions *are* in fact interventions into science teachers' everyday practices. We would argue that conducting research on *changes* in teachers' practices in the light of these revisions is valuable. This kind of research allows us to discuss our possibilities (and limitations) of modifying science teaching in a school context, aligning it with knowledge generated outside the school environment.

Curriculum reforms happen in all disciplines accompanied by a variety of pedagogical approaches. It is worthwhile reflecting on whether the findings of this review pertain specifically to competency-oriented curriculum reforms in science education. To recall, competency-oriented curriculum revisions in science education emphasize scientific literacy, encompassing the understanding of scientific concepts, engagement with scientific methods, and application of principles to real-world problems. These revisions prioritize 21st-century skills, fostering inquiry-based learning where students are encouraged to design experiments, collect data, and draw conclusions through hands-on activities. Critical thinking and problem-solving are central, and student-centered approaches are emphasized, placing students at the center of their learning process.

A core component of competency-oriented curriculum revisions in science education is its multidisciplinary nature, often combining disciplines to provide broader contexts. This approach is crucial for creating alignment between teaching in school settings and the requirements of industry (OECD, 2019). As shown in this review, this approach challenges the organization of schools and the structuring of knowledge forms: it disrupts traditional mono-disciplinary institutional organizations, where disciplines are confined to their own schedule blocks, and assessment formats that are not aligned with curricular ambitions. In addition, it challenges the way knowledge is structured and delivered: teacher training is focused on single-subject expertise and not in the art of bringing together a coherent approach to multidisciplinary problems (Kitchen et al, 2018; Quigley et al., 2017; NRC, 2013).

The results of our paper point to two central questions to consider when implementing a competency-oriented curriculum revision in science education: I) What specific support do teachers need to effectively implement curriculum changes, including the kind of knowledge

needed, and how to allocate time, resources and organizational support? And II) to what extent does the current organization of the educational system support (or hinder) teachers in complying with the requirements of a competency-oriented science curriculum? Are there competing agendas and/or priorities that teachers struggle to navigate, such as examination systems, that leave teachers in a position where they are forced to prioritize one over the other? While this review offers some answers to how PD could be designed that can be used to address some of the needs, unanswered questions still remain. For instance, the issue of how we determine the contents of PD programs aimed at supporting curriculum implementations, e.g. a set of principles to meet the demands of curriculum changes.

Conclusion

This paper has investigated how the implications of competency-oriented curriculum revisions for science teachers' practices have been studied, and the factors that affect their implementation of such curricula. To address these questions, we conducted a qualitative systematic review of 41 research articles. Our study found an overweight of case studies, and that only very few studies consider qualitative changes of science teacher' practices after curriculum revisions. More often, studies focus on how teachers perceive how their practices have changed after the curriculum revision or their perception of the curriculum changes in themselves. Moreover, there is a tendency that the effects of curriculum revisions on science teachers' practices are studied in the context of PD and /or intervention setting.

Our study also found hindering factors for science teachers' implementation of competency-oriented curriculum revisions at the system level and the teacher level. At the teacher level, teachers' knowledge and beliefs can hinder implementation of curriculum revision. At the system level, lack of allocated time and resources as well as a mono-disciplinary and content-specific organization of science education appeared to hinder the implementation of competency-oriented curriculum revisions. The favorable conditions that support implementation of competency-oriented curriculum revisions concern that PD should be organized to build on teachers' existing practices, involve coaching/sparring and be based on active learning pedagogy. Moreover, schools should provide administrative, collegial and organizational support to aid science teachers' curriculum implementations. If these factors are met, it is possible to increase science teachers' knowledge and confidence that can help ensuring curriculum implementation. Our study has highlighted that curriculum revisions in themselves do not lead to changes in the classroom. Rather, changes rely on competent

teachers to enact ideas expressed in the curriculum. Efforts in adjusting and developing science curricula should thereby be accompanied by carefully thought-out support strategies to prepare teachers in enacting the ideas. Our study also highlights that we should acknowledge that curriculum revisions in science education are not implemented in a vacuum – teachers have established practices and experiences that should be activated, not neglected, when new ideas are introduced. Our study showed that systemic changes are needed to accompany competency-oriented curriculum changes if they are to be implemented. If curricula are changed, so should national assessments, so that teachers are not asked to choose between complying with curricula or preparing their students to do well in high-stake tests. In this paper, we have considered the science teachers as a unified population and not distinguished between teachers of primary or secondary school. Future work could consider whether different teachers work under different systemic conditions, e.g. whether they are specialized in teaching few subjects or are involved in teaching many subjects, and whether this result in specific challenges and opportunities for curriculum implementation.

Lastly, it seems timely and needed that we acknowledge curriculum revisions in themselves as interventions in science teachers' work lives, and that we still have insufficient empirical knowledge on how teachers navigate such changes, what they find difficult, and how we can support them. We believe that an obvious direction for future research would be to address this matter in a more targeted manner.

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Paper 2

Mind the Gap: Understanding Danish Science Teachers' Agency in Implementing Competence-oriented Curriculum Reforms

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Abstract

The dynamic landscape of science education necessitates ongoing curriculum adaptation to meet the demands of a complex world. This paper examines a group of Danish science teachers' work with implementing competence-oriented, multidisciplinary teaching following a recent curriculum reform. Through observations of teacher group planning sessions and reflective talk-in-interactions, the study explores how eighteen lower secondary teachers navigate new curriculum requirements and construct agency amidst the reform. The findings reveal that the teachers construct agency by primarily drawing on their past professional experiences and existing patterns of thought and action. This practice often fails to align with the new curriculum's intentions due to individual capacity constraints and contextual influences. While the teachers demonstrate some understanding of the reform's requirements, they lack the capacity to fully comply, leading to actions that do not meet the curriculum's objectives. Emphasizing the concept of agency as an achievement rather than solely an individual capacity, this study underscores the importance of addressing cultural and structural factors alongside enhancing teachers' capacities to promote meaningful curriculum implementation. Further, the findings highlight the need for a balanced approach to curriculum implementations that values teachers' experiential knowledge and considers the complex interplay between individual agency and contexts. Overall, this study contributes to the discourse on teacher agency and curriculum changes, advocating for nuanced, context-specific research to inform future educational policies and practices.

Key words: Curriculum revisions; science education; competencies; teacher practice; teacher agency

Introduction

Recent shifts in science education globally reflect a move towards competence-oriented curricula, prioritizing application of knowledge over content acquisition (OECD, 2017; Crujeiras & Jiménez-Aleixandre, 2013). This change aims to prepare students for complex 21st-century challenges by equipping them with the skills, knowledge, and attitudes necessary for success in diverse contexts (OECD, 2017). However, despite these curricular revisions, many teachers find it difficult to align their practices with these competence-focused demands, creating a gap between intended curriculum changes and actual curriculum enactment (Crujeiras & Jiménez-Aleixandre 2013; Nielsen & Dolin 2016). While previous studies have explored teachers' perspectives on curriculum changes (Haglund & Hultén, 2017; Arias et al., 2016; Rinehart et al., 2022), further research into teachers' real-life curriculum enactment within authentic environments seems crucial. To better understand the practices of teachers in the context of a curriculum reform and consequently to guide future reform implementations, this study investigates how Danish science teachers work with implementing a competence-oriented curriculum and exercise agency in their professional context (Priestley et al., 2015).

Background for this Study

The Danish Folkeskole (encompassing both primary and lower secondary education) underwent a significant reform in the academic year 2015/2016. Similar to other countries, the previous curriculum in Denmark heavily emphasized students' learning of scientific content knowledge, segregating skills and content knowledge into distinct domains. The main objective now is to prepare students for further education, future life, and cultivate their desire to learn more.

The Danish Ministry of Education developed curricula and teacher guides for each discipline and topic to clarify the framework for instruction and to support teachers' curriculum enactment (UVM, 2019a; UVM, 2019b). The national framework for teaching is framed in

the national standards, “Fælles Mål” (UVM, 2019c). Four cross-cutting competence areas are formulated for the science disciplines: Investigation, modelling, communication, and contextualization (UVM, 2020). These are a central aspect of the reform and are key in the science disciplines. In continuation of the competence areas are mandatory competence goals for what students should be able to do at different levels within each competence area. Thus, the learning goals in the new curriculum overall specify what the students should be able to *do* (as opposed to what the students should *know*, as emphasized in the previous curricula) (UVM, 2020).

Multidisciplinary, Competence-oriented Teaching Units

For the science disciplines in the Danish lower secondary school (the last three years of *Folkeskole*, grades 7-9, students typically between the ages of 13-16), a mandatory number of multidisciplinary teaching units were introduced as a central tool for the science teachers to work with competence-oriented science teaching, in order to actively contribute to the realization of the fundamental objectives of the Danish lower secondary school (UVM, 2021). Science teachers must work with the four areas of competence *within* each discipline and in the *interaction between* them, i.e. in these newly introduced multidisciplinary teaching units.

The primary aim of multidisciplinary science teaching is to afford students’ opportunities for immersion and comprehension of interconnections within science, enabling them to form informed opinions and make decisions in complex, real-life situations. It is stipulated that in the multidisciplinary units, students must engage in problem-based learning with the aim of enhancing their perception of nature and the working methods in science, as well as supporting their motivation for each discipline (UVM, 2019b). Teachers are expected to activate different science disciplines in an integrated manner, and the regulations emphasize that working with the disciplines in separate silos in the multidisciplinary teaching does not

comply with the intentions, since it is impossible for the students to make it multidisciplinary on their own. The prevalence of the multidisciplinary teaching units is underlined by the fact that the organization of the newly introduced exam format is centered around the focus areas and the accompanying problems that the students have worked with, in order to assess the students' level of competence, as the students must, in an integrated manner, demonstrate competencies within all four competence areas (UVM, 2022).

Against this backdrop of significant changes, this paper explores the characteristics inherent in the planning of, and discussions about, competence-oriented multidisciplinary teaching units among a group of Danish science teachers in the context of competence-oriented reform changes. The paper seeks to answer the following research question:

What characterizes Danish science teachers' construction of agency in their planning of and discussions about multidisciplinary teaching units in the context of adopting the new competence-oriented reform?

Based on my findings related to this question, I will engage in a discussion about how the teachers' construction of agency aligns with the stipulated curriculum requirements.

State of the Art

Previous research has identified various obstacles to the implementation of competence-oriented science curricula, including teachers' lack of well-suited pedagogical skills (Schneider et al., 2005), knowledge (Diehl, 2016; Archer-Bradshaw, 2017), and lack of time and resources (Farirah et al., 2021; García Carrillo et al., 2021; Braskén & Pörn, 2021). Organizational structures also struggle to align with these changes, evidenced by inadequate assessment formats (Ling et al., 2021; Zhan et al. 2021), and top-down approaches to implementation that fail to accommodate the perspectives and needs of teachers (Haney, 1996). Moreover, previous research has found that a barrier to competence-oriented teaching lies within the fact that a mono-disciplinary organization of teaching often counterworks the

multidisciplinary ideals associated with competence-oriented reform goals (Nsengimana et al. 2023; Dare et al., 2018).

Examining the role of science teachers in the implementation of curriculum reforms, previous research emphasizes science teachers as key players in successfully integrating changes: Numerous studies have delved into teachers' *perspectives on* and *perceptions* of revisions to the science curriculum (e.g. Haglund & Hultén (2017); Arias et al. (2016); Rinehart et al. (2022); Smith et al. (2018)). Indeed, as emphasized by Tidemand and Tamborg (n.d.), a singular focus on teacher practice is insufficient; research into and understanding real-life teacher curriculum enactment - which includes teachers' planning, instruction, assessment, and their adaptation to curriculum requirements in authentic educational settings (Remillard & Heck, 2014) - is crucial. However, comprehensive studies into teacher curriculum enactment within the context of curriculum revisions appear to be underrepresented. Previous studies often have a distinct focus on *either* the individual teacher *or* the external contextual factors impacting curriculum enactment. What appears to be missing are contextualized studies investigating teacher curriculum enactment within a natural setting, while *also* paying attention to the (organizational) context in which they navigate. This approach extends beyond understanding teachers' knowledge and capabilities to exploring their implementation in their given environment.

Addressing the gap between the two areas of research seems crucial for a comprehensive understanding of the challenges and facilitators teachers encounter when navigating curriculum reforms. This necessitates studies that investigate teacher curriculum enactment within a natural setting, considering teachers' practices and perceived difficulties against the organizational context in which they navigate. To address this gap, this study investigates Danish science teachers' implementation of a competence-oriented curriculum change from an agency perspective (Priestley et al. 2015). Priestley et al.'s (2015) framework for teacher

agency can serve as both a theoretical and methodological framework for examining how teachers exercise agency within their professional contexts. Thus, it allows analyses of how and to what extent teachers are able to achieve agency amid reforms through an interplay between their individual capacity and the organizational context. The following sections will outline the methodological framework applied in this study.

Method and Research Design

This paper is part of a wider study that examines 18 Danish lower secondary school science teachers' curriculum enactment in the context of adopting a recent educational reform. Specifically, I present findings derived from the analyses of teacher group planning sessions and teacher group talk-in-interactions. The teachers came from three schools in a municipality located in the Capital Region of Denmark and were selected due to a commitment at the managerial level to focus on the implications of the recent reform. Thus, the study reflects the work of all science teachers in one municipality in the Capital Region of Denmark. Below, I describe the schools from which the teachers were recruited, as well as how and in what context the data was collected.

The Schools

The three schools and consequently three participating teams, represent various organizational approaches to handling the curriculum changes mandated by the reform. This diversity in their approach was a key criterion for their selection, as it allows for a more comprehensive understanding of how different schools implement the same policy under varying conditions and contexts:

School A: The team had previously dedicated time to organizing the multidisciplinary teaching units and received managerial approval for specialized days to comply with curriculum changes. The team was allocated time to facilitate these days and engaged in discussions regarding the newly introduced oral exam format, making efforts to comprehend and prepare for its requirements. The teachers reported that they had previously organized

sessions to discuss their teaching, to assess what worked and what needed to be improved. Despite managerial efforts to organize collaboration and provide resources to meet the demands of the new curriculum, the teachers expressed a lack of coordination and sharing of knowledge.

School B: Limited collaborative experience, with no uniform enthusiasm for collaboration. The school administration had not allocated dedicated time for the coordination of multidisciplinary teaching, and, overall, the teachers felt unsupported. In previous years, they had opportunities for science teaching units with the presence of two teachers, facilitating mutual insights into each other's teaching practices. However, such collaborative initiatives had been discontinued in the academic year that the study took place in.

School C: As a new initiative, this team was granted the opportunity to structure their multidisciplinary teaching as in School A. They expressed strong motivation for collaboration but described their current situation under new reform as an "organizational nightmare".

The participating teachers exhibited a wide range of teaching experience (from three to over 20 years) and each taught one to two science disciplines. They were fully briefed on the study's purpose and procedures, time frame, anonymity protocols, as well as their right to withdraw; and all participants were assured of confidentiality.

Data Sources

To elucidate the research question, I conducted observations in the teachers' (Creswell, 2012) planning sessions, and collected data from group discussions about their curriculum enactment in the context of implementing reform changes. The data was collected over the course of one school year, and consists of three planning sessions on School A, two planning sessions on School B, and three planning sessions on School C, yielding eight hours of recorded data in total. The total amount of planning time observed was the same for each school, though the number of data points vary. For practical reasons, School B engaged in

longer planning sessions than the two other schools. The talk-in-interactions (45 minutes each) were carried out in five groups. I collected these two types of data in order to get a rich insight into their practice, by observations of their *actual* planning practices, as well as their reflections and discussions *about* challenges and affordances related to enacting the revised curriculum.

Teacher Group Planning Sessions

The data from the planning sessions were gathered from a range of team meetings at each school, where the teachers cover all three scientific disciplines (biology, geography and physics/chemistry). During the planning sessions, I carried out direct observations of the teachers' planning sessions as a nonparticipant observer (Creswell, 2012). These sessions occurred within the teachers' classrooms or designated planning areas. I employed a multi-faceted data collection approach during the sessions: Field notes were taken to capture the teachers' actions, discussions, and any contextual factors that might influence the planning process (Creswell, 2012; Bryman, 2016). Audio recordings of the planning sessions were made using a recording device (Creswell, 2012). All participants were informed about the recording process, and their consent was obtained prior to initiating recordings.

