THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Composing Connections to Society

Enacting Academia's Third Mission Through Science Communication and Industrial PhDs

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Cover:
Composing Connections (painting by Maria Cervin-Ellqvist)
Illustration of people on a bridge between academia and society, including industry. The blue person on the bridge represents people coming from academia and communicating to or with society, the orange person represents people coming from industry to academia, and the green person represents those who are in the middle. The painting was digitised by Magnus Axelsson.

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Abstract

Universities are increasingly expected to engage with society, in addition to their traditional missions of research and teaching. This is often framed as academia's *third mission*. While pushed for at the policy level, it is realised by individuals composing connections between academia and other parts of society in their everyday practices. To promote engagement in practice, it is important to understand, support, and encourage it at the individual level.

This thesis examines two aspects of the third mission: science communication and industrial PhDs. The former refers to the communication of research to audiences outside academia, while the latter is a form of collaborative doctorate involving both academia and industry. Bringing these together, the thesis focuses on individuals who contribute to connecting academia with other parts of society. The thesis builds on four studies using both qualitative and quantitative methods. It addresses two overarching questions: how researchers engage in science communication and self-regulate their science communication practices; and how industrial PhD students broker knowledge between academic and industrial contexts.

The findings show variation in science communication practices across disciplines and individuals, in terms of engagement, genres, and audiences, and a broad range of writing and self-regulation strategies used by researchers with extensive science communication experience. The findings on industrial PhDs show that these students often take on, and are expected to take on, the role of knowledge brokers between academia and industry, here theorised as different discourse communities and communities of practice, but often struggle to navigate their dual contexts. Overall, the findings illustrate that enacting the third mission provides opportunities for learning and knowledge exchange but also challenges related to time, recognition, and institutional support.

Bringing together perspectives on science communication, doctoral education, and knowledge brokering, the thesis suggests that the enactment of the third mission depends not only on policy ambitions but, to a large extent, on the practices and conditions of individuals. It highlights the need to better recognise and support the third mission as part of academic work, through training, structures, and institutional support. Finally, it underscores the importance of communities in composing connections to society.

Keywords: third mission, science communication, industrial PhD students, knowledge brokering, higher education, doctoral education, industry-academia collaboration, communities of practice, discourse communities, self-regulated learning

Svensk sammanfattning (*Eng: Summary in Swedish*)

Universitet och högskolor förväntas samverka med det omgivande samhället i allt högre utsträckning, utöver sina traditionella uppgifter inom forskning och utbildning. Detta benämns ofta som den *tredje uppgiften*. Även om tredje uppgiften betonas på policynivå, omsätts den i praktiken av individer som i sitt dagliga arbete skapar och upprätthåller kopplingar mellan akademin och andra delar av samhället. För att främja denna uppgift i praktiken är det därför viktigt att förstå, stödja och uppmuntra den på individnivå.

Denna avhandling behandlar två aspekter av den tredje uppgiften: forskningskommunikation och industridoktorander. Den förstnämnda avser kommunikation av forskning till målgrupper utanför akademin, medan den senare är en form av forskarutbildning i samverkan mellan akademi och industri. Genom att föra samman dessa perspektiv riktar avhandlingen fokus mot individer som bidrar till att skapa förbindelser mellan akademin och det omgivande samhället. Avhandlingen bygger på fyra studier som använt både kvalitativa och kvantitativa metoder och behandlar två övergripande frågor: hur forskare engagerar sig i forskningskommunikation och reglerar sina forskningskommunikationspraktiker, samt hur industridoktorander fungerar som kunskapsförmedlare mellan akademiska och industriella miljöer.

Resultaten visar att forskningskommunikationspraktiker varierar mellan discipliner och individer vad gäller engagemang, genrer och målgrupper, samt att forskare med omfattande erfarenhet av forskningskommunikation använder en bred repertoar av skriv- och självregleringsstrategier. När det gäller industridoktorander visar resultaten att dessa ofta tar på sig, och förväntas ta på sig, rollen som kunskapsmäklare mellan akademi och industri, vilka här teoretiseras som olika diskurs- och praktikgemenskaper, men att de samtidigt ofta möter utmaningar i att navigera mellan sina två sammanhang. Sammantaget visar resultaten att arbetet med att omsätta den tredje uppgiften i praktiken skapar möjligheter till lärande och kunskapsutbyte, men också innebär utmaningar kopplade till tid, erkännande och institutionellt stöd.

Genom att kombinera perspektiv på forskningskommunikation, forskarutbildning och kunskapsmäkleri visar avhandlingen att den tredje uppgiftens genomförande i praktiken inte enbart är beroende av politiska ambitioner, utan i hög grad är avhängigt individers praktiker och villkor. Den pekar på behovet av att i större utsträckning erkänna och stödja den tredje uppgiften som en integrerad del av akademiskt arbete, genom utbildning, strukturer och organisatoriskt stöd. Avslutningsvis betonas betydelsen av gemenskaper för att skapa och upprätthålla kopplingar mellan akademin och samhället.

List of appended papers

This thesis is based on the following papers:

Paper 1 Cervin-Ellqvist, M., Johansson, S., Persson, M. Sjöberg Hawke, C., & Negretti, R. (2023). The silent tribe: Mapping the variety of researchers' science communication practices across STEM disciplines. In Nelson, M., Michanek, M., Rydell, M., Sayehli, S., Skogmyr Marian, K., & Sundberg, G. (Eds.). *Språk i praktiken - i en föränderlig värld*. Rapport från ASLA-symposiet, Stockholms universitet, 7-8 april 2022. [Language in practice – in a changing world. Papers from the ASLA symposium. Stockholm University, 7–8 April, 2022] (pp. 60–85). ASLA, The Swedish Association of Applied Linguistics. Stockholm. https://doi.org/10.17045/sthlmuni.24321526

I contributed to the study design, data analysis and writing up the study. Specifically, I was responsible for the analysis of metadata and full texts, but not for the network analysis aimed to explore co-authoring patterns.

Paper 2 Negretti, R., Sjöberg Hawke, C., Persson, M. & Cervin-Ellqvist, M. (2023). Thinking outside the box: Senior scientists' metacognitive strategy knowledge and self-regulation of writing for science communication. (2023). *Journal of Writing Research*, *15*(2), 333-361. https://doi.org/10.17239/jowr-2023.15.02.04

I contributed to the study design, data analysis and writing up the study together with all co-authors. I did not participate in the data collection.

Paper 3 Cervin-Ellqvist, M., Negretti, R., & McGrath, L. (2026). The industrial PhD: Student perspectives on learning, communicating and knowledge brokering. *Studies in Graduate and Postdoctoral Education*. https://doi.org/10.1108/SGPE-09-2025-0128

All authors contributed to the study conception and design, with Maria in lead for this process. Material preparation, data collection and analysis were performed by Maria Cervin-Ellqvist. The first draft of the manuscript was written by Maria Cervin-Ellqvist and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Paper 4 Cervin-Ellqvist, M. (*In review*). Being, becoming and brokering: Industrial PhD students' positioning within industrial and academic communities.

Under review for Industry and Higher Education. I was the sole contributor in conceiving, carrying out and writing up the study.

Other relevant publications

Negretti, R., Cervin-Ellqvist, M., & Johansson, S. (2020). *Scientific Communication Beyond Academia*. Report from the research project "Scientific communication and metacognition: Thinking outside the box". Chalmers University of Technology: Department of Communication and Learning in Science. https://doi.org/10.17196/cls.genie.001

Cervin-Ellqvist, M., Larsson, D., Adawi, T., Stöhr, C., & Negretti, R. (2021). Metacognitive illusion or self-regulated learning? Assessing engineering students' learning strategies against the backdrop of recent advances in cognitive science. *Higher Education, 82*(3), 477-498. https://doi.org/10.1007/s10734-020-00635-x

Cervin-Ellqvist, M. (2022) *(Re)harmonising the Academy: Integrating life-long learning and science communication into Swedish higher education* [Licentiate thesis, Chalmers University of Technology].
https://research.chalmers.se/publication/533644/file/533644_Fulltext.pdf

Cervin-Ellqvist, M. (2025, 15 April). Like a bridge over troubled water?. *Sheffield Institute of Education blog*, https://blogs.shu.ac.uk/sioe/2025/04/15/like-a-bridge-over-troubled-water/

Cervin-Ellqvist, M. (2025). *Industrial PhD Students' Acknowledgements: Navigating Conventions and Constructing a Publishable Version of Reality*. [Bachelor's thesis, University West]

Khuder, B., Cervin-Ellqvist, M., Vander Borght, M., & Wingrove, P. (2026). Academic socialisation through AI and peer feedback in doctoral writing: information and orientation in feedback ecologies. *Assessment & Evaluation in Higher Education*, 1–20. https://doi.org/10.1080/02602938.2026.2653882

Statements

Reusage of text from my licentiate thesis

Two of the four papers included in this doctoral thesis were also included in my licentiate thesis, and the theses thus overlap to some extent though the foci and framing are different. Therefore, parts of the introductory text (kappa) are reused from the licentiate thesis. This material has been incorporated where relevant, specifically in the parts concerning science communication, and is reused in accordance with institutional guidelines.