Teacher Group Talk-in-interactions

This segment of the data collection employed a collaborative and participatory approach in focus groups (Hennink, 2013), focusing on teachers' talk-in-interactions about their own thoughts about their approaches in the context of curriculum revisions and their planning strategies in general. I organized group sessions, where the teachers engaged in reflective conversations about their curriculum enactment. I intentionally remained absent during these sessions, allowing a more natural and uninhibited discourse among teachers (Creswell, 2012). These sessions involved five groups with teachers mixed from the participating schools, to facilitate a reflective and generative dialogue, drawing on the teachers’ diverse experiences

and perspectives, and to ensure that teachers felt free to speak openly about their practice, without being constrained by the presence of close colleagues (Hennink et al., 2020; Bryman, 2016). Regarding the format, I assumed that talk-in-interactions could yield richer information than interview sessions. Moreover, a focus group setup is well-suited for exploring and emphasizing teachers' shared views and understandings (Hennink et al., 2020; Kvale, 2006). The teachers were provided with questions on paper to prompt their talk-in-interactions:

i) *How are the competences from the curriculum integrated into your teaching (both your individual disciplinary teaching and the multidisciplinary teaching)? Feel free to use specific examples from your teaching and discuss them with your peers.*

ii) *How confident do you feel about teaching in a competence-oriented manner in general? Where would you describe it as going well, and what is a challenge, according to your own thoughts about your practice?*

Theoretical Framework

Teacher Agency

To address the research question, I draw on the concept of teacher agency, using Priestley et al.'s (2015) framework to examine how Danish science teachers navigate curriculum changes. This framework views agency as the interplay of habit, imagination, and judgment. Agency, in this sense, is not simply acting *within* an environment, but the potential to act *by means of it*, influenced by individual efforts, resources, and cultural and structural factors (Biesta and Tedder, 2007; Leïjen et al., 2020).

Drawing on the temporal-relational perspective of agency (Emirbayer and Mische, (1998); Biesta and Tedder, (2007)), Priestley et al. (2015) present an ecological model of understanding the achievement of agency. The model comprises three dimensions: the

iterational, the practical-evaluative, and the projective, and it is through the interplay between these, agency is achieved.

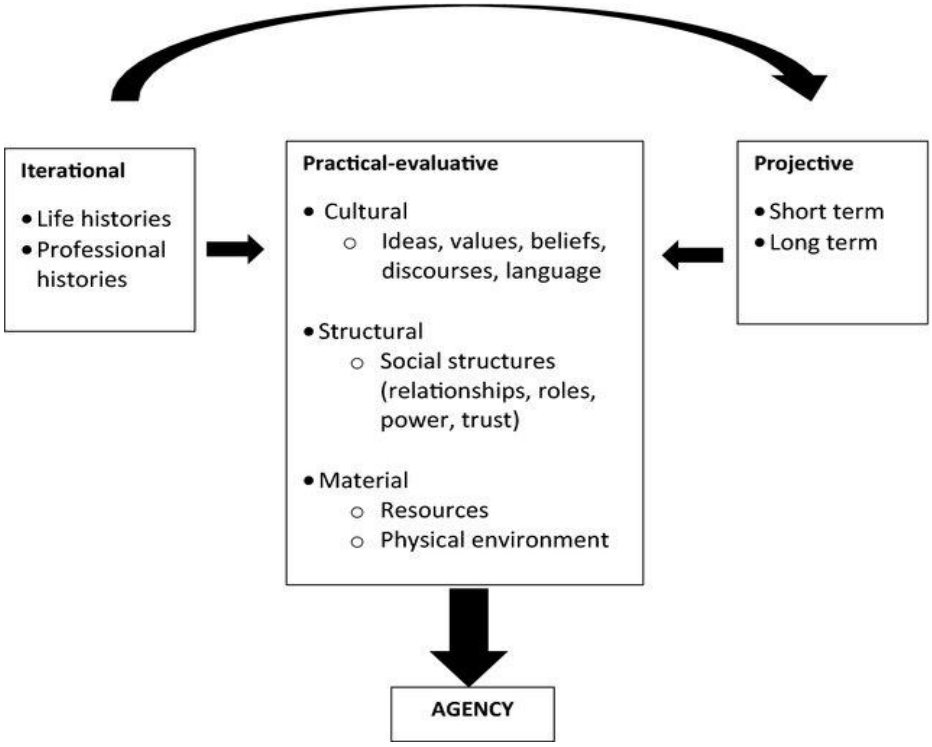

Figure 1 Teacher Agency (adopted from Priestley et al., 2015)

In the iterational dimension of the model, Priestley et al. (2015) differentiate between the influence of the teachers' general life histories and their professional histories. Thus, while the authors do not frame teacher agency as a personal capacity, they acknowledge that personal capacity is crucial for its emergence. Iterational aspects include personal capacity (skills and knowledge), beliefs (professional and personal), and values – all rooted in past experiences. In addition, the individual teacher's professional education, previous experiences in schools, past interactions with peers, exposure to school culture, as well as participation in professional development activities all contribute to the iterational dimension of agency (Priestley et al., 2015).

The practical-evaluative dimension forms the teacher's decisions in the present-day. It involves the teacher's capacities to assess and choose among alternatives while navigating cultural, structural, and material conditions that may act as enablers, constraints, or resources.

Cultural factors encompass teacher beliefs, the language and discourse they use to express these beliefs, their intentions, expectations, and goals within the given school context (Priestley et al., 2015; Poulton, 2020). Structural factors pertain to social and professional relationships, as well as the dynamics of roles, power, and trust (Priestley et al. 2015). According to Priestley et al. (2015), strong relational conditions, particularly within a collaborative school culture, are essential for fostering teacher agency. Material factors involve physical resources that promote or hinder agency, and the wider physical environment (Priestley et al. 2015). The projective dimension encompasses teachers' short- and long-term aspirations for their professional work, which guide their actions and plans for the future (Priestley et al. 2015). These aspirations can range from positive goals, such as improving student outcomes, to more cautious or restricted goals, such as maintaining existing practices that diverge from current policies to ensure stability or comfort (Osborn et al. 1997). Regardless the form of the aspiration, Priestley et al. (2015) suggest that they are largely rooted in teachers' prior experiences.

Thus, according to Priestley et al. (2015), the ecological model of agency is both relational, emphasizing how humans operate *by means* of their social and material contexts, and temporal, as it *draws on* past experiences, is *directed toward* future goals, and is *situated within* the contingencies of the present (Priestley et al., 2015). The model underscores that agency is always exercised within a specific context; shaped and influenced by the discursive, material, physical, and relational resources accessible to teachers (Priestley et al., 2015). This perspective is relevant in the context of this study, because a singular focus on teacher practice is insufficient; research into and understanding real-life teacher curriculum enactment is needed.

Approach to Analysis

The data consisted of verbatim transcriptions of 11 hours and 45 minutes of audio recordings. To begin the analysis, I analyzed the data in two steps utilizing Priestley et al.'s (2015) conceptualization of agency: First, I conducted an initial search in the transcribed data for instances to identify instances where the teachers talk about issues related to the multidisciplinary teaching units they must conduct, instances where they talk about scientific competencies, or issues related to curriculum reform implementation. Second, I explored the configuration of agency in each case, by identifying which of the three dimensions of agency the teachers activated during these instances.

Following the initial coding, I conducted a cross-case thematic analysis based on the configurations of agency to compare the data across the three schools (Braun & Clarke, 2006). This approach allowed me to identify recurring patterns that spanned across all three schools while also accounting for context-specific variations. Themes that emerged were synthesized to reflect broader aspects across all sites rather than isolated examples. Instances from one school were cross-referenced with similar examples from other schools to ensure the robustness of the themes. The findings follow a structure in which I first describe the themes and the schools the themes spanned across, provide descriptions of specific illustrative examples or situations and subsequently argue why and how the specific example can be seen as the teachers' pursuit of constructing agency. The empirical situations selected to illustrate key points within each theme were chosen to be as rich and nuanced as possible. The examples represent typical cases that encapsulate broader trends within the data. Although they do not encompass the entirety of the data set, they offer aggregated insights that reflect recurring patterns across the schools. By presenting such detailed and representative examples, the aim was to provide a comprehensive understanding of the

teachers' practices and how this contributed to their pursuit of agency within the context of multidisciplinary teaching, scientific competencies, and curriculum reform implementation.

Results

Characterizing Danish Science Teachers' Agency in their Planning of and Discussions about Multidisciplinary Teaching Units in the Context of Adopting the Competence-Oriented Reform

The following sections report how the teachers' agency unfolds in relation to their work with implementing the competence-oriented curriculum. The findings specifically address the characteristics of the teachers' agency in relation to their i) planning for and ii) discussions about their work with implementing curriculum requirements, focusing on the organization and contents of the competence-oriented multidisciplinary teaching units as well as curriculum requirements in general.

Theme 1: Agentic Enactments of Competence-Oriented, Multidisciplinary Science Teaching

In this section, I will illustrate the following thematic finding that spanned across all three schools: The teachers planned their teaching units under the label of multidisciplinary science teaching, yet treated the three scientific disciplines as isolated entities. Although their planning sessions showed initial alignment with the curriculum's focus on interdisciplinary themes, the actual organization of content reflected discipline-specific silos rather than integrated units. Following the terminology of the framework of teacher agency (Priestley et al. 2015), I found that the teachers operated in the process of constructing agency – i.e. heavily *anchored* in the iterational dimension, *influenced* by the context – the revised curriculum – that seemed to guide their planning practice, but in a manner that does not comply with the intentions in the curriculum.

In an illustrative example from School C, six science teachers collaborated in a planning session to structure their multidisciplinary teaching units. During the session, the teachers gathered around a table, and initially reached a consensus on the headings for the units.

Leading the discussion, Sebastian, one of the teachers, read aloud the mutually agreed-upon titles: “Sustainable Energy Supplies at a Local and Global Level”, “Production with a Sustainable use of Natural Resources”, “The Impact of Radiation on the Living Conditions of Living Organisms” and “The Importance of Technology for People’s Health and Living Conditions”. The teachers collectively decided that these would serve as the overall themes for the multidisciplinary units, and they decided to create posters with headlines to be displayed in the classrooms.

Subsequently, the teachers discussed the scientific content to be covered in these units, and how each discipline would contribute to addressing the unit’s title. For instance, Sebastian suggested for biology: “osmosis - we can talk about osmosis and biological purification”, Marianne, suggested incorporating “something about cell biology” in her biology classes, and Daniel, a physics/chemistry teacher, suggested “yes, and in my class, we can go outside into the woods, talk about lake eutrophication and we will conduct a chemical analysis”. He later added “in a topic like this, it will be my duty as a physics/chemistry teacher, when I talk about atomic physics here, to also talk about the consequences”. Michael, the geography teacher, contributed by expressing his intention to cover topics related to climate and climate changes in his classes.

This illustrative example from School C mirrors similar approaches to planning the multidisciplinary units at School A and B, where there were also examples of planning an overall theme, e.g., at School A with the theme “the Water Circle” and teachers proposing, discussing and allocating contents as “photosynthesis” (biology), “water as a molecule and the various state forms” (physics/chemistry), and “fresh water and the oceans” (geography), reflecting that all teams exhibit the practice of what I refer to as discipline-specific silos.

These examples illustrate how this group of teachers structure the units: a discussion of title (focus areas outlined by the Ministry of Education (UVM, 2019c)) and contents in the

multidisciplinary units but separated into isolated discipline-specific silos. In the examples, the teachers construct agency by activating both the iterational and the projective dimensions. Teacher aspirations are predominantly rooted in prior experiences (Priestley et al., 2015). It is evident from the planning sessions that the teachers' aspirations are directed towards what they refer to as multidisciplinary: their interpretation of multidisciplinarity is a collection of individually isolated disciplines. The teachers activate the projective dimension when constructing their agency, as they try to align with the intentions in the curriculum by determining the focus areas (initially outlined by the Ministry of Education, their aspirations seem to mirror the curriculum's intentions). However, they lack predispositions to meet the expected outcomes of the curricular intentions. Instead, they activate the iterational dimension – shaped by their prior experiences and beliefs deeply rooted in a curriculum emphasizing scientific content knowledge and isolation of disciplines. This activation has a decisive impact on the practical-evaluative dimension of their agency, where they plan for multidisciplinarity based on their prior experiences and allot scientific content knowledge related to the theme into separate silos.

Theme 2: Agentic Enactments of Competence-Oriented, Multidisciplinary Science Teaching in a Collaborative Organizational Context

This theme pertains to findings from School A, where it was evident that the organizational and social context within schools, such as collaborative efforts, do not necessarily enhance teachers' capacity to align with the curriculum requirements. To recall, School A is a case where collaboration was (and had previously been) supported, but where teachers' heavy reliance on prior experiences limited their ability to achieve the intended interdisciplinary integration: The otherwise favorable organizational context turned out insufficient to compensate for the teachers' lack of ability to achieve agency, and ultimately lead to a similar

outcome as in the examples above, since the iterational dimension was yet determining for their agency.

During a planning session in School A, as the teachers discussed the organization of their teaching, the specialized days initially devoted to deviating from conventional science teaching structures were organized in a manner that counteracts the intention. The organization that the teachers planned for was as follows: Students from all classes convene in plenary for a brief introduction to the unit's theme. This introduction includes a short presentation or movie to serve as an appetizer/motivation for the theme. Subsequently, the teachers depart to take charge of scientific "workshops" held in isolated rooms. Students then rotate between the rooms during the day, with each workshop shedding light on the multidisciplinary unit from the perspectives of different scientific disciplines, either via teacher presentations, student group work related to the theme and/or experiments.

In a collaborative planning session, the teachers engaged in a discussion about their upcoming multidisciplinary unit titled "Drinking Water for Generations". During their discussion, the physics/chemistry teachers agreed that they would cover the various forms of water. The geography teacher added that in his teaching, he intended to cover "(...) threats to the water supply and knowledge about the political consequences of a water shortage" as well as "general knowledge about water's cycle and how we can harness water resources". Following this, another teacher suggested that coverage of the water cycle could be expanded beyond geography alone, but in the same line suggested that it stays isolated in geography in practice: "(...) in principle, it is possible that the water's cycle can be covered by more disciplines than geography in isolation, but wouldn't it be fine if you just cover water's cycle", to which the geography teacher reassured "yes. Damn good." The other teacher then replied, "and it is not, because, I mean, we can accommodate to it, but/" and the geography teacher answered "no, it's fine, I will do it". Subsequently, a biology teacher outlined her

plan to cover legal aspects related to fertilizers and pesticides on a local and global level, in addition to exploring the dynamics between organic versus conventional farming.

The analysis of this instance reveals the same pattern as for the other schools in this study: teachers directing their discussions towards the projective dimension; the multidisciplinary teaching units as themes outlined in the new curriculum. However, it becomes apparent that they do not possess a capacity to organize their teaching in a manner that complies with the intentions. To recall, this group of teachers (School A) received managerial approval to conduct specialized days focused on deviating from conventional science teaching structures to exclusively address multidisciplinary teaching to comply with curriculum requirements. However, their construction of agency is heavily shaped by their past experiences in the iterational dimension - exemplified by means of the previous curriculum and past ways of organization - characterized by a clear segregation of disciplines, and a heavy emphasis on scientific content-specific knowledge.

Theme 3: Agentic Enactments of Competence-Oriented, Multidisciplinary Science Teaching: Teacher Awareness of Non-Compliance

Pertaining to all three schools, this theme reflects an additional aspect to the characteristics of this group of teachers' construction of agency: at several instances, both during the planning sessions and during the talk-in-interactions, the teachers expressed an awareness that they do not comply with the regulations. Following the terminology of the teacher agency framework (Priestley et al., 2015), it was evident that despite their aspirations in some instances to align with the projective dimension (the new curriculum's objectives), they did not possess the capacity to realize these aspirations in the practical-evaluative dimension, and their experiences from the iterational dimension appeared redundant.

Awareness of the misalignment in organizing multidisciplinary teaching was evident in an illustrative example from a planning session at School C, where discussions about themes and posters took place. Biology teacher, Sebastian, noted "we will have two units in 8th grade and

two units in 9th grade; the Ministry claims that we ought to do so". He activated the projective dimension by drawing on the short-term aspirations for the future, put forward in the curriculum. Immediately after, another biology teacher, Marianne, questioned whether students would "(...) only be presented with the headlines of the posters?", whereafter Sebastian confirmed this, but emphasized the need to keep reminding the students of the themes throughout the school year. Marianne then proposed to plan to take one of the posters and teach in unison based on the given poster – again, an activation of the projective dimension, exemplified by referring to curricular requirements - but Sebastian rejected the proposal in agreement with other members of the team, and a third teacher agreed, stating "no, that is too difficult, right?". Thus, the potential construction of agency by the activation of future aspirations in this situation seems to be hindered by the teachers' solid anchoring in the iterational dimension related to their professional beliefs about their (lack of) capacities. In another planning session, they discussed the new oral exam format and how their single-discipline teaching roles limited their abilities to comply with the curriculum and develop students' scientific competences. Initially, they activated the projective dimension of their agency, as they directed their discussion towards future aspirations, i.e. the intentions in the curriculum and the oral exam format, by discussing the exam format. They expressed strong beliefs about what is important in this context emphasizing student autonomy and motivation, by for example discussing "what I like about this format is that it is *their* exam" and "(...) it is the students who decide what the presentation is centered around, they bring forward what they think is interesting, which is motivating(...), they lead the discussion to where they feel strongest" and "(...)the premise for the exam has sort of changed they have to problematize the issues, demonstrate competencies(...) and this is also why this exam format is better for the students, it is better because it is not about rote learning". Right after this appraisal of the format, the biology teacher, Lena, drew on the iterational dimension of teacher agency - her

professional knowledge about what this would require from the teachers, by expressing concern: “but how do we make sure that they bring something that is good enough?”. Sebastian, still drawing on the projective dimension, suggested that they ought to act as student supervisors before the exam, but Lena remained worried, stating “(...)it places greater demands on us as teachers (...) there are some disciplinary borders, and now that we talked about radiation, I have absolutely no idea about that”. They discussed this a bit further and agreed that teachers do not possess enough knowledge in all science disciplines to accommodate the requirements in the curriculum: “(...)but that is the thing here. We do not possess enough knowledge (...) we can also end up in situations where we do not know what the students are referring to during the exams or know how to guide them in the right direction in dialogues”. During this discussion, one of the teachers stated that the way they organize their teaching focusing on isolated disciplinary science knowledge is not in alignment with the requirements in the exam format “(...)actually, we are doing the students a disservice”. Despite the concerns, when the sessions concluded, the solution to the challenges remained unresolved.

During the teacher talk-in-interactions on their work with implementing the revised curriculum, it became evident that the teachers are aware that their current practices do not comply with the regulations. This awareness is exemplified in a sequence, where one of the teachers remarked “(...)we are holding the students hostages. We are running our own race in each discipline, and in the end, it is up to the students to link it all together. Of course, we sometimes talk about it explicitly, but somehow, we kind of throw them in the pool without bathing wings, right? And then we tell them “well, but you do possess a lot of geographical knowledge, you know a lot about chemistry, but now you just have to connect the dots (...)””. Another group of teachers discussed their lack of capacity (skills and knowledge) related to the new curriculum: “overall, I can say that when I just try to recall the four competencies, I

can’t even remember them. I mean, that says a lot about where we are, and/or where I am personally. I would say that the way these competencies are a part of my teaching seems like a dark cloud above my head (...) things are not going well here. We actually do not attend to them, we don’t know how to, so when we do what we refer to as multidisciplinary, we actually run it as discipline-specific" another teacher adds that this awareness makes her nervous: “It makes me nervous, I mean, the thought of if I had to explain where my students have applied the competencies, that really makes me nervous”. Another group also discussed their lack of professional skills and knowledge, adding that their prior knowledge seems redundant in the requirements of the new curriculum, exemplified by the fact that they struggle to connect “old habits” (iterative) and “new practices” (projective) explicit: “actually, I do a lot of experiments with my students, but I’m still stuck in the old way of teaching it, where they get handed a set of instructions (...) I find it insanely difficult to have them do something where they have to come up with an experiment themselves that demonstrates something, so it ends up being very teacher-administered in terms of how they should carry out the experiment.”. Another group member confirmed this and referred to similar experiences: “I experience the exact same (...) I have grappled and tried to find a middle ground, where I say there must be some reflection beforehand (...) I have made this standard form that always accompanies a cookbook experiment, where they write down their thoughts beforehand (...) I’m trying to get a bit more reflection into these cookbook experiments, but going from there to fully aligning with the intentions, I don’t know, how to manage.”

The examples above introduce an additional dimension to the teachers’ agentic enactments in the context of the present curriculum revision. So far, we have observed how the teachers construct agency by navigating in a manner that is heavily anchored in the iterational dimension, *influenced by* the context that guides their curriculum enactment, but which is *not*

in accordance with the new requirements. In addition, as this theme reflects, the teachers activate the projective dimension in their process of constructing agency, as they exhibit an understanding of the curriculum revisions that is sufficient to make them aware of their inabilities to accommodate to the curricular changes and their non-compliance with the intentions. This awareness pertains to both their personal capacities, the organization of teaching and to the reliance on students to connect the overall picture. In general, the teachers are aware of their own inadequacy in their current enactment but lack capacity that they can activate to be able to comply with the new curriculum.

Discussion

The results from this study demonstrate how a group of Danish science teachers navigates curriculum changes. While influenced by the context - both the new curriculum as context for the planning sessions and the organizational framework conditions - their navigation in these contexts results in practices that do not align with the curriculum's intentions. Specifically, the introduction of the multidisciplinary teaching units is central for the work with competence-oriented science teaching. As stipulated in the regulations, it is imperative that the actual work within the focus areas is concretized through problem-based teaching. According to the curriculum, the teachers must ensure that students work with the science disciplines in an integrated manner, and working with the disciplines in separate silos does not comply with the intentions in the curriculum. It seems that they do not possess capacities to fully comply with the intentions in the curriculum, resulting in a construction of agency primarily shaped by the iterational dimension, thereby limiting their agency. While curriculum changes can serve as a means to update classroom instruction to reflect scientific advancements in society (OECD, 2017), this study shows that there is a risk of neglecting the teachers' valuable experiences, when altering the legal requirements. Striking a balance between embracing new requirements and honoring teachers' expertise seems crucial to

avoid undermining teachers' expertise and unintentionally de-professionalizing their role in the classroom.

Previous studies attribute teachers' non-compliance with curriculum changes to uncertainties in implementation (e.g. Chadwick et al., 2023; Sherwood et al., 2020) and lack of comprehension of the new curriculum (e.g. Diehl, 2016; Archer-Bradshaw, 2017). However, this study showcases an additional facet of these challenges: an awareness of their non-compliance. Thus, curriculum revisions can potentially challenge teachers' professional ethos, placing them in dilemmas where they must choose between i) adhering to established practices, where they, as seen in this study, may become aware that they do not align with the intentions in the revised curriculum, or ii) choose to embrace new curriculum requirements by trying to engage in a practice that they do not possess the capacity to properly operationalize. Hence, the internal consistency of the curriculum appears eclectic. Considering the findings from this study, it seems imperative to recognize that teachers' preexisting professional skills are far from redundant, especially considering the continued demand for disciplinary-specific knowledge in the revised curriculum, as is reflected in both the objectives and the assessment format in the Danish context here. Hence, the revised curriculum may, for a range of teachers, be perceived as a supplementary layer to their existing practices, and there seems to be little support available for teachers in developing these supplementary layers to their practice. As evidenced by this study, teachers perceive this situation as challenging.

Existing research tends to focus *either* on the individual teacher (e.g. Haglund and Hultén (2017); Arias et al. (2016); Rinehart et al. (2022)) *or* external contextual factors impacting practices (e.g. Nsengimana et al. 2023; Dare et al., 2018). A literature review conducted by Tidemand and Tamborg (n.d.) illustrates a clear divide between empirical studies that focus on the individual teacher and those that focus on contextual factors in the context of

curriculum revisions. In this study, the participating schools exhibited a considerable diversity in terms of backgrounds and conditions fostering their collaboration in planning multidisciplinary science teaching. While this contextual diversity influences the way they organize their planning approaches, the overall pattern of their agentic enactments remains somewhat consistent.

Priestley et al. (2015) stress that teacher capacity is a necessary but insufficient condition for the achievement of agency. The findings from this study emphasize that it is neither teacher capacity nor the (organizational) context respectively in isolation that determines the character of curriculum implementation, and thus it stresses the shortcomings of such a dichotomy in research and emphasizes the need for more contextualized research. It seems that it is not possible to solve issues related to (lack of) personal capacity through organizational initiatives *or* changes in isolation. Research that focuses on contextual factors in the context of curriculum revisions tends to advocate for robust organizational structures and resources to facilitate curriculum implementation. The findings from this study reveal a potential pitfall: an emphasis on organizational support (e.g. lessons allocated to collaborative planning or multidisciplinary teaching) alone may put the responsibility for translating the curriculum onto the individual teacher. This not only places a burden on teachers but also risks undermining the coherence and fidelity of curriculum implementation. Hence, we do not solve the problem by giving the teachers more time for planning or by organizing their teaching differently. Conversely, research that focuses on the individual teacher often underscores the importance of professional development initiatives (Tidemand & Tamborg, n.d.). While this approach honors teacher autonomy, there is a risk of overseeing the expertise that teachers already possess. In addition, relying solely on professional development initiatives may overlook systemic inequities and organizational barriers that hinder effective curriculum enactment.

Using the framework of teacher agency, this study provides insight into the complexity of enacting a revised curriculum, offering perspectives and a better understanding of teacher practices, and subsequently emphasize implications for future reform implementations. The findings do not advocate for complete teacher autonomy, which, as seen from the results, can lead to a lack of regulation and result in teachers retaining agency by not complying with the curriculum. The use of the teacher agency framework not only identified this, but helped provide an understanding of the reasons for this: their solid anchoring the iterative dimension and their lack of capacity to activate in the practical-evaluative dimension, where the teachers ought to perceive and interpret a particular temporary situation (i.e. the requirements related to multidisciplinary teaching) based on their professional competence described in the iterational dimension and professional purpose described in the projective dimension of agency. Hence, this study highlights the significance of regulation, emphasizing that it should be appropriate, recognizing teachers' professionalism, valuing their existing knowledge and experiences, and enabling them to achieve agency in their work with translating the curriculum into their own practices. This form of regulation could be better characterized as *guidance* to support teachers in embracing educational core principles.

Constructive agency is when teachers can make choices that are based on judgements made in light of an understanding of the purposes of their practice (Priestley et al., 2015). In light of this, moving beyond merely advocating for more professional development, this study suggests a nuanced perspective. While professional development remains crucial, its design must ensure that teachers' experiential knowledge is not neglected. Effective strategies should aim to harmonize the incorporation of new curriculum elements with teachers' existing expertise, as for example seen in Bowers et al. (2020), where professional development incorporated teachers' expertise while guiding student learning fostering a symbiotic relationship between innovation and experience. Implementation strategies should however

also consider how organizational contexts could be designed to support rather than hinder that teachers can activate competencies gained through professional development.

Conclusion

The purpose of this paper was to investigate the characteristics of Danish science teachers' construction of agency in their planning of and discussions about competence-oriented, multidisciplinary teaching. To address this, I conducted a study observing the planning practices and recorded a group of Danish science teachers' talk-in-interactions about their work with implementing a competence-oriented curriculum. Utilizing Priestley et al.'s (2015) framework of teacher agency, I explored how and to what extent they construct agency, considering both their capacities and the context in which they navigate.

In the Danish context, the reform has introduced new demands concerning *what* and *how* science is taught and assessed, placing new demands on teachers' practices, by for example requiring a close collaboration in implementing multidisciplinary teaching units. The teachers constructed agency by drawing heavily on their professional experiences, as they tended to draw on activation of accumulated patterns of thoughts and actions from the past. They were influenced by the context that guided their enactment, but in a manner that was not in accordance with the new requirements. Despite instances where they demonstrated a certain degree of understanding of the intentions and requirements of the new curriculum, and even acknowledge discrepancies between their practices and these intentions, their inabilities to fully comply, due to individual capacity constraints, resulted in actions that do not align with the curriculum's intentions.

It remains crucial to view agency as an achievement, not just a capacity. While capacities are important, they alone are not enough for achieving agency, which is always situational (Priestley et al., 2015). Fostering teacher agency requires addressing cultural and structural factors, not just enhancing education and professional development. Neglecting these aspects

undermines the goal of empowering teachers to act as agents of change in science education and does work to bridge the gap between intended practices outlined in curricula, and actual practices carried out by science teachers. In summary, this study provides insights into the discourse on teacher agency and curriculum changes. It advocates for a balanced approach that respects teachers' experiential knowledge, acknowledges the complex interplay between individual teachers and external factors, and calls for more nuanced, context-specific research to inform future educational policies and practices.

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Paper 3

Despair and Discontinuity: The Challenges of Adhering to a Competence-Oriented Curriculum Reform from a Science Teacher Perspective

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Despair and Discontinuity: The Challenges of Adhering to a Competence-Oriented Curriculum Reform from a Science Teacher Perspective

Abstract

Curriculum revisions play a key role in shaping science education, dictating both content and pedagogical methods (Bybee, 1997). Despite the global shift towards competence-oriented curricula aimed at equipping students with 21st-century skills (OECD, 2017; OECD, 2019), the practical implementation by teachers remains fraught with challenges (Schneider et al., 2005; Archer-Bradshaw, 2017). This study examines Danish science teachers' responses to such a reform, emphasizing their experiences and the contextual obstacles they face. Using the Future Workshop method (Jungk & Müllert, 1984), data was collected to explore 18 Danish lower secondary science teachers' experiences and responses to the curriculum changes. Drawing on the ecological model of teacher agency (Priestley et al., 2015), findings reveal that teachers struggled to align their previous experiences and capacities with the new curriculum's demands. Despite recognizing the disconnect and expressing a willingness to adapt, practical implementation faced significant barriers. Teachers' aspirations often clashed with the realities of the existing organizational context, leading to compromises and scaled-down ambitions. This tension highlights the complex interplay between teacher agency and systemic constraints. The study underscores the challenges science teachers encounter in transitioning to competence-oriented curricula. While teachers show awareness and willingness to meet new demands, their efforts seem hindered by contextual constraints. Addressing these issues requires targeted support strategies that consider both individual and systemic factors to effectively bridge the gap between curriculum aspirations and classroom realities.

Introduction

Curriculum revisions are central milestones in the evolution of science education, influencing what and how science is taught (Bybee, 2013). Serving as authoritative frameworks, these revisions not only shape educational practices but also delineate the legal guidelines dictating the content and methodologies to be employed in classrooms. However, the effectiveness of altering teaching practices through curriculum adjustments is contingent on the premise that curriculum revisions serve as an effective method for changing science teachers' practices.

In recent years, there has been a global movement towards educational reforms, particularly within the realm of science curricula. This trend reflects a departure from traditional approaches focused solely on enhancing students' scientific content knowledge to embracing a competence-oriented paradigm (OECD, 2017, 2019; Crujeiras & Jiménez-Aleixandre, 2013; Berland et al., 2016). Emphasizing the application of knowledge, this approach underscores the importance of equipping students with the requisite skills, attitudes, and aptitudes to navigate the complexities of the 21st century and their personal lives (OECD, 2017; Kelly, 2008).

Throughout the literature, teachers emerge as central figures in implementing revised curricula, often regarded as "agents of change" central in effectively integrating new practices into existing educational frameworks (Fullan, 2003; Priestley et al., 2015). Understanding the dynamics of how teachers navigate in response to curriculum revisions is therefore imperative for informing policy decisions and guiding future reform implementations.

Implementing competence-oriented science curricula presents challenges for teachers, including lack of pedagogical skills (Schneider et al., 2005), knowledge about competences (Archer-Bradshaw, 2017), and limited time and resources to carry out the curricular ambitions (Farirah et al., 2021; García Carrillo et al., 2021; Braskén and Pörn, 2021).

Previous studies on curriculum revisions often focus on professional development or intervention programs. These interventions typically involve the development of teaching resources (e.g. Bismack et al., 2014), professional development formats and/or workshops (e.g. Bowers et al., 2020; Maeng et al., 2020. While such studies provide insights into support strategies, they often focus on either individual teacher characteristics or external factors influencing practices. Furthermore, research on teachers' work with implementing competence-oriented curricula often view teachers as research objects rather than participating subjects (Tidemand & Tamborg, n.d.). There is a gap in literature regarding studies that give voice to teachers, supporting them in expressing challenges, desired futures, and support them in implementing new approaches. Understanding how science teachers navigate curriculum changes and identifying areas of difficulty is essential for the efficiency of future support strategies.