Usage of Artificial Intelligence

I declare that I am the author of this thesis and that I used Artificial Intelligence (AI)-based tools (Microsoft Copilot and occasionally ChatGPT) in a limited capacity during the writing process. All AI use was based on my own drafts and text material. Specifically, AI was used after producing initial drafts to improve language, clarity, and structure, and at later stages for proofreading and minor revisions. AI tools were not used for data analysis, interpretation, or the development of arguments and conclusions. All content has been critically reviewed and I am solely responsible for it as the author of this PhD thesis.

Acknowledgements

During my PhD, a postcard with an untitled painting by Birgit Jürgenssen has hung above my desk. It shows blades of grass grow that, as they grow, gradually transform into green birds flying on grass-green wings. Learning to fly requires both skills and a supportive environment; the birds need opportunities to test their wings but also support to avoid crashing too hard. This painting reminds me of the PhD journey, of its beginning, its process, and its goal. Flying, or conducting research independently, may seem impossible at first, but over time, through practice and with the right support, wings develop and one gradually learns how to use them. This acknowledgment is an attempt to thank the many people who have contributed to my PhD journey in various ways and provided the support and encouragement I needed along the way.

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discussing, and talking with you. Note that this thank you is of course for those of you who have been (or will be) directly involved in my PhD in some way, perhaps as an examiner, director of studies, manager, teacher or participant in a course, an opponent, or part of my grading committee. But it is also for those of you who have not been directly involved, because also other things, like chatting at lunch or in a corridor, are needed in a PhD journey and to enjoy going to work. A specific thank you to Stina, Carina, and Maria, my wonderful co-authors for Papers 1 and 2. Anna, Malin, and those I have met through DrGenie, thank you for all our interesting and refreshing discussions on diversity, equality, and inclusion as well as on other matters. Thank you also to my master's thesis students from Learning and Leadership who have brightened three of my spring semesters with your ambitious projects and eagerness to explore, improve, and learn.

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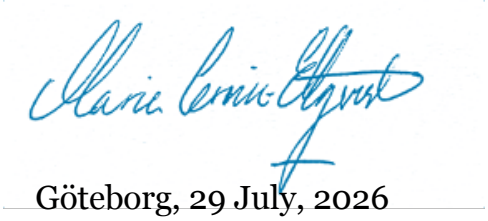


Göteborg, 29 July, 2026

Table of Contents

1. Introduction

Academia is sometimes portrayed as an ivory tower—an entity that is largely separate from the rest of society and focused on knowledge for its own sake rather than concretely contributing to society (Hancock & Walsh, 2016). The ivory tower metaphor might never have been entirely accurate, but it is by necessity becoming less accurate. While some might feel that "sometimes we need to accept that science is just for the sake of the science" (participant in Paper 4), today's complex societal challenges have in fact increased the societal demands on academia. Universities are expected to contribute not only indirectly by advancing knowledge generally, but also directly and concretely to solving pressing problems and providing highly skilled people to the workforce (Grimm, 2018; Hadgraft & Kolmos, 2020; Hancock & Walsh, 2016; Mitic & Okahana, 2021; Pertuz et al., 2021). Consequently, communication and collaboration between academia and external actors, for instance industry, policy-makers, governmental agencies, and the public, are increasing (Perkmann et al., 2021; Pertuz et al., 2021; Tomlinson, 2018; Thune, 2009).

Governments across the globe are pushing for this development through policies and funding, emphasising that the public should benefit from research conducted by higher education institutions (e.g. SFS 1992:1434; Perkmann et al., 2021; Sjöö & Hellström, 2019). In Sweden, communication of science to audiences outside of academia—often referred to as the third mission (Compagnucci & Spigarelli, 2020)—was already included in law in 1977 (Hetland et al., 2020). While the first and second missions are referring to research and teaching, the third mission is that of reaching outside the ivory tower (Perkmann et al., 2021), which today entails connecting, communicating, and collaborating with, as well as brokering knowledge to, other actors in society. The third mission has been around for a long time now, especially in Sweden, and there is clearly a policy push for it. However, research into how it is enacted in practice shows that there are still issues to resolve to make sure the policy intentions are enacted in practice to a higher extent (e.g. Bohlin & Bergman, 2019).

In practice, the third mission takes many forms (Compagnucci & Spigarelli, 2020). In this thesis, I explore two: *science communication*, meaning communication of science to audiences outside of academia (Bucchi, 1996; Davies, 2021; Entradas et al., 2020; Hetland et al., 2020; Kappel & Holmen, 2019; Renwick et al., 2020; SFS 1992:1434), and collaborations with external organisations, specifically collaborations in *industrial PhD projects* (Compagnucci & Spigarelli, 2025; Jones, 2018) where the PhD student is employed by an external organisation and affiliated to a university.

Note that while previous research highlights the importance of communication to ensure knowledge exchange between academia and the outside world (e.g., Kihlander et al., 2011; Santos et al., 2021), communication alone is not enough to ensure actual knowledge utilisation (Bulkeley & Mol, 2003; Turnhout et al., 2013). Instead, *knowledge brokering* (Wenger, 1998; 2002) is needed to ensure that "knowledge production and use" (Turnhout et al., 2013, p. 356) are linked. *Knowledge brokers* can then be broadly defined as "experts who interact, communicate, facilitate learning, share, and create knowledge across sectors" (Garcia-Morante et al., 2025, p. 303). Overall, despite policy ambitions and an agreement on the importance of the third mission, to what extent and how brokering actually happens in practice seems to depend on individual researchers and PhD students. However, they often lack sufficient support and need to prioritise other tasks, for example research, or fulfilling the formal academic requirements of a PhD. These issues risk causing academia to remain too disconnected from society compared to what is needed to solve today's societal challenges. Knowledge brokers between academia and other parts of society may, for example, be full-time researchers at an academic institution who engage in dialogue with policymakers or other audiences, or industrial PhD students with one foot in industry and one in academia. Understanding their roles, conditions, and support needs is essential for strengthening and creating new connections between academia and other parts of society, and ultimately promoting the enactment of the third mission in practice. I therefore focus on these two groups, their communication and brokering as well as social dimensions and training relating to their enactment of the third mission.

Regarding the first example, science communication, research internationally shows that while policies may be well intended, there is a lack of incentive for researchers to engage in science communication (Pérez-Llantada, 2021; Schimanski & Alperin, 2018). This is an issue given that engagement and initiatives often come from the researcher themselves, who do so because they want to, though funding agencies sometimes require communication to society to some extent (Wilkinson et al., 2023). Even in Sweden, with its long policy tradition, researchers report lacking time, training and incentives needed to engage in science communication, despite positive attitudes towards science communication (Bohlin & Bergman, 2019; similar to findings from other countries, e.g., Llorente et al., 2019; Pérez-Llantada, 2021; Schimanski & Alperin, 2018). In addition, researchers' engagement varies across disciplines and topics (Bohlin & Bergman, 2019) and so does the public's interest (Ampollini & Bucchi, 2020; Bucchi, 1996; Jönsson et al., 2018).

Taken together, these circumstances make it difficult to measure, evaluate and teach science communication (Baram-Tsabari & Lewenstein, 2017; Olesk et al., 2021; Pinheiro et al., 2015). It is further complicated by the fact that science communication is an umbrella term for many different types of communication with audiences outside of academia (Davies, 2021; Kappel & Holmen, 2019). Papers 1

and 2 address some of the issues by mapping science communication output at a large Swedish STEM[1] university (Paper 1) and examining what strategies senior researchers use in writing science communication and how they self-regulate their writing (Paper 2). In addition, these papers respond to calls for further research on the perspectives of the individuals who enact the third mission through science communication, their processes when engaging, and the people surrounding them (e.g. Perkmann et al., 2021). The insights from Paper 1 provide a starting point to better support and promote researchers' science communication by mapping what it actually entails. The insights from Paper 2 add to the understanding of what characterises active and successful science communication practices.