This study investigates Danish science teachers' responses to a recent competence-oriented curriculum reform. By giving voice to groups of teachers' experiences and reflections, it captures the nuanced ways in which teachers navigate and implement curriculum changes. By coming to understand *both* the individual teachers *and* the context in which they navigate, the study aims to provide a more comprehensive understanding of the challenges and support needs associated with curriculum revisions in science education.

The study seeks to answer the following research question:

How do teams of science teachers navigate in the context of a competence-oriented curriculum reform?

To address the research question, the study is structured around the following operational sub-questions: Which specific challenges do science teachers experience when implementing a competence-oriented curriculum? What alternative desired scenarios do they envision?

How and to what extent are the science teachers capable of realizing their desired alternatives through participatory methods? As such, this study aims to give a voice to teachers amid the implementation of a reform, to provide an in-depth understanding of the dynamics through which science teachers navigate the complexities of a competence-oriented curriculum reform, identifying both barriers and pathways to successful implementation.

Background

In the academic year 2015/2016, the Danish elementary school underwent a significant reform, reshaping the educational landscape with a strong emphasis on competence-oriented learning. This reform marked a departure from the previous curriculum's focus on content and knowledge, where skills and subject matter were treated as distinct and isolated. The new reform sought to integrate these elements through a more holistic approach that underscored the development of competencies applicable across the science disciplines. Central to this reformation was the introduction of comprehensive guidelines and examination requirements that targeted four key competence areas for the science disciplines: investigation, modelling, communication, and contextualization (UVM, 2020). These areas are integral to the updated national standards, known as *Fælles Mål* (UVM, 2019), which outline the essential competencies students are expected to cultivate within the science subjects. The reform also emphasized the importance of multidisciplinary collaboration, fostering a learning environment where science subjects are not taught in isolation but are instead approached in a manner that encourages cross-curricular connections. This shift supports the development of student skills that transcend individual disciplines, aligning with the broader educational goal of preparing students for complex problem-solving and critical thinking in real-world contexts (UVM, 2020). In practice, science teachers must now plan for and conduct multidisciplinary teaching units in the lower secondary school (grades 7-9), engaging with the four competence areas within and between disciplines. These units are

central to implementing competence-oriented science teaching and fulfilling the objectives of the Danish Compulsory School (UVM, 2021). The significance of the multidisciplinary teaching units is highlighted by the introduction of a new exam format that assesses students' competencies across all four areas, centered around the topics covered in the multidisciplinary units (UVM, 2022).

Research Design and Data Collection

This study examines 18 Danish lower secondary school science teachers' practices in the context of a recent educational reform. Data is derived from a Future Workshop (Jungk & Müllert, 1984), conducted with teachers from three schools in the Capital Region of Denmark, selected for their managerial commitment to the reform.

Future Workshops, a participatory approach for creative problem-solving, are organized in three phases in this study: i) *Critique Phase*: Teachers expressed criticisms and concerns about the current state, identifying problems without focusing on solutions, ii) *Fantasy Phase:* Teachers articulated visions for an improved future, imagining ideal scenarios free from current constraints, iii) *Implementation Phase:* Teachers transformed their fantasies into concrete action plans, aligning their current situation with their visions (Jungk & Müllert, 1984).

The workshop was held at an external venue to encourage open thinking (Bryman, 2016; Creswell & Creswell, 2017). Teachers were introduced to the workshop theme, "implementing a new, competence-oriented curriculum" and method with its focus on the democratizing purpose, which set the context and clarified objectives (Vidal, 2006).

In the first two phases, teachers were organized into mixed groups to promote open dialogue without the possible constraints of close colleagues (Creswell & Poth, 2016). In the final phase, they returned to their original teams to formulate action plans for each school. Each

workshop phase lasted one hour, with groups working in adjacent rooms. Teachers used pens, paper, and post-it notes to document criticisms, utopias and action plan proposals. To begin with, they had five minutes to individually write down topics, followed by a group discussion where everyone took the chance to speak, and the themes were organized thematically to facilitate structured discussions (Vidal, 2006). After each phase, teachers reconvened in a plenary session where groups presented their poster boards and shared key points. These sessions included opportunities for questions and comments, allowing for the exchange of diverse perspectives and reinforcing collective understanding of the issues, aspirations, and action plans (Vidal, 2006; Jungk & Müllert, 1984).

Data collection included audio recordings of group discussions to capture the teachers' communication (Creswell, 2012), which were transcribed for detailed analysis (Bryman, 2016; Creswell, 2015). Visual artifacts produced by the teachers provided a structured overview of key themes. Together, these data sources offered a robust foundation for understanding teachers' work with the new curriculum.

Participants had varying teaching experience (3 to over 20 years) and taught one or two science disciplines. They were informed about the study's purpose, procedures, anonymity protocols, and their right to withdraw, ensuring confidentiality.

Theoretical Framework

Teacher Agency

To address the research question, I utilize Priestley et al.'s (2015) framework of teacher agency, inspired by Emirbayer and Mische (1998). This model views human agency as shaped by past experiences, present-day decision-making, and future aspirations.

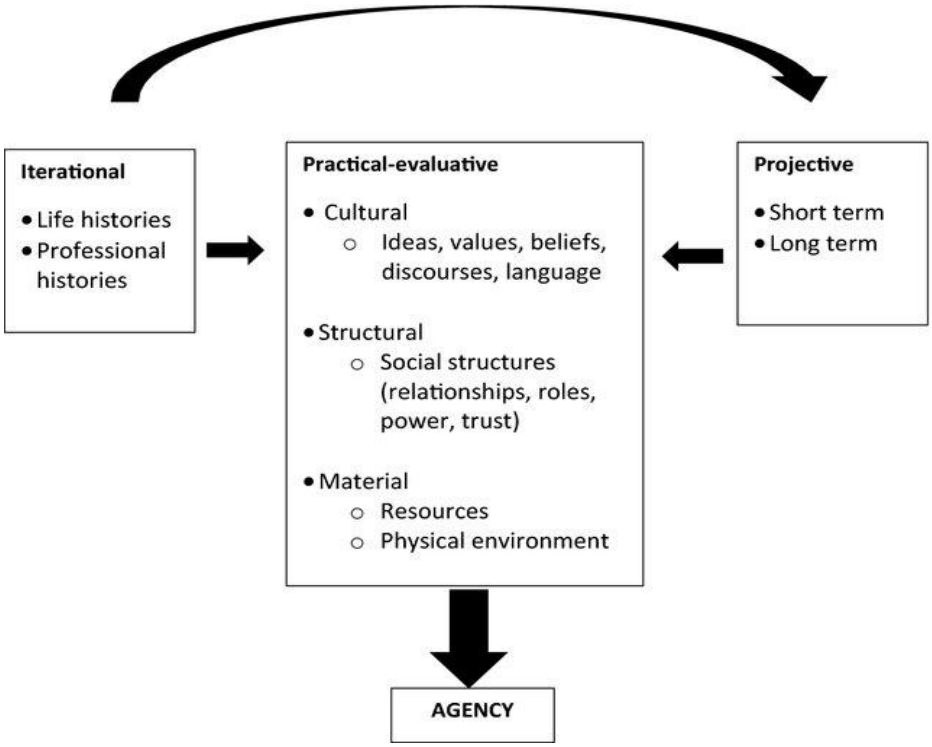

Figure 1. Teacher Agency, adopted from Priestley et al. (2015)

Priestley et al.'s (2015) model of teacher agency highlights that it is shaped by past experiences, orientated by future aspirations, and enacted in present situations through the interplay of three dimensions: *The iterational dimension* considers the influence of teachers' general life histories and professional backgrounds on their agency. It includes personal capacity (skills and knowledge), beliefs, and values, all rooted in past experiences. Thus, while the authors do not frame teacher agency as a personal capacity, they acknowledge that it is crucial for its emergence. *The practical-evaluative dimension* involves teachers' present-day decision-making, shaped by cultural, structural, and material conditions. Cultural aspects include values and beliefs, structural factors encompass social relationships, and material aspects involve physical resources and environment (Poulton, 2020). *The projective dimension* relates to teachers' short-term and long-term future aspirations, which guide their actions. These aspirations, whether aimed at student achievement or maintaining current practices, are rooted in prior experiences and influenced by strongly held beliefs about

identity and motivations. Their aspirations can take on different forms, ranging from positive to reserved (Osborn et al. 1997).

Agency is achieved through the interplay of these dimensions, varying in different contexts. The context, comprising external factors and environments, crucially shapes and enables teacher agency (Priestley et al., 2015).

While the Future Workshop format in this study supports teachers' development of agency. Analyzing workshop data with the teacher agency framework allows me to critically assess teachers' opportunities to achieve agency within their organizational context.

Approach to Analysis

The data included verbatim transcriptions of 7 hours and 10 minutes of audio recordings, serving as the primary source for identifying emerging themes. Teacher artifacts were cross-referenced with transcripts to ensure comprehensive coverage. I analyzed the data using Priestley et al.'s (2015) conceptualization of agency, examining how various factors shape teacher agency across three dimensions. During the critique phase, the teachers engaged in discussions about what they find challenging in their work with implementing the new curriculum. I categorized statements according to the three dimensions of the model. Statements on previous practices, experiences, or own skills and knowledge related to the new curriculum were categorized in the iterational dimension. Statements on own present capacity to make decisions while engaging with cultural (e.g. shared understandings), structural (e.g. administrative policies) and material conditions (e.g. school facilities) were categorized in the practical-evaluative dimension. Statements on interpretations of the curricular guidelines' aspirations and requirements of science teachers' practices were categorized within the projective dimension. I followed a similar approach to analysis of the data from the fantasy phase, with the only difference that the object of analysis was teachers' visions for a future ideal situation contrary to the current situation. When analyzing the data

from the implementation phase, I examined: 1) how proposed solutions addressed critiques and visions, and 2) to which extent the proposed solutions are feasible. So, while analysis of data from the first two phases was primarily driven by Priestley et al.'s framework (2015), the analysis of the third phase thus has a broader focus on the consistency and continuity between critiques, visions and proposed actions.

Results

The following sections report on how the science teachers navigate in the context of implementing a competence-oriented curriculum reform.

The Critique Phase

Misfit between iterational and projective dimension of teacher agency

In this section, I illustrate two key aspects contributing to the perceived misfit between the iterational and the projective dimensions: i) the lack of clarity on enacting the new curriculum and ii) the redundancy of teachers' prior experiences and knowledge within the new curriculum, limiting their agency. Following the terminology of the teacher agency framework (Priestley et al., 2015), teachers express a perceived misfit between these dimensions when implementing a new curriculum.

Uncertainty in Enacting the Curriculum

The teachers face dilemmas in understanding and enacting the prescribed curriculum objectives. During the critique phase, they express confusion over the curriculum's intentions and contents, as highlighted by one science teacher: "*I feel that I lack an in-depth understanding of the idea behind the requirements. I have a feeling that that is how I experience it, but I also have a feeling that most of my colleagues feel the same way. (...) delving into the gut feeling of - what is the purpose of this, and what exactly are we supposed to do?*". Another teacher notes the difficulty in organizing teaching: "*Sometimes I see the students looking like big question marks, and they cannot see the connections, [...] it is challenging to get them to understand the subjects and have an idea about it, and what the*

idea and purpose is, like you say, we do not even know deep down in our stomachs what the purpose and idea is, and thus it is a challenge to teach them". Here, the difficulty in conveying subject matter becomes more pronounced due to lack of clarity with curriculum purpose. Some teachers resort to familiar methods that do not align with the new curriculum due to their lack of personal capacity: *"to be honest, I do a lot of cookbook experiments, (...) it is also just very time consuming to teach competence-oriented in that way, compared to just conducting a cookbook experiment, because, yeah I mean, I do not yet feel competent doing so yet (...) it is much easier to just hand them a cookbook experiment and then they will all do that. This thing [the curriculum] is a huge challenge, and not something that lies on our backbone."*

Using the teacher agency framework (Priestley et al. 2015), I can interpret the teachers' perceptions pertaining to their personal capacities: skills and knowledge, specifically of how to adhere to the new curriculum. The teachers experience a misfit between the iterational dimension and the projective dimension, i.e. the (short and longterm) aspirations about the new curriculum. The teachers claim they do not possess capacities required to carry out the ambitions of the new curriculum, which seems to limit their agency. Furthermore, it is noteworthy that the excerpts document that the teachers are aware of this and express professional dissatisfaction about the situation.

Redundancy of Prior Experiences

The second aspect of the misfit is that teachers' accumulated experiences and expertise seem redundant within the new curriculum's framework. This devaluation undermines their confidence and inhibits their ability to engage fully with the implementation process. The challenges here pertain to both personal capacities and values in the iterational dimension. Teachers feel unprepared for the new curriculum, as one teacher states: "*the didactical challenges associated with this is the biggest challenge (...) it is a huge task that has just been*

thrust upon us without any preparation (...) if we felt that we were competent teachers before, I don't feel that I am a competent teacher." Teachers also note the lack of professional development following the new curriculum requirements, feeling that it is "(...) *a condition we must accept or learn to live with".* The profound misfit leaves some teachers with a sense of discouragement: *"(...) where I previously felt like a competent teacher, I have experienced a decline (...) I find myself on uncertain ground, somehow unsure of what I should be doing".* Others express resignation and resistance: "*(...) many teachers say that they don't even want to bother understanding it, like "I will just carry on as I always have, and it will work out in the end"",* and some feel they must compromise their professional values: "*One feels like compromising their own professionalism, which is hard to swallow. This constant feeling of guilt because one doesn't feel capable of properly teaching the students, both due to lacking competences and time, and because there are vague expectations regarding what this should result in".*

The misfit between the iterational and projective dimensions of teacher agency leaves teachers with a sense of despair, struggling to reconcile their experiences with the new curriculum demands. Some exhibit resignation, while others feel compelled to compromise their professional values. The teacher agency model suggests that agency builds on the iterational dimension - past achievements, understanding. In building on the iterational dimension in the context of agency, Emirbayer and Mische (1998) describe a selective reactivation of past patterns of thought and action by individuals. Priestley et al. (2015) argue that in the construction of agency, individuals can identify and reshape past behaviors and experiences, using them to navigate present situations and engage in orientations about the future. In this sense, the construction of agency becomes "motivated" (Priestley et al., 2015) as it is tied to the desire to create a future distinct from both the present and the past. Thus, to be able to construct agency, actors must be able to draw on past experiences to clarify their

motives, goals and intentions, recognize potential future constraints, and identify possible courses of action (Priestley et al., 2015). However, it seems that for this group of teachers, they are *not* in a position where they can reconcile their past patterns of thought and action with orientations about the future, since the gap between the previous and the current curriculum is too big for the teachers to narrow by themselves.

Organizational Constraints

Throughout the critique phase of the future workshop, the teachers deliberated on a spectrum of challenges encompassing both what the teacher agency framework terms as the cultural and material aspects of the practical-evaluative dimension. These challenges include difficulties related to *teacher collaboration*, *resource scarcity*, and *lack of support from the management.* In the following section, I will lay out these challenges.

Regarding teacher collaboration, the teachers express concerns about varying levels of motivation among teachers and differing perceptions of the value of collaboration in the context of the new curriculum: "*I experience a challenge in that our team has different perceptions of whether collaborating is a waste of time and frustrating or if it can be beneficial"*. Additionally, they argue that time constraints prevent them from meeting to plan teaching effectively: "*Time, it's the issue of once again lacking time for collaboration. And every time you think you've scheduled a meeting, a new meeting from management overrides it*." As evident from the excerpt, the teachers' own efforts to allocate time for meetings are hindered by other priorities set by the administration.

For the material aspects in the practical-evaluative dimension, the teachers highlight concerns about inadequate time and resources for competence-oriented science teaching, including planning, conducting lessons, as one teacher argues: "*Lack of time for collaboration, um, and yes, across the team in general, right? And I also think the lack of preparation time affects our ability to understand the competences and everything else. We simply don't have time for*

it. And, um, too few hours; I think it occupies too little space considering that we have to prepare them for written exams, help them understand all the academic content, understand multidisciplinary subjects, and engage them in biology and project-oriented work. It's impossible with one hour per week". Other aspects mentioned by the teachers are lack of resources allocated to purchasing equipment suitable for diversifying teaching methods required to comply with the new curriculum, updating facilities, and funding field trips, as exemplified by one teacher: "*Then there are financial issues, both in terms of resources for off-site activities and having two teachers, but we also discussed the lack of equipment and outdated subject-specific classrooms. This is a practical issue, but it's also quite important for an exam where students need to be very innovative and such, right?"*. The absence of these organizational prerequisites, as one teacher remarks, significantly limits their agency: *"(...) is low practical, but it means something in terms of engaging in development, doesn't it?".* Hence, while the teacher's comment here suggests that the perceived organizational constraints are low practical, at the same time it has a substantial impact on the teachers' ability to engage in continuous professional development and should thus not be considered seemingly minor.