Regarding the second example of the third mission, collaborations between industry[2] and academia, collaboration may take many forms, whereof one increasingly common form is collaborative doctorates (Compagnucci & Spigarelli, 2025). These collaborative doctorates are particularly common in STEM, where the overall push for industry-academia collaboration is also especially evident (Compagnucci & Spigarelli, 2025; Hadgraft & Kolmos, 2020; SCB, 2024). Perhaps this is because STEM disciplines are assumed to be especially important in solving some of today's biggest societal problems (e.g., climate change, pollution, and loss of biodiversity; Grimm, 2018; Hadgraft & Kolmos, 2020; Pertuz et al., 2021). In addition, STEM companies can benefit from academic research and expertise to drive innovation (Grimm, 2018; Gustavsson et al., 2016; Thune & Børing, 2015). Ideally, collaborative doctorates bring industry and academia closer, entail knowledge brokering and result in research that is valuable from an academic perspective and applicable in industry (Compagnucci & Spigarelli, 2025; Tomlinson, 2018). The doctoral students also presumably learn skills needed not only in academia—as traditional doctorates are often critiqued for—but also in industry and in industry-academia collaborations (Ashonibare, 2023; Granata & Dochy, 2016; Jones, 2018; Mitic & Okahana, 2021). However, previous research shows that almost all communication in these projects goes through the doctoral student (Bernhard & Olsson, 2023), who is often the sole knowledge broker (Wallgren, 2007), suggesting similarities to science communication in terms of the importance of individual researchers and their initiatives.

Previous research has examined the challenges and the realities of collaborative doctorates to some extent, concluding that it is challenging to navigate dual contexts, deal with differing expectations, communicate in and across their contexts, learn the skills needed and get sufficient support (Compagnucci &

[1] STEM: Science, Technology, Engineering, and Mathematics

[2] *Industry* in my thesis, as well as in Papers 3 and 4, refers to companies and other non-academic organisations, including non-governmental organisations (NGOs) and governmental agencies.

Spigarelli, 2025; Grimm, 2018; Jones, 2018; Tavares et al., 2020; Thune, 2009; Wallgren, 2007; Wallgren & Dahlgren, 2007). However, many questions remain and more detail and theorising are needed in several areas. Two such areas are 1) industrial PhD students'[3] communication in and across their two contexts and 2) what roles various people and groups play in the industrial PhD. In Paper 3, I address the first area and theorise industrial PhD students as knowledge brokers between discourse communities (DCs), examining their communication and communication challenges in their academic and industrial discourse community as well as in brokering between the two. In Paper 4, I address the second area and theorise industrial PhD students as knowledge brokers between communities of practice, exploring what actors are involved in this type of collaborative doctorate, what roles they play and the students' connections to communities of practice in the different contexts. In both papers, I conclude with implications clearly grounded in both empirical evidence and theory to ensure the research is useful in practice.

By exploring two ends of the spectrum of activities included in the third mission, science communication and brokering in industrial PhDs, in this thesis I provide insights into the roles, practices, and challenges of individuals who presumably enact the third mission, and the conditions that enable constructive connections between academia and other contexts. While science for the sake of science can be interesting (to paraphrase a participant in Paper 4), I focus strongly on the implications of this research: what it means for support and training of those who engage in the third mission, and the composition of constructive connections between academia and the rest of society.

The aim of my thesis is therefore to explore how the third mission is enacted through science communication and industrial PhDs in STEM, with a particular focus on the roles, practices, and challenges of individuals presumably enacting the third mission and the implications for support, training, and policy.

To address this aim, my thesis is guided by two research questions (RQs):

1. How do researchers engage in science communication, and what strategies can be used to successfully self-regulate science communication writing? (Papers 1 & 2)
2. In what ways do industrial PhD students broker knowledge between academic and industrial contexts, and what challenges influence this process? (Papers 3 & 4)

[3] There are several types of collaborative doctorates, which I will discuss in chapter 2, section 2.3, but in brief, I focus on industrial PhD students, who are typically employed in industry by a company or other organisation who funds their PhD, affiliated to a university, and have to fulfil the academic requirements as traditional PhD students (Compagnucci & Spigarelli, 2025; Grimm, 2018; Jones, 2018).

Combined, my papers show what factors enable the enactment of the third mission, and provide insights that can inform support, training, and policy.

Note that I intentionally use the term *communities* to maintain conceptual inclusivity across the four papers. Paper 4 draws on the theory of communities of practice (CoPs) to explore industrial PhD students' networks and brokering roles, while Paper 3 is instead framed through the lens of discourse communities (DCs). Papers 1 and 2 address science communication practices involving communication to or with not only professional or practice-based communities but also the general public. By using the broader term *communities*, I try to capture the relational and contextual dimensions of my thesis without imposing a single theoretical framework. My choice to use this broader term also reflects that engagement with society can occur in many ways, to or with many types of communities—with CoPs, DCs, or broader audiences such as newspaper readers or citizens.

The specific research questions for each study are described in Table 1.1, where I also link each study to the overarching aim of the thesis.

1.1. Thesis structure

The structure of the thesis is as follows. In section 1.2, I provide a positionality statement. In chapter 2, I present an overview of my conceptual and theoretical framework. I present previous research and theory relating to first the third mission broadly, then science communication, and finally industrial PhDs. In chapter 3, I describe my methodology, including the philosophical underpinning as well as the methodologies for each paper. In chapter 4, I summarise the findings of my three papers. In chapter 5, I discuss my findings and what they together with previous research suggest about how the third mission is enacted through science communication and industrial PhDs in STEM, with a particular focus on the roles, practices, and challenges of individual brokers. In this chapter, I also give suggestions for further research, discuss limitations, and summarise implications and contributions. Finally, in chapter 7, I come back to my main conclusions.

1.2. Positionality statement

Doing a PhD is often described as a journey, a rollercoaster, perhaps something transformative, as so many other things in life. Who we are is shaped by genes, environments, and our journeys (Plomin et al., 2016). But who we are also shapes our journeys and in academia our research (Greenbank, 2003). Therefore, knowing

Table 1.1. My specific research questions for each study and additional research questions for this thesis, as well as descriptions of how each study links to the overarching aim of the thesis.

Title	Research questions or aim	Link to overarching aim
Paper 1: The silent tribe? Mapping the variety of researchers' science communication practices across STEM disciplines	The study aimed to explore researchers' practices for science communication at a Swedish university of technology by mapping their actual written output as available in the university's publication repository.	Investigating how researchers engage in science communication and who chooses (or has the opportunity) to engage in it.
Paper 2: Thinking outside the box: Senior scientists' metacognitive strategy knowledge (MSK) and self-regulation of writing for science communication	What is senior scientists' metacognitive strategy knowledge (MSK) of writing for science communication, and what strategies do they use? How do they self-regulate their writing for science communication?	Investigating what characterises expert science communication writers' writing process, to provide input to training as well as what incentives might be effective to promote science communication and learning to communicate to non-academic audiences.
Paper 3: The industrial PhD: Student perspectives on learning, communicating, and knowledge brokering	What are industrial PhD students' experiences of communication within and across DCs? What are industrial PhD students' training and support needs regarding communication?	Investigating in what ways industrial PhD students broker knowledge between academic and industrial contexts, what challenges they face in doing so, and what support they need.
Paper 4: Being, becoming and brokering: industrial PhD students' positioning within industrial and academic communities	What expectations do they, as presumed knowledge brokers, face? What social agents and communities of practice are involved and what are their roles?	Further investigating the knowledge brokering of industrial PhD students' brokering between academic and industrial contexts, focusing on the roles of various social agents in the industrial PhD.

who the person behind the research is can be an important part of contextualising the research (Bourke, 2014). I will now briefly let you know who I am as the author of this thesis and where I come from as a researcher. Given that this thesis concerns liminalities between academia and other contexts, I think it is important to first state explicitly that I myself have sought liminalities. I find ways and places where I can draw on many parts of my background at once. Similar to some of the participants in my research—who somehow bring academia and society closer by reaching out, discussing, or collaborating—I like being in many contexts, providing bridges, getting new perspectives from various places and people, and trying to contribute to practice somehow.

Communication and Learning in STEM, the name of the research school in which my PhD was carried out, sums up several aspects of my background. At university, I studied Biology for a year, Bioengineering for three years, then Learning and leadership for two years, and some English, Gender studies, and Diversity on the side. I am a bioengineer, but also certified to teach Biology, Chemistry, Mathematics, and English in upper secondary school. My participants often have engineering degrees, or other degrees in STEM, and my background has proven useful in my research, for example in understanding and connecting to the industrial PhD students I interviewed. Like many of them, I am originally an engineer who tries to navigate a PhD, and like them, I did not choose to do a traditional PhD in an area closely related to my engineering degree. They went for industry; I went for a combination of educational science and applied linguistics. They are bridging contexts in terms of industry and academia; I am bridging contexts in terms of disciplines. My participants, researchers and industrial PhD students, often express that they want to compose connections, and so do I.