Furthermore, the teachers express a pervasive sense of lacking support from the management. One teacher cites the absence of prioritization, emphasizing the need for top-down structures that demonstrate a managerial commitment to prioritize science subjects aligned with the new curriculum's weighting: "*There is also a lack of structure from above, where the management demonstrates a commitment to prioritizing science subjects"*. Another teacher emphasizes the need for managerial support to schedule teaching in a way that supports the new curricular ambitions: "*If I had more time and if the schedule was organized in blocks, for example, and there were more consideration given to when flexible days are scheduled, well, then we could*

certainly offer more to the students. We could always do better if we had better opportunities, but I believe that is a task for the management."

Overall, teachers face constraints due to (lack of) organizational prerequisites. The teachers generally perceive a limited room for maneuvering in relation to curriculum regulation.

The Fantasy Phase

During the fantasy phase, the teachers in this study primarily engaged in discussions about how they would *act* in an ideal situation. Consequently, their statements primarily relate to the practical-evaluative dimension of the teacher agency framework. To recall, the practical-evaluative dimension involves an individual's capacity to make informed judgements among alternatives in the present context, while interacting with cultural, structural, and material conditions that may be seen as enablers, constraints, or resources (Priestley et al., 2015).

The teachers articulated their ideal strategies and solutions to their curriculum implementation, which can be categorized into two overarching themes: "*facilities and resources*" and "*teacher collaboration"*, and "*physical organizational structures*". In the following sections, I will present these themes and argue how they relate to the practical-evaluative dimension of the teacher agency framework.

The first theme of the fantasy phase that I will elaborate on is facilities and resources. In this theme, the teachers envisioned *more time to plan and conduct teaching* and *suitable facilities to meet the revised curriculum's demands*. The teachers emphasized the critical importance of time allocated to science teaching, time management, and careful planning to adhere to the new curriculum. The teachers advocated for structured planning sessions where they can collectively design comprehensive, multidisciplinary, and motivating lessons. In particular, the multidisciplinary aspect inherent in the revised curriculum turned out to be challenging. They assert, "*where we can sit down and determine how much time we truly need to plan this properly... to create challenging, cross-curricular, competence-building, and, above all,*

engaging teaching." In addition, one of the teachers states that lack of time to comply with the new curriculum leads to reliance on outdated textbook material: "(...) *when we have so little time, I don't know about you, but then I tend to rely on the table of contents in the textbook material. And in that context, the science subjects don't necessarily go hand in hand. That can make it problematic in terms of planning in accordance with the new curriculum.*" They express that with the introduction of the new curriculum, they feel that they need to "reinvent the wheel" for competence-oriented science teaching. They suggest that in an ideal situation, they would have time allocated specifically for planning science teaching: "*It would be really, really great if we could start having scheduled collaborative planning sessions, so that we wouldn't have to rely on hoping that everyone else has scheduled meetings during the shared planning pool (...) Instead, we would have it integrated into our timetable, where all science teachers would have one free hour to come together."* This sentiment is echoed, as the teachers express the need for sufficient time allocation to ensure that they meet the demands of the new curriculum.

For the second part of *facilities and resources*, the teachers envisioned adequate resource allocation to enrich the learning experiences of their students. A clear call for funding is evident in the plea for resources to conduct relevant experiments: "*I believe there should be money available to conduct meaningful experiments.*" Additionally, there is a desire for updated facilities, such as new science laboratories, to support hands-on learning opportunities, as one teacher states: "*yeah, I know it is a fantasy, but I would like to update the rooms we teach in, in a way that matches the exam as it looks now. It does not work now*". This resonates with the broader theme of enhancing the educational environment to facilitate effective teaching practices. Furthermore, the teachers stress the importance of curriculum integration and alignment to facilitate cohesive lesson planning and multidisciplinary connections. They express concerns about the variation in instructional

materials and advocate for more consistent, coordinated resources. Furthermore, they propose alternative teaching arrangements, such as team teaching or shared subject responsibilities, to alleviate individual workload burdens. This sentiment is encapsulated in the desire for "*fewer teaching hours and more time for academic exploration."* Hence, they underscore the need for systemic changes to support teachers in delivering high-quality instruction effectively.

According to Priestley et al. (2015), the material conditions of the practical-evaluative dimension of the teacher agency framework concern resources and the physical environment that promote or hinder agency, e.g. school facilities and resources. As time management and planning can be conceptualized as resources that, according to these teachers, would assist them in achieving agency in their given situation, this theme refers to the material conditions of the practical-evaluative dimension.

Teacher collaboration emerges as the second cornerstone of the teachers' aspirations, with a strong emphasis on structured planning sessions and shared professional development. The teachers acknowledge that change does not happen from one day to the other, as exemplified here: "(...) *it is also a culture that needs to be developed. It is not something that happens overnight".* The proposition for scheduled collaborative planning periods within school schedules reflects a collective desire for teamwork among the science teachers: *"It would be really great if we could start scheduling some common planning sessions so that all science teachers have a free hour to collaborate."* This collaborative ethos extends beyond individual schools, with suggestions for community-wide initiatives and thematic events to promote interdisciplinary approaches and scientific engagement. According to the teachers, an increased focus on teacher collaboration could ensure a "*development in teacher competences"* to match the curricular demands, and, in addition, a "(...) *shared knowledge about and understanding of the competences".* In articulating desired outcomes for their future, the teachers express that they feel overwhelmed and need proper professional

development: "*I don't know, it's kind of like "we come up with a new plan where science should play a much bigger role: new exam format and so on. But, you know, it's kind of like saying we should make this dish but if we don't have the ingredients for it, then there will be no dish".* The teachers envision a future, where they have knowledge about and clarity on their roles and responsibilities: "*a clearer understanding of what our roles are as teachers in all these new objectives, both related to teaching, supervision of students, examinations and to colleagues. (...) in general, we need an update, so we don't feel exposed in terms of what we are actually capable of doing".*

Emirbayer and Mische (1998) describe cultural and structural conditions as a socially organized context in which individuals are embedded. According to Priestley et al. (2015), cultural elements in the practical-evaluative dimension relate to ways of speaking and thinking, as well as the values, beliefs and aspirations that encompass both inner and outer dialogue. Structural aspects are the social structures and relational resources related to the achievement of agency, such as teachers' duties, administrative policies, or teacher collaborative relationships. In the discussions about teacher collaboration, both structural and cultural aspects emerge, as the teachers envision teacher collaboration emphasizing shared understandings and values. Additionally, they envision a clear definition of their roles in fostering this collaboration, highlighting the interplay between cultural and structural conditions in shaping teacher agency.

In summary, the teachers' discussions about an ideal future reflects a shared aspiration for an educational environment that prioritizes effective teaching practices, teacher collaboration, resource allocation, and support structures. My analysis has shown that their statements relate to all three aspects within the practical-evaluative dimension, as they discuss issues related to both cultural, structural, and material aspects.

The Implementation Phase

The third and final phase of the workshop – the implementation phase – aims at developing concrete steps and plans to realize the solutions discussed during the fantasy phase. Here, the teachers were asked to work together to develop actions for their future work based on the ideas generated during the fantasy phase.

While the teachers successfully formulated future scenarios and envisioned solutions during the fantasy phase that addressed the issues raised in the critique phase, they encountered challenges when attempting to translate these ideas into practice.

The suggestions across all three schools primarily revolve around ensuring allocated time for preparing multidisciplinary teaching and teacher collaboration. For instance, one teacher emphasized the importance of cross-school collaboration within the municipality to: *"assess and plan multidisciplinary teaching. And create the red thread. Make a collection of possible scientific experiments",* while another teacher proposes "*Yes, and ensure those topics. Figure out precisely what should be the shared focus, academic areas – so what should we cover in 7th grade? What should we cover in 8th grade and 9th? When do we schedule them? When do we start them? (...) we create a completely fixed plan for it to happen like that every time, right? And then specify which topics are the ones we approach in this way, right?*". Furthermore, they emphasize the need for an increased focus on their internal relationships: "*in relation to us building some relationships now, getting to know each other also makes it easier, I believe, to schedule more meetings. (...) I think it's very important to have some relationships".* They agree that knowledge sharing is crucial: *"where you talk about what have you done? What went well? What went poorly for you in the test? Where did you have some gaps?".* One teacher emphasizes that this could potentially ease some of the pressure they feel as teachers "*(...)clearly, the more we know, the easier it becomes for us to alleviate some of that planning pressure that can exist."* Overall, the teachers agree that change does

not happen overnight, and it takes time: "*And it's going to take some time. One day is really not enough for it, but we'll really get something good out of it when the school year starts, because then you can go and see, "Okay, this is where we are." Then you can be sure that everyone else is there too."*

The teachers agree that creating concrete actions related to allocating time to meet, plan and discuss multidisciplinary teaching and their work with implementing the new curriculum is crucial. The teachers suggest concrete (short) teacher meetings e.g. during lunch: "*(...) Perhaps we could say, once every fortnight during a lunch break or maybe just for 30 minutes after the last lesson, we could get together and say, 'Is this still on track? Should we plan something else?' We can still do that. I just think it gets deprioritized because once the school year starts, there's always something. There's always something going on.".* According to the teachers, this is something they can easily implement: *"So perhaps, that thing during lunch break shouldn't be on just one day. So you don't have that lunch or yard duty at any time. So, we have it on that Monday or Tuesday, or whenever it is. Then we can meet there. It should be quite easy."*

The only concrete action proposed by the teachers is meetings during lunch break. They perceive this as the only feasible solution from the idealized scenarios envisioned during the fantasy phase, as other aspirations would require extensive support from management to be realized. One teacher expressed this by stating: *"But that's just what I can see we can do immediately. And much else, we need help from elsewhere for. I think many of these things, like creating motivating teaching and better structure, maybe even better supporting each other to find some peace of mind regarding our own expertise. It would be a dream if we had this opportunity for collaborating and sparring. I think. I might be naive about it."* Overall, the teachers recognize that many of their proposed issues are beyond their capacity to address, as one teacher articulated: *"We also need to, what's it called? Prioritize the tasks*

that are desired to be implemented. Um. So some of it is beyond our control, so to speak." Another teacher echoed this sentiment, stating, *"It's difficult to discuss that reality phase because much of it falls under management. (...) we can't make decisions, we can't say, 'Well, we want to realize this,' because it's not our concern".*

Despite acknowledging the need for broader changes, such as implementing motivating teaching methods, establishing better structures, and enhancing collaboration, the teachers feel constrained in their ability to enact these changes. They perceive them to be outside their sphere of influence, making their agency contingent upon managerial decisions. This leads to a sense of powerlessness among the teachers. It appears that the teachers have attempted to communicate their desires to management previously: "*(...) with this big examination that has been imposed on us, without extra time allotted (...) there is a need to prioritize this in the upcoming years to make it happen (...) we need to emphasize to them again that it requires that type of teaching (...) leading up to the current examination format".* Another teacher emphasized the importance of management involvement, stating: "*it's obviously the management that needs to, we need to involve management and have them participate in terms of sparring and knowledge sharing*." It appears that the teachers have made efforts to engage with the management before: *"(...) I don't think they'll figure it out unless we tell them again. Again, and again, and again (...)",* here highlighting a bottom-up approach in persuading the management. They recognize the importance of advocating for their needs, such as prioritizing science subjects and emphasize the necessity of conveying these priorities to the management.

In summary, the teachers acknowledge their limited ability to effect change independently and recognize the necessity of managerial support. Despite attempts to communicate their needs, they feel powerless. Teacher agency - the capacity to *actively* shape professional environments and influence educational practices - is constrained by a lack of support. Their

efforts to allocate time for multidisciplinary teaching and collaboration reflect their aspirations, but recurring frustrations and a lack of responsiveness from management hinder their agency. The literature on teacher agency underscores the dynamic interplay between individual teachers and their broader contexts, including institutional structures, policies, and leadership dynamics (Priestley et al., 2015). In this study, the teachers' agency highly depends on contextual factors beyond their immediate control. This tension between aspiration and constraint highlights the complex nature of teacher agency and the ongoing negotiation between individual autonomy and systemic influences within educational settings.

Summary of Main Findings

During the critique phase, the teachers struggled to align their past experiences, personal capacities, and values with the demands in the new curriculum. Following the teacher agency terminology (Priestley et al., 2015), they are not in a position where they can reconcile their past patterns of thought and action with orientations about the future to construct agency.

The apparent alignment between the issues raised in critique phase and the fantasy phase indicates the teachers' awareness of the existing misfit. While they acknowledged a disconnect between their actions and the demands placed upon them, they also expressed a willingness to address these demands. The apparent alignment between the issues raised in the workshop's initial phases and their awareness of the existing misfit suggests that they may implicitly possess some understanding of the requirements to comply with the new curriculum.

In the implementation phase, the teachers were not able to maintain the alignment between the phases when confronted with the practical realities in the implementation phase. In other words, the lofty aspirations articulated during the fantasy phase collided with the contextual constraints of the existing organizational landscape, revealing a stark contrast between the

teachers' idealized solutions and the complexities of real-world application. Bridging the gap between "fantasy" and implementation required compromise, leading to scaled-down ambitions, such as proposing short bi-weekly teacher meetings. Ultimately, most of the envisioned changes could not be integrated into their practices.

The tension between aspiration and constraint illustrates the complexity of teacher agency and the ongoing negotiation between individual autonomy and systemic influences in educational settings. While teachers aspire to exercise agency in shaping their professional practices, their ability to do so depends heavily on contextual factors beyond their control. These highlights and their implications will be discussed below.

Discussion

The disconnect between the utopian visions of the fantasy phase and the practical limitations of the implementation phase highlights the limited scope within which teachers can enact change. It is noteworthy that the aspirations voiced by the teachers in the fantasy phase do not appear utopian, unrealistically idealistic, or unreasonably demanding within the context of implementing the new curriculum; they (simply) request time allocated for collaborative planning of multi-disciplinary lessons and resources to conduct relevant experiments in their science teaching. Both requests can be considered highly reasonable and likely essential to enable teachers to in fact effectively adhere to central aspects within the new curriculum. In fact, lack of time and resources is a general problem that has been found in multiple studies on competence-oriented curriculum implementation (e.g. Farirah et al. (2021), García-Carrillo et al. (2021) or Braskén and Pörn (2021)). Rather than viewing the teachers' requests as fantastical, they should be regarded as fundamental prerequisites for the successful implementation of the new curriculum. The nature of these requests rather illustrates the absurdity of assuming that changing the curriculum will change teaching accordingly.

It is evident that most of the aspirations articulated by the teachers pertain to organizational aspects, highlighting the need for strong leadership mandate for effective action. The findings of this paper demonstrate how the absence of organizational support to accompany curricular reforms not only fails to lead to improved teaching, but also runs the risk of fostering despair and a sense of discontinuity with respect to the teaching experience and expertise among the professionals who are seen as responsible for building students' science competencies. Consequently, this lack of organizational support constitutes a major barrier for curriculum implementation.

The importance of organizational support is a crucial aspect of successful curriculum implementation. Research indicates that successful implementation of new educational competence-oriented frameworks goes beyond individual teacher engagement: Organizational structures, leadership support, and available resources are vital for translating visions into actionable plans (Hackman et al., 2021; Herman et al., 2019; Cottone et al., 2021; Kang and Keinonen, 2016). The findings from this study confirm this and demonstrate that without the requisite leadership mandate and organizational support, even the most well-founded ideas from teachers may stagnate or fail to materialize. Furthermore, this study affirms the necessity of organizational change and support alongside curriculum implementation and emphasizes that these changes must be closely aligned with eliciting what the teachers bring to the situation as well as their needs. Considering teacher capacity in the context of achieving agency, Priestley et al (2015) argue that teachers may enter a specific situation with significant skills, knowledge, and strong educational aspirations. However, they suggest that innovation can sometimes be too challenging or risky to implement. They explain that this is why the term "capacity building" can be misleading as it inherently suggests that teacher agency is solely dependent on their individual capacities. According to Priestley et al. (2015), in reality, agency results from the interaction between what teachers

bring to a concrete situation and the conditions inherent in the situation itself, which can either facilitate or hinder their actions. This underscores the indispensable role of organizational support in curriculum implementation. If we regard teacher agency as a key driving force in the implementation of competence-oriented curricula, then we ought to carefully consider the factors that enable or hinder its realization.

The Future Workshop is a participatory methodological approach designed to foster democratic and emancipatory engagement (Jungk and Müllert, 1984). Rooted in democratic principles, it empowers participants by dynamically identifying challenges, exploring future possibilities, and developing concrete action plans. In this study, it serves as a framework that enables teachers to express their perspectives on current challenges and their aspirations for the future in relation to curriculum changes.

The ecological model of teacher agency, as articulated by Priestley et al. (2015), and the future workshop methodology share a common focus on empowering teachers to actively shape their educational environments. Both emphasize the importance of past experiences, future aspirations, and practical actions within specific contexts. Therefore, future workshops can be seen as operationalizing the principles of Priestley et al.'s (2015) ecological model of agency by providing a structured method for teachers to collaboratively explore and enhance their agency.

The setup in this study enables the amplification of science teachers' voices within the context of curriculum change - a perspective notably absent in the literature (Tidemand & Tamborg, n.d.), and it highlights the importance of actively involving teachers in curriculum modifications. In studies of competence-oriented curriculum implementations, teachers are often viewed as research objects rather than participating agents (Tidemand & Tamborg, n.d.). This study indicates that the future workshop methodology serves as an effective format

of gaining insight into their existing practices, allowing for curriculum changes to be implemented in continuity with their experiences and expertise. However, the teachers' inability to act on needs expressed during the fantasy phase indicates a limitation of future workshops without the involvement of management. The setup inadvertently transfers responsibilities onto the teachers, expecting them to be able to solve problems that the literature suggests requiring managerial support to achieve organizational change (Poulton, 2020). Conversely, this setup likely enabled teachers to feel secure enough to openly express their unpreparedness for the new curriculum's demands. If future workshops are to be used for future curriculum changes, it will be necessary to consider how, when, and not least in what ways management can participate, ensuring a safe space for teachers to voice concerns while providing leaders with sufficient insight into the challenges faced by teachers to make necessary organizational adjustments.

Conclusion

The aim of this study was to examine how Danish science teachers navigate implementing a competence-oriented curriculum. By employing the Future Workshop method (Jungk & Müllert, 1984) and drawing on the ecological model of teacher agency (Priestley et al., 2015), this research aimed to amplify teachers' voices, investigate the relationship between their aspirations and the practical realities they face, and explore the conditions necessary for successful curriculum adaptation. The findings revealed that while teachers were aware of the misalignment between their existing practices and the new curriculum's expectations and expressed a readiness to adapt, their ability to enact these changes was severely constrained by organizational factors.

The tension between the teachers' aspirational visions, articulated during the fantasy phase, and the limitations encountered in the implementation phase underscored the importance of systemic support. Despite the teachers' reasonable requests for resources, time for

collaborative planning, and opportunities to engage in multidisciplinary work, these aspirations were not realized due to a lack of organizational support. This finding challenges the assumption that curriculum changes alone can shift teaching practices; without structural changes and leadership engagement, even the most capable and motivated teachers are unable to bridge the gap between ambition and practice effectively.

The study highlights the need for strong leadership that provides clear mandates and allocates necessary resources to facilitate curriculum implementation. When leadership is absent or insufficient, teachers may experience a sense of disillusionment and a disconnect from their professional roles. These findings confirm that successful curriculum reform extends beyond teacher engagement and requires a cohesive approach that integrates teacher agency with organizational capacity. Participatory approaches such as Future Workshops can be valuable for surfacing teacher concerns and aspirations, but their effectiveness is contingent upon management's willingness to act on the insights generated.

In conclusion, curriculum reforms aimed at developing 21st-century competencies must be supported by a comprehensive strategy that aligns teacher agency with structural and organizational support. To truly realize the potential of competence-oriented curricula, future research should explore how best to integrate participatory methodologies with managerial action to create an environment conducive to effective change. In this way, educators may better be empowered to transform their practices in ways that benefit both their students and the broader educational system.

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Paper 4

Assessing What Matters: How Assessors Frame Competence-oriented Oral Integrated Science Examinations

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Abstract

This paper presents findings from a study investigating the types of questions assessors ask during oral examinations to elicit information about students' scientific competences, in the context of a recent competence-oriented curriculum reform in Denmark. The study examines oral examination practices among 18 Danish lower-secondary science teachers and external examiners, in a new oral examination format designed to elicit students' level of competence, focusing on the questioning techniques used to assess students' competence levels. Drawing on data from ethnographic observations of 31 students' oral examinations, we identified and categorised assessor prompts and follow-up questions to elicit students' level of competencies. Our analyses revealed a concerning trend: while the new curriculum emphasises developing students' scientific competencies, the majority of questions posed by assessors were of a closed nature and focused predominantly on eliciting factual knowledge. Although there were open-ended questions aiming at higher-order thinking, these were infrequently employed and often centred on content knowledge rather than competencies. This imbalance indicates a misalignment between curriculum objectives and assessment practices, suggesting that current questioning practices may not sufficiently facilitate students' demonstration of their competencies. These findings underscore the need for targeted professional development for science teachers to enhance their questioning strategies and ensure that assessment practices align with the goals of competence-based science education.

Introduction

This paper presents findings from a study that investigates the types of questions assessors ask students during oral exams to elicit their levels of scientific competencies, in the context of a recent competence-oriented curriculum reform in Denmark. In recent years, there has been a global shift in educational reforms, particularly within science curricula, moving away from traditional content-focused approaches towards a competence-oriented paradigm (OECD, 2017; OECD, 2019a; Crujeiras & Jiménez-Aleixandre, 2013; Berland et al., 2016). An essential aspect of this paradigmatic shift has been the emphasis that science education should strive to build students' abilities to activate skills, attitudes, and aptitudes within unknown contexts (OECD, 2017; Kelly, 2008) - not just acquire scientific knowledge. One of the key challenges is the need for a fundamental change in assessment practices, which now requires teachers to assess students' competencies and design opportunities for students to demonstrate these competencies (Rönnebeck et al., 2018; Schneider et al., 2005; Archer-Bradshaw, 2017). This new paradigm has brought formative assessment and the role of classroom questioning to the forefront of educational literature (Black & Wiliam, 2009). Research has particularly emphasised the critical role of questioning techniques in shaping student thinking and fostering the development of competencies through feedback (Chin, 2006; Ruiz-Primo & Furtak, 2007). These techniques - often aligned with formative feedback practices - have proven effective in eliciting student understanding, diagnosing misconceptions, and promoting higher-order thinking skills (Black & Wiliam, 1998; Dolin et al., 2018c). In the context of assessment studies, Moss (2013) has argued for a need for research designs that go beyond teachers' self-reports, surveys, and inventories, to provide a richer and more comprehensive understanding of how teachers evaluate student achievement. In this study, we focus on two key aspects to address this need: (i) the types of

questions assessors ask during oral exams, and (ii) the opportunities these questions offer for students to demonstrate their scientific competencies. Our article contributes to this area by providing insights into how science teachers and examiners implement competence-based education in examination practices - an area that, to our knowledge, has received limited attention in the research literature. We do so by addressing the following research question:

What are the types and distributions of questions asked by assessors in oral exams that are to elicit information about students' levels of scientific competencies?

Based on our answer to this question, we will engage in a discussion about the extent to which the types and distributions of these questions provide reasonable opportunities for students to demonstrate their scientific competencies in an assessment context.

Assessment in Science Education

Historically, assessments in science education have primarily focused on students' mastery of factual knowledge and procedural skills (Harlen, 2015). However, the shift towards competence-oriented curricula calls for assessment approaches that allow students to demonstrate not only what they know but also how they can apply their knowledge in novel situations (OECD, 2017; OECD, 2019b; Dolin et al., 2018a). This change is particularly evident in Denmark, where a recent educational reform has restructured oral examinations in science subjects to assess students' competencies rather than content alone (UVM, 2020; UVM 2022).

An essential distinction in the research literature on assessments is that between formative and summative assessment. Formative assessment refers to ongoing practices that support and improve student learning by providing timely feedback (Black & Wiliam, 2009), whereas summative assessment evaluates students at the end of a learning period (Harlen, 2007; Dolin et al., 2018c). However, several scholars argue that this distinction should not be viewed too rigidly

(e.g. Dolin et al., 2018c). Wiliam (2011), for instance, suggests that formative and summative assessments exist on a continuum, where e.g. summative assessments can have formative effects if the results are used to guide future learning. Similarly, Harlen (2005) highlights the synergies between formative and summative practices, suggesting that they can complement each other depending on how the assessment results are utilised. Thus, the distinction between formative and summative assessment does not lie in the type of knowledge they seek to provide about students, but in how that knowledge is used by teachers or assessors. For the purpose of our paper, we consider oral examinations to be a form of summative assessment, in which the assessment criteria are formalised in legislative curriculum documents. In such assessment contexts, it is evident that assessors play a critical role in shaping the assessment environment, particularly through the questions they pose during oral examinations (Black & Wiliam, 2009). Since formative and summative assessments both aim to provide insights into students' understanding but differ in the purposes for which these insights will be used, assessors' strategies to elicit student understanding may draw on formative assessment approaches.

Based on the above, and given the limited research on science education examinations, particularly in the context of competence-based education, the following section reviews related work with respect to two areas relevant to our study: (1) oral assessment practices and (2) approaches for assessing students' understanding. Building on insights from these strands of literature, we then situate the contribution of our study within this body of knowledge.

Related Work

Research on Assessment Practices in Oral Examinations

The area of assessment is important. Especially in the context of examinations, the stakes are high for both students and schools. Examination results have significant implications for

students' access to further education and, ultimately, career opportunities. Furthermore, politicians use exam results to exert control over education. Given this importance of examinations, one might expect it to be an area of great interest in research literature. However, research on oral examinations in science education remains limited, particularly at the lower secondary level. While other fields, such as English language assessment, have explored assessor practices (e.g. Bøhn, 2015; Borger, 2018), there is little research-based knowledge available on how assessors in science education formulate and follow up on their questions during competence-oriented assessments.

In general, oral exams are described as an adequate format for assessing higher order thinking such as application and understanding (Maugesten, 2011). A frequent focus in studies of assessment practices in oral examinations concerns the strategies and effects of assessors' questions and follow-up questions. Kalthoff (2013) found that assessors questions generally shape the interactions at examinations and argued for the importance of using the full grading scale to reflect student abilities. Along a similar line, but in the context of PhD defences, Dobson (2018) studied examiners' influence on interaction patterns, and argued that oral exams are flexible practices shaped by the dynamics of interaction. The influence of assessors on students' opportunities to demonstrate their capacities thereby not only lies in the initial questions that are posed, but also how subsequent questions frame dialogue and discussion. The research literature illustrates several ways to do so. Rolin (2013) for example identified both follow-up questions and explicit requests for arguments during assessment in exam contexts and found that the former foster stronger student argumentation than the latter. Other studies highlight the impact of examiners' prompts on student responses. For example, Vonen (2024) found that explicit corrections during oral exams often disrupted student narratives, whereas implicit corrections

allowed smoother transitions for students to continue discussing the topic. Previous research thus underscores that assessors indeed play an active role in mediating the assessment environment, which scopes and influences students' opportunities to provide answers with depth and set the tone for the types of competencies that are prioritised (Hamp-Lyons, 2007).

Gathering Evidence of Student Understanding

An essential aspect of any assessment context is to provide insights into students' understanding. Griffin (2007) argues that humans can provide evidence of cognitive and affective learning through four observable actions, what they: i) say, ii) write, iii) make, or iv) do. These actions serve as indicators of underlying learning and provide a means for others to infer comprehension. According to Sadler (1989), the assessor's role in assessment contexts, be it formative or summative, is to design methods that elicit responses from students that reveal their level of understanding. Dialogues during oral examinations can provide evidence on *what* and *how* students are thinking. Hence, this format holds the potential to make students' thinking (and thereby understanding) explicit (Dolin et al., 2018b; Harrison, 2006; Ruiz-Primo, 2011). However, the *way* assessors facilitate dialogues impacts both *what* and *how much* of the students' understanding is voiced (Dolin et al., 2018b).

In the context of science education, competence is defined not only by knowledge of facts but also by the ability to engage in scientific reasoning and problem-solving in unknown contexts (OECD, 2017; OECD 2019b). Previous research emphasises that open questions generally encourage students to engage in higher-order thinking by prompting them to analyse, synthesise, and apply their knowledge in novel contexts (Chin, 2006). Open-ended questions invite students to explain their reasoning, connect ideas, and demonstrate their capacity to apply scientific concepts to real-world scenarios (Osborne & Dillon, 2008). For instance, asking students to

explain how a particular scientific principle works in practice can reveal their deeper understanding, rather than simply recalling definitions. In contrast, closed questions, while useful in assessing specific factual knowledge or basic procedural skills, are less effective in revealing students' broader conceptual understanding and their ability to think critically about scientific problems (Hattie & Timperley, 2007) and tend to limit the scope of student expression to recall-based tasks, often leaving deeper conceptual understanding unexplored (Black & Wiliam, 1998).

The literature on assessment generally acknowledges the need for continuous questions and dialogue. Follow-up questions allow assessors to probe deeper into a student's response, moving beyond initial surface-level answers. These questions are particularly useful for diagnosing misconceptions, encouraging students to elaborate on their reasoning, or challenging them to justify their conclusions (Chin, 2006; Sadler & Good, 2006). By prompting students to reflect on their thought processes, follow-up questions not only help assessors better understand student thinking but also encourage students to engage in metacognitive practices, such as self-monitoring and reflection on their own understanding in dialogues with teachers and peers (Ruiz-Primo & Furtak, 2007).

Previous research highlights the interplay between the types of questions posed and the subsequent follow-up dialogue. For example, an open-ended question followed by a targeted follow-up question can encourage deeper reflection, prompting students to clarify or expand upon their initial response (van Zee & Minstrell, 1997). This combination is particularly effective in competence-based assessments, where students are expected to demonstrate not only knowledge but also the ability to apply and integrate scientific concepts in complex ways. Conversely, if closed questions dominate the dialogue without follow-up opportunities, assessors may miss valuable insights into students' higher-order thinking skills. In a competence-oriented

assessment context, the nature and amount of follow-up questions asked by assessors thus appear significant if they are to provide sufficient information about students' level of competencies.

Situating the Contribution of our Study

This study seeks to investigate science teachers' practices within the new examination format introduced in Danish lower secondary schools, with a specific focus on the types of questions they ask during assessments. In light of the above, understanding these practices is essential as the questions posed by assessors are instrumental in shaping the assessment environment and can significantly impact students' ability to demonstrate their competencies (Hattie & Timperley, 2007; Dolin et al., 2018b). Secondly, gaining insight into this provides relevant information for the ongoing efforts to align teachers' practices with the goals of competence-based education, ensuring that assessments truly reflect the competencies students are expected to develop (Nielsen et al., 2018; Darling-Hammond, 2014).

In summary, existing research on both the role of assessors and the nature of questioning in assessment highlights the complex dynamics at play during science exams. The interactions between assessors and students - mediated by different types of prompts and questions - are central to how students' scientific competencies are assessed, revealing important insights into the frame-setting of science assessment dialogues.

While the shift towards competence-oriented education has prompted some research on the challenges teachers face in implementing and assessing students' competencies in science education, there remains a significant gap in understanding how these changes are operationalised in practice, particularly during oral examinations. Existing studies have focused on assessment practices in other disciplines, classroom summative assessment or written exams/test constructs, leaving oral science examinations in lower secondary education

underexplored. This gap in the literature highlights the need for an in-depth investigation into how assessors frame and manage the dialogue during oral exams. Below, we briefly describe oral examinations of science competencies in Danish lower secondary schools in Denmark, where the present study was conducted.

Background

In the academic year 2016/2017, the Danish elementary school system underwent a substantial reform. Where the previous curriculum emphasised content knowledge, treating skills and knowledge as separate entities, the reform emphasises students' development of competencies introducing guidelines and exam requirements for four key competence areas: investigation, modelling, communication, and contextualization (UVM, 2020). These areas form the foundation for competence goals in the national standards, "Fælles Mål" (UVM, 2019), which specify the learning objectives students are expected to fulfil (UVM, 2020).

The emphasis on student competencies is especially evident in the science disciplines (biology, geography, and physics/chemistry), where teachers are required to plan for and conduct multidisciplinary teaching units for grades 7.-9., engaging with the four competence areas within and in collaboration between disciplines. These units are central to implementing competence-oriented science teaching and fulfilling the objectives of the Danish Compulsory School (UVM, 2021a). The significance of competence-orientation is highlighted by the introduction of a new oral exam format that is constructed to assess students' competencies across all four areas, centred around the topics covered in the units (UVM, 2022).

The new oral exam

Exam format

The examination is an integrated oral examination common to the disciplines of physics/chemistry, biology, and geography. The students can attend the examination individually or in groups of 2-3 students. Students or groups draw one of the multidisciplinary focus areas by lot. Within the chosen focus area, students are obliged to formulate a scientific problem with related questions from each of the disciplines, the problem being characterised by "(...) *one or more questions with scientific content, to which there is no clear answer*" (UVM, 2022). The problem becomes the basis for the investigation and preparation, which includes planning how they will address the problem during the exam. The problem and associated questions must be approved by teachers from alle three disciplines, and the examiners will prepare additional, unknown questions that assess the students' level of competence to be proposed during the exam.

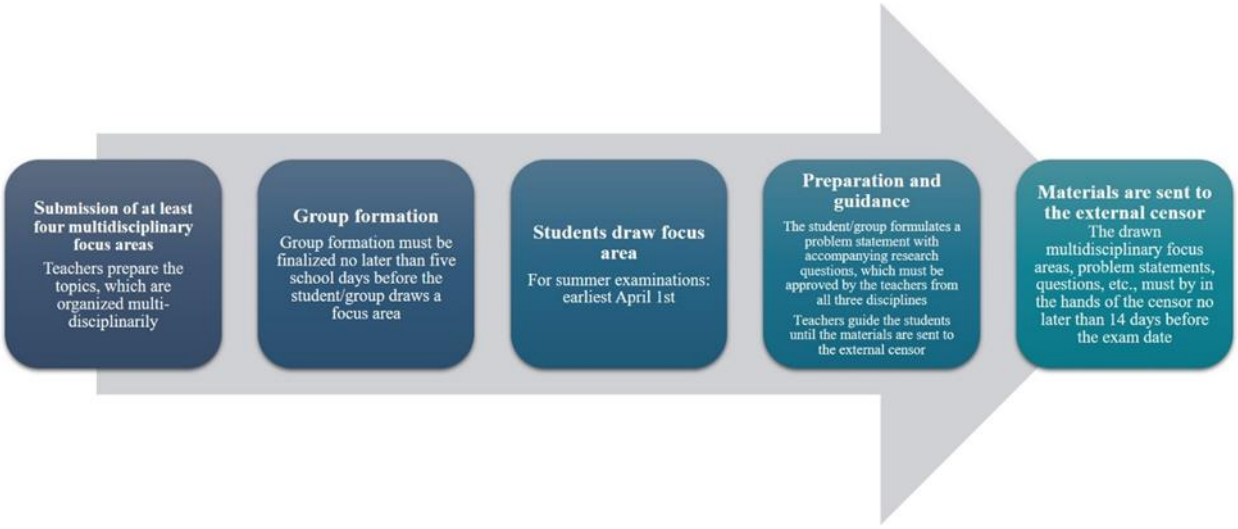

Figure 1 The process leading up to the exam (UVM, 2021b)

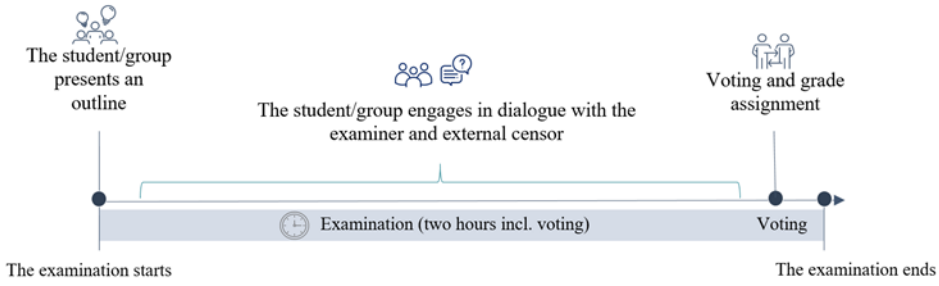

Figure 2 Examination day, adopted from (UVM, 2021b, translated from Danish)

The exam is conducted over a two-hour period (figure 2), during which groups of students are assessed simultaneously in the same room, each working on their individual problems.

Assessment Criteria and the Examiners' and Censor's roles

According to the regulatory examination guidelines, students are assessed based on their abilities to demonstrate scientific competence, focusing on how well they apply relevant scientific knowledge to specific, unknown problems rather than their performance in individual subjects (UVM, 2021b).

Each student is assessed individually, and both examiners and the censor share the responsibility for gaining a comprehensive understanding of each student's abilities through observation and dialogue with each student during practical work. Students are assessed across the three scientific disciplines, demonstrating their ability to:

A. Explain and justify the choice of investigations and models
B. Design, conduct, and draw conclusions from scientific investigations in conjunction with relevant models and perspectives
C. Apply, evaluate, and develop models in the context of investigations and perspectives
D. Argue scientifically

E. Use relevant terminology from physics/chemistry, biology, and geography
F. Propose and justify relevant courses of action

These assessment criteria are linked to the competence goals of the scientific disciplines, ensuring that the student is assessed based on their level of competence in the competence areas, with application of relevant subject-specific content from each of the three disciplines in relation to the chosen problem.

The assessment must be grounded in four competence goals outlined in the objectives for the science disciplines (UVM, 2021b). Examiners and the censor collaborate to establish a foundation for assessment of the student's competencies, guided by probing questions as the following examples provided in the exam guidelines (table 1):

Competence	**Competence goal**	**Directional questions/focus areas**
Investigation	The student can design, conduct, and evaluate investigations in physics/chemistry, biology, and geography.	• *Does the investigation stem from a question that illuminates the student's scientific problem?* • *Has the student formulated a hypothesis, and do they conclude based on this hypothesis?* • *Has the student considered variables in the investigation, and are data collected systematically?*
Modelling	The student can apply and evaluate models in physics/chemistry, biology, and geography.	• *Does the student use a varied selection of relevant models to illuminate their problem?* • *Does the student justify their choice of models based on the problem and critically reflect on their decisions?* • *Does the student reflect on the relationship between the model and reality?*
Contextualization	The student can relate physics/chemistry, biology, and geography to the external world	• *Does the student relate their chosen problem to the subject-specific content described in the skill and knowledge areas of the subjects?*

	and connect the content of the subjects to the development of scientific knowledge.	• *Does the student incorporate perspectives from their own environment and broader societal contexts?* • *Does the student propose solutions and actions related to the problem and justify these potential solutions and actions?*
Communication	The student can communicate about scientific issues using physics/chemistry, biology, and geography.	• *Does the student use relevant scientific terms related to the problem, demonstrating understanding and an overview of interconnections?* • *Does the student communicate effectively using well-chosen investigations, models, objects, and media?* • *Does the student argue scientifically, drawing from the content described in the skill and knowledge areas of the subjects?*

Table 1 Scientific competences for the Danish lower secondary school (translated from Danish), (UVM 2019)

According to regulations, the roles of both the examiners (teachers) and the censor (external assessor) are crucial to ensuring a comprehensive assessment. It is stated that their responsibilities go *beyond* observing student performance, as the examination regulation emphasises their roles tasked with actively engaging with students to assess their abilities to apply knowledge in an unknown context. According to the exam regulations, the examiner plays a central role by posing *open-ended* questions, unknown to the students beforehand, designed to probe deeper into their understanding of the chosen scientific problem. These questions should be designed to encourage critical thinking and student inquiry.

The dialogue between examiners, censor and students aims to prompt students to articulate their reasoning and justify their approaches, ensuring that the examination is based on a dialogue more than a test of a recall – it is stated in the regulations that it is an assessment of applied knowledge, problem-solving skills, practical work and ability to adapt to new challenges

presented during the examination. Throughout the exam, the assessors rotate between groups, observing their work and posing questions to stimulate further exploration.

Method and Data collection

This paper is part of a wider study that examines 18 Danish lower secondary school science teachers' practices in the context of adopting a recent educational reform. The teachers came from three schools in a municipality located in the Capital Region of Denmark and were selected due to a commitment at the managerial level to focus on the implications of the recent reform. Specifically, we present findings derived from the analyses of questions posed at oral exams, which means that all schools and teachers from the municipality are represented in this study. In total 31 students participated in the exams.

Data collection

The data for this study was collected through non-participant observation, following an ethnographic approach (Emerson et al. 2011). We observed three examination days at the three schools, adopting a "fly-on-the-wall" position to minimise our influence on the interactions between students, teachers, and examiners. Due to ethical restrictions, we were unable to obtain consent for audio recordings. Consequently, we relied on extensive field notes to capture the interactions and dialogues as accurately as possible. These notes include observations and verbatim quotes of dialogue between students, teachers, and external examiners (censors), written in real-time.

Immediately following each examination session, we transcribed the handwritten field notes into a digital format, annotating the data with details about the school, date, and the roles of speakers

in the dialogue. The transcription process also involved organising the data to clearly indicate who was speaking and what was being said.

Coding the Data

The data analysis followed an abductive approach (Timmermans & Tavory, 2012), blending deductive and inductive elements. It was deductive in that it was guided by a predefined focus on questioning practices, but specific codes and categories emerged inductively from the data as our analysis progressed. In practice, our coding process unfolded in two steps:

Step 1: Abductive coding process

We began by reading through the data and identifying all occurrences of assessor prompts. Although we had a general focus on assessors' questions, we did not apply any predefined codes at this stage. As patterns began to emerge, we iteratively developed and refined a set of codes to categorise different types of questions. This process involved constant comparison, revisiting previously coded data to ensure that the emerging codes remained grounded in the empirical material (Braun & Clarke, 2006).

To ensure coding reliability, we developed a coding scheme with three key columns: one for the code name, one for its description including the criteria for when a particular code should be applied (MacQueen et al., 1998), and one with illustrative examples of each code. Each code was developed to reflect differences in the nature and level of cognitive demand it would require for a student to answer it. This schema was iteratively refined, and inter-coder reliability checks were conducted throughout the analysis (Campbell et al., 2013). Any discrepancies in coding were discussed among the two authors, and the coding scheme was adjusted accordingly to reflect a shared understanding of each code. This process resulted in 9 codes. Among these, 2 codes were types of comments/prompts, 2 were types of closed questions, 2 were types of open-ended

questions, and 3 were types of follow-up questions posed immediately after another question. To clearly differentiate questions, we refined their descriptions informed by PISA's competence framework (OECD, 2019a). More specifically, we distinguished the codes by specifying whether the question typologies targeted an elicitation of student's knowledge (content knowledge, procedural knowledge, epistemic knowledge) or competencies (*activation* of knowledge, skills, attitudes and aptitudes appropriate in a specific, unknown context). We applied this specification to refine the description of all 9 codes.

Step 2: Coding focused on open questions

As the analysis progressed, we identified two distinct types of open-ended questions in our dataset. However, the differences between these two types were initially difficult to articulate explicitly. To resolve this, we also here drew on the PISA framework, more specifically their definitions on types of knowledge, cognitive demands and competence levels (OECD, 2019a; OECD, 2017). This allowed us to differentiate our two types of open-ended questions with respect to their differences in cognitive demands they would place on students. For example, some open-ended questions required a lower cognitive process, such as recalling or organising information, while others demanded a higher cognitive process, such as applying knowledge to unfamiliar contexts or evaluating multiple perspectives. Table 2 below provides an overview, description and examples of each code that emerged.

Code	**Description**	**Examples from data**
Comment from teacher or examiner attempting to continue dialogue	Examiner or censor makes a comment or statement that helps to a continuation of the dialogue with the student	*"Let us count"*
		"But here, the model shows something else"
		"Yeah, and then we will get to...?"
		"*I am not so sure about that"*

		"don't worry, that is okay!"
Comment from teacher or examiner shutting down dialogue	Examiner or censor makes a comment/statement/explanation that leads the dialogue with the student to stop.	*"They sail using bunker. Maersk will change their motors to sail using less polluting oil."*
Closed knowledge question limited to science process (experiment/presentation)	Examiner or censor asks a (closed) question aiming to elicit the student's knowledge related to the topic or experiment the student presented. Questions are characterised by being related to students' experiment and/or presentation and having only one correct answer.	*"When the plants produce oxygen, what is that process called?"*
		"What is osmosis?"
		"What is it comprised of, the layer that creates the greenhouse effect?"
Closed knowledge question without context	Examiner or censor asks a (closed) question unrelated to the student's prior presentation or experiment. The question has one correct answer.	*"What is an atom comprised of?"*
		"Why is it called ionising radiation?"
		"The photosynthesis, could we please see that?"
Open-ended question related to context, competence-oriented	Examiner or censor asks an (open-ended) question that requires students to apply knowledge and skills within a specific context unknown to the student. The question challenges students to extrapolate, develop, or consider alternatives and consequences. They help assess the student's ability to transfer their learning to new or unfamiliar situations.	*"What is your hypothesis here?"*
		"What could be a possible mistake in the way you created the experiment?"
		"Why is it that not all countries use sustainable sources of energy?"
		"What should happen during the next 60 years?"
		"What could be potential disadvantages to this?"
		"Could you expand your experiment in any way?"
		"Is it possible that you could have such a circuit at home?"
Follow-up closed question to elicit student knowledge	Examiner or censor asks a closed follow-up question. Questions are characterised by being related to students' experiment and/or presentation and having only one correct answer.	*"and is it something that is given from birth where one is to live and look?"*
		"and the windmill, what does that depend on?"

		"and what is that green spot there down by Antarctica?"
Follow-up open-ended question attempting to elicit level of competency	Examiner or censor asks an open-ended follow-up question that requires students to apply knowledge and skills within a specific context unknown to the student.	*"and why is that?"*
		"and what did you expect?"
		"then what would happen if we keep having fields without food for the animals?"
		"does the rest of the world have a responsibility, then?"
Follow-up open-ended question related to experimental setup or model	Examiner or censor asks an open-ended follow-up question related to aspects about the experimental setup or model used in presentation. This question type is different from open-ended competency-oriented follow-up questions and closed follow up questions in that the question requires students' application of knowledge, but not within a specific/unknown context.	*"what is supposed to happen with that thing in the middle, there?"*
		"something's cooking now! What else could you do there?"
Open-ended question inviting for scientific explanation of scientific content	Examiner or censor asks an (open-ended) question to which an answer requires the student to activate a cognitive process, which is of a more "straightforward nature", requiring the student to apply known facts or explain familiar concepts, knowledge or phenomena. While still open-ended, it is more focused and pertains to known concepts (e.g. the experiment or presentation or previous explanation). This question type is different from an open-ended competency-oriented question, and closed questions in that the question requires students' application of knowledge, but *not* within a specific/unknown context. The emphasis here is on the direct application of existing knowledge.	*"what happens when you burn off these things?"*
		"Earlier, you talked about good agricultural soil. Why do people look for those ions in the soil?"
		"what is it I am looking at in this model here?"
		"but what happens to the cell that is ionised?"

Table 2 Codes and descriptions

Approach to Analysis

At this stage, we quantified the distribution of codes to provide an overview of the types of questions/comments posed by teachers and external examiners. Using the coding scheme, we

counted the frequency of each code to quantify the types and distribution of questions and comments across the dataset. This quantitative analysis allowed us to identify patterns in the types of questions asked by assessors and was both conducted on the total data set and separately to each 3 schools.

In parallel with these analyses, we conducted an analysis of the assessor questions that followed their initial competence-oriented prompts. For each competence-oriented question, we analysed i) whether the competence-oriented questions posed by assessors were followed up by probing questions and ii) the distribution of the follow-up questions and whether the follow-up questions provided scaffolding of students' level of competence. The aim of these analyses was to reveal variations in assessment practices across different contexts.

Findings

We organise the findings of our analysis around three main sections: the distribution of questions at the municipal level based on data from all three school, the distribution of questions at each school and finally the types and distribution of follow-up questions asked by assessors after a competence-oriented question.

Municipality level

The following sections present the distribution of various types of questions and comments posed by examiners and censors during the exams. The total data set consists of 448 references to questions or comments, categorised into 9 types:

Code	Schools (n)	References (n)
Comment from teacher or examiner attempting to continue dialogue	3	55
Comment from teacher or examiner shutting down dialogue	3	43

Closed knowledge question limited to science process (experiment/presentation)	3	176
Closed knowledge question without context	3	8
Open-ended question, competence-oriented	3	34
- Follow-up closed question to elicit student knowledge	2	18
- Follow-up open-ended question attempting to elicit level of competency	3	10
- Follow-up open-ended question related to experimental setup or model	2	5
Open-ended question inviting for scientific explanation of scientific content	3	99
Total		448

Table 3 Results

Table 3 shows the distribution of 448 instances of teacher and examiner questions and comments during exams. The most frequent were *closed knowledge questions limited to science process* (n=176), focusing on elicitation of student knowledge. *Open-ended questions probing for scientific explanation* (n=99) and *dialogue-continuing comments* (n=55) also appeared prominently. However, *dialogue-stopping comments* (n=43) were also common. *Competence-oriented open questions* (n=34), show attempts to elicit student competencies, though these were less frequent compared to knowledge-based questioning. *Closed questions unrelated to the student's prior presentation or experiment* equivalent to a total of 8 number of questions in numerical values, represent the least frequently asked questions.

Figure 3 below presents the distribution of questions asked by teachers and examinators across all three schools.

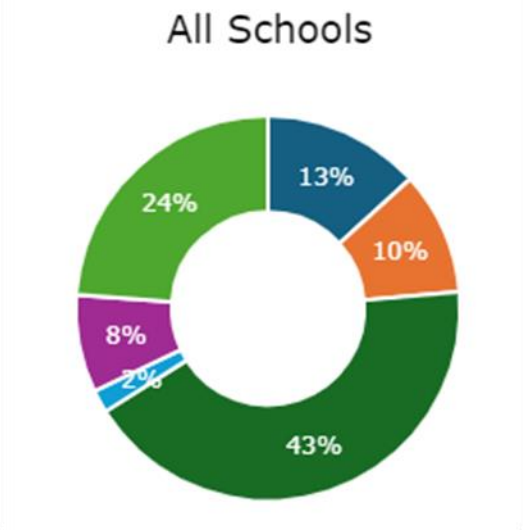

Fig. 3. The distribution of questions and comments from assessors during the oral exams grouped by type: Closed knowledge question limited to scientific process (dark green), Open-ended questions inviting for scientific explanation of scientific content (light green), dialogue-continuing comments (dark blue), dialogue-stopping comments (orange), open-ended competence-oriented questions (purple), and closed knowledge questions without context (light blue), with the percentages indicating how frequently each type of prompt occurred.

School level

Figure 4 below shows the distribution of questions asked at each of the three schools.

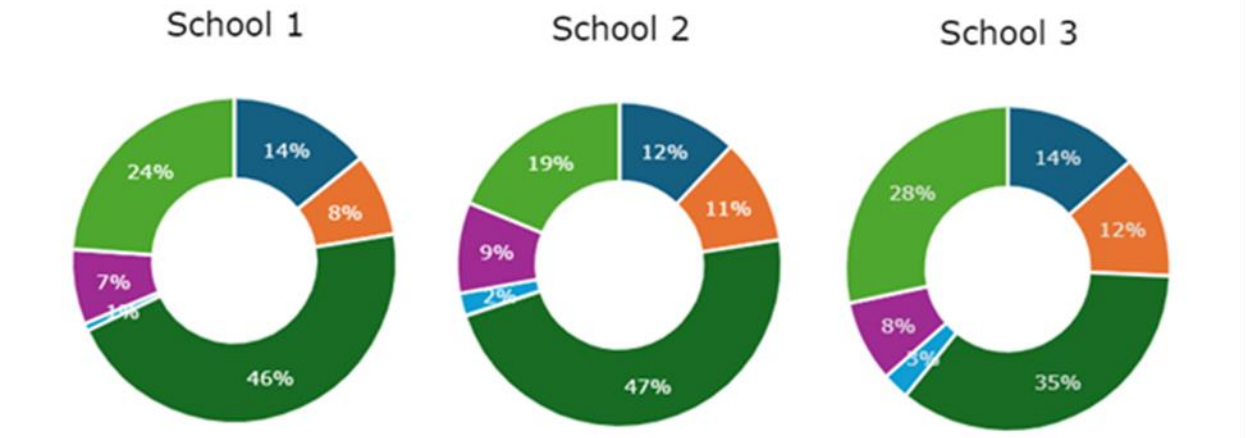

Fig. 4. The distributions of questions and comments from assessors during the oral exams grouped by type: Closed knowledge question limited to scientific process (dark green), Open-ended questions inviting for scientific explanation of scientific content (light green), dialogue-continuing comments (dark blue), dialogue-stopping comments (orange), open-ended competence-oriented questions (purple), and closed knowledge questions without context (light blue), with the percentages indicating how frequently each type of prompt occurred.

As illustrated in the three charts, the distribution of questions is notably similar across all three schools. Generally, the figure mirrors the tendency at the municipal level that closed questions aiming to elicit student knowledge is dominant. The second most frequent type of question is open-ended questions inviting students' scientific explanation of science content, and we see an approximately equal distribution across the schools of comments from assessors either stopping or continuing the dialogue, open-ended competence-oriented questions, and closed knowledge questions without context. In all three schools, closed questions unrelated to the student's prior presentation or experiment are by far the least frequently asked.

The number of dialogue-shutting comments varied between schools, with School 1 having 11 instances, School 2 with 14, and School 3 with 18. Open-ended questions related to context, competence-oriented, which requires students to activate knowledge and skills within a specific context, is relatively consistent across the three schools: School 1: 10 instances, School 2: 12 instances, and School 3: 12 instances.

Follow-up questions

To recall, we conducted an analysis of the follow-up question(s) that followed competence-oriented questions (table 3). There were 34 questions across all three schools that sought to elicit students' level of competence. In total, 18 of these questions were followed by follow-up questions. Figure 5 below shows the distribution of the types of follow-up questions in these instances.

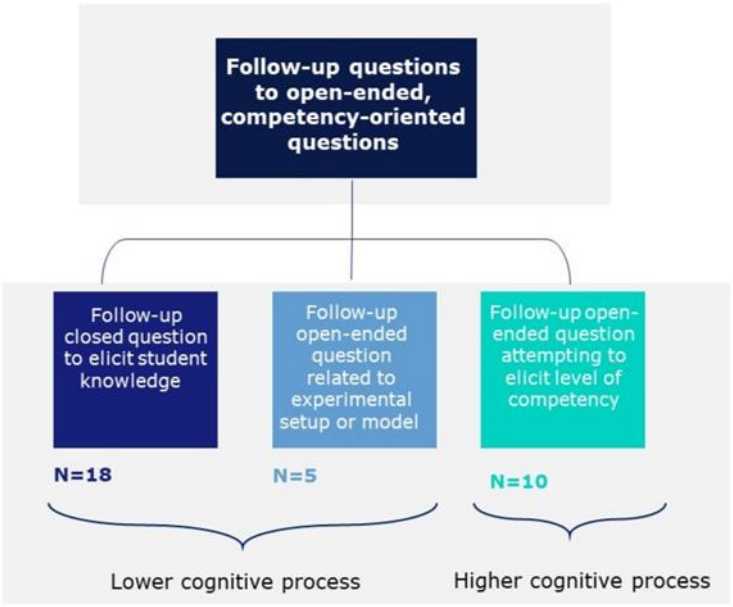

Fig. 5 Follow-up questions

The most prominent follow-up questions are closed questions that seek to elicit student knowledge (n=18) and open-ended questions that seek to elicit students' level of competence (n=10). In all three schools, open-ended follow-up questions related to the students' experimental setup or model (n=5) are the least frequently used. Building on PISA's definition of competence, which emphasises the ability to apply knowledge, skills, and attitudes in unknown contexts to meet complex demands, the follow-up questions can be categorised into two distinct groups based on their focus: *open-ended questions attempting to elicit competence-acquisition* (10) aligning closely with PISA's broader conception of competence, as they demand a higher cognitive process from the student, by for example applying knowledge/evaluating multiple perspectives in unfamiliar contexts and encourage students to reflect, apply reasoning and demonstrate higher-order thinking. In contrast, the other group of questions which represents the overweight of follow-up questions, i.e. *closed questions attempting to elicit student knowledge* (18) and *open-ended questions about experimental setups or models* (5) are all questions that

demand a lower cognitive process, such as recalling and/or organising information by probing for specific knowledge or verifying understanding in a straightforward manner.

Discussion

Previous studies have documented that science teachers often struggle to adapt their teaching practices to adhere to competence-based curricula (Bybee, 2013; Christiansen et al., 2013). This is particularly true among science teachers in Denmark who have expressed immense difficulties in making use of their teaching experience in adhering to the new, competence-oriented science curriculum (Tidemand, n.d.). Thus, changing the science curriculum should not be assumed to automatically result in corresponding changes in teachers' practices. Conversely, the term backwash refers to the phenomenon that teachers tend to change their practices to align with the assessment format and contents (see e.g. Dolin et al., 2018a; Black, 2000; Alderson & Wall, 1993; Cheng, 2014). This makes Danish oral exams in science an interesting case to study, as the introduction of a competence-based science curriculum has recently been accompanied by a new format for oral examinations. The key question becomes: How do science teachers navigate within such a context?

As outlined in the related works section, assessors play a critical role in shaping students' opportunities to demonstrate scientific competencies, particularly through the questions they pose in assessment contexts. Our analyses revealed several concerning trends. First, it is noteworthy that the by far most frequent type of question was closed a closed question aiming at eliciting students' knowledge related to the experiment or presentation. This suggests that a significant portion of the assessment is focused on evaluating students' subject knowledge rather than their competencies. Second, although there were open-ended questions targeting higher-

order thinking, the majority of questions in our data focused on student knowledge about discipline-specific contents.

Our findings show that the assessors' approaches to frame the oral exams by far prioritise knowledge over competencies. In quantitative measures, our study documents a striking imbalance between what is prioritised in the curriculum learning objectives, how the regulatory exam guidelines describe the assessors' roles in eliciting a foundation for assessing the students, and the actual questions posed during the examinations. In other words, our results indicate an alignment issue: what is emphasised in the curriculum does not align with the focus of the oral exam questions. This is particularly troubling given that the Danish lower secondary education requires science teachers to teach and assess students' scientific competencies, which, as we know from previous research, is highly challenging.

Given that changes in exam formats are known to affect teacher practices, we wondered whether the introduction of a formalised competence-oriented oral examination format would mirror the type of questions asked by the assessors. This turned out not to be the case. Both the regulatory guidelines and the research literature emphasise that oral examinations should offer a dialogic assessment context, where assessors gather evidence of students' understanding and levels of competencies (Griffin, 2007; Dolin et al. 2018b). This potential, however, relies on how teachers orchestrate these dialogues.

Previous research highlights the importance of follow-up questions in promoting dialogues that go beyond surface-level responses. Particularly, we know from research that open-ended questions followed by targeted follow-ups, which encourage students to clarify and elaborate their initial responses, are considered effective in the context of assessing competencies. In contrast, dialogues dominated by closed questions are seen as counterproductive. This stands in

stark contrast to our findings, where closed questions were the norm and with a limited frequency of follow-up questions following competence-oriented questions, which indicates that while *some* competence-oriented questions are posed, assessors do not frequently build on these questions to further explore students' competencies in depth. This raises concerns about whether the teachers' assessment practice is truly accurate for assessing students' level of competence. Furthermore, the limited use of open-ended follow-up questions may restrict assessors' ability to fully explore students' competence development, which highlights a potential gap in the assessment dialogue: This infrequent use of iterative open-ended follow-up questions could hinder the thorough diagnosis of students' understanding and reasoning processes, ultimately affecting the robustness of the competence-based assessment.

A key takeaway from this study is the need to explore how confident science teachers feel in assessing student competencies during oral examinations. The shift from traditional knowledge-based to competence-based assessment presents a significant pedagogical challenge, particularly because it requires teachers to engage with a different taxonomy of questioning and assessment than they are used to (McMillan, 2013). Despite the introduction of the new exam format in Denmark, many teachers have not necessarily been provided with sufficient professional development or guidance to support this shift. The official guidelines offer limited support, leaving many teachers without a clear understanding of how to frame questions and dialogues to assess competencies effectively. This lack of support places unreasonable demands on teachers, expecting them to develop new approaches assessment without adequate training or resources.

Our findings suggest the need for professional development should go beyond classroom instruction and include formal training in assessment practices. It must equip teachers with practical tools for formulating open-ended, competence-focused questions and structuring

dialogues that allow students to demonstrate higher-order thinking. Peer learning, coaching, and real-time feedback have been shown to improve teachers' confidence and abilities to implement changes in their practice (Wyatt-Smith et al., 2010; Kilday et al., 2011). Strengthening teachers' skills in this area will help ensure that their assessment practices align more closely with the goals of the new curriculum, which is essential to pay attention to if we wish to continue to rely on the validity of exam results.

Our study offers initial insights into a highly under-studied research context. Given the significance of assessor questions in shaping dialogues, we chose to limit our focus on this aspect. Although prior studies have warned against self-reported studies and surveys (Moos, 2013), moving forward it would be interesting to explore teachers' perspectives on their role as assessors of competencies. Qualitative studies investigating how teachers perceive and approach assessment of student competencies in the context of oral exams will provide deeper insight into how assessment practices can be better aligned with curricular goals. Do they feel competent to facilitate such an examination? What specific challenges do they encounter? When do they believe to have sufficient knowledge about students to assess their levels of competencies? Moreover, examining the impact of targeted professional development on teachers' questioning techniques and the affordances for students during oral examinations could further illuminate ways to bridge the gap between curriculum and practice.

Conclusion

The purpose of this paper was to investigate the types and distributions of questions asked by assessors during oral exams aiming at eliciting information about students' levels of scientific competencies in a newly introduced competence-based oral assessment format for lower

secondary school in Denmark, in the context of a recent competence-oriented curriculum reform. To address this, we observed and subsequently the questions posed Danish science teachers and external examiners during oral examinations at three schools within one municipality.

Our investigation of the types of questions asked by assessors revealed a concerning misalignment between the aims of the new curriculum and the exam regulations and the assessors' actual assessment practices. Although the curriculum emphasises the development of students' scientific competencies, the by far most frequent types of questions posed by assessors focused on eliciting students' knowledge, particularly through closed questions. Moreover, we saw a low frequency of follow-up questions, especially to open-ended, competence-oriented prompts, which is described essential in the assessment of competencies. Overall, these approaches provide limited opportunities for students to demonstrate the full range of their scientific competencies.

This misalignment raises questions about whether current practices allow for an accurate and comprehensive assessment of students' competencies and suggests the need for professional development to better equip teachers in competence-based assessment techniques. Given that prior research has shown that changes in assessment formats can influence teaching practices, it is critical that teachers are supported in the form of professional development. Without targeted training and guidance, the shift from knowledge-based assessment to competence-based assessment will continue to present challenges for teachers, potentially hindering the effectiveness of these reforms.

For reforms in science education to be successful, there must be a concerted effort to align curriculum, assessment practices, and teacher training. Professional development programs must address the specific demands of competence-based assessments, ensuring that teachers are able

to pose questions and guide assessment dialogues at the appropriate taxonomic level. Without this alignment, the long-term goals of competence-based education may remain unrealised, and the educational system risks conserving outdated assessment practices that fail to meet the needs of both students and society.

Although the context and background of this study are specific to Denmark, the research focus is highly relevant from a broader, international perspective. The challenges associated with competence-based education and assessment practices are not unique to Denmark but reflect global trends in educational reforms. As such, the findings from this study have the potential to contribute to the wider discourse on how competence-oriented approaches are operationalised in assessment practices across different educational systems.

Ethics statement

The present study does not require approval from an ethical committee as the collected data does not contain any personal information. The study complies with the Danish Code of Conduct for Research Integrity. Consent was obtained from all participants after they were fully informed about their involvement in the research and the purpose of the study. They were explicitly informed that their participation was voluntary and that they could withdraw at any time (Creswell & Poth, 2016). All data collected during the study was anonymized and securely stored. Identifiable information was removed from data to safeguard the identities of the participants (Brinkmann, 2020).

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