The title of this thesis starts with *composing connections*, playing with the musical term *compose*. To me, it captures how my participants actively compose connections when, in some way or the other, reaching outside of academia and enacting the third mission. They are not just conducting what someone else composed, but building the actual connections themselves, like a composer composes a piece of music. The title is also a tribute to a part of my own interdisciplinary background, where I have spent considerable time over the years playing the tuba and other instruments. This thesis is also a follow-up to my licentiate thesis *(Re)harmonising the Academy: Integrating Life-Long Learning and Science Communication in Swedish Higher Education* which also had a musical connotation to the title. Note that the licentiate title mentions the *Academy*, while this doctoral thesis mentions *Society*. As an engineer and teacher, I, like my participants, highly value contributions to society and research moving beyond academic circles. The thesis title thus reflects my positionality to some extent, just like my research inevitably does.

In the methodology chapter, I will revisit some aspects of positionality when elaborating on my research philosophy and how my background is very much connected to my pragmatist approach to research.

2. Conceptual and theoretical framework

This thesis draws on a number of concepts, theories and lines of previous research. The common denominator is that of the third mission, which is also where this chapter starts. I then move on to science communication, self-regulated learning in science communication, industrial PhDs, knowledge brokering, communities of practice and finally industrial PhD students' communication and discourse communities. The aim of this chapter is to provide enough overview and insight for the reader to better understand the appended papers as well as this thesis. It situates my research in relation to previous research and theories and motivates my choices of theoretical frameworks, but it does not provide a comprehensive review of all previous research or extensive descriptions of each concept and theory.

2.1. The third mission

In this sub-chapter, I will present an overview and previous research on academia's third mission, the third mission specifically in Sweden and Swedish policies, how the third mission is and can be enacted in practice, including science communication and industrial PhDs. Thereafter, I will provide a visualisation of how the third mission, science communication, industry-academia collaborations in industrial PhDs, and knowledge brokering relate to each other (see section 2.1.1.).

The *third mission* is a broad term which often includes many different connections between academia and the rest of society (Compagnucci & Spigarelli, 2020). In addition, the term *third mission* is not used in all contexts. In this thesis, I find it useful since it captures a variety of connections to society, a relation to research and teaching (academia's first and second mission), and is commonly used in a Swedish context. It is also used internationally, though a comparatively recent literature review concluded that there are many synonyms to the third mission, resulting in the term being "unclear and multi-interpretable" (Compagnucci & Spigarelli, 2020, p. 5), partly because research on the third mission is "still in its infancy" (p. 5).

In my licentiate thesis, I wrote that science is disseminated to non-academic audiences at increasing rates, resulting from a shift of perspective about the role of higher education in society (Pinheiro et al., 2015), on what academic scholarship should include (Boyer, 1990), and political will (Watermeyer, 2015). While that is

not false, the term *dissemination* raises questions regarding if the third mission entails only monologue or also dialogue, and to what extent it includes knowledge brokering. I elaborated to some extent on the question of monologue and dialogue in the licentiate thesis and will elaborate on the knowledge brokering aspect in this PhD thesis. My perspective has shifted from primarily dissemination and how researchers communicate to and with non-academic audiences in various ways, which is what I examined in Paper 1. I now instead focus on the third mission, as it is described in, for example, Swedish law, encompassing both communication and other connections such as collaborations on research or practice-based problems (Bragesjö et al., 2012; Hetland et al., 2020).

Policies concerning the third mission vary across countries (Compagnucci & Spigarelli, 2020; Pinheiro et al., 2015), as does engagement in science communication (Entradas et al., 2020). Science communication is a term often used in previous research, across countries, though the definitions vary (see section 2.2). It is an umbrella term for communication of science/research to audiences other than researchers (Vetenskap & Allmänhet, n.d.-b). For example, science communication includes communication of research to professionals in trade magazines as well as participation in public debate through opinion pieces in newspapers, as, for example, shown in Paper 1. According to some definitions, it also includes engagement and communication in collaborations with actors outside of academia, such as in industrial PhD projects, though this is perhaps more often referred to as collaborations or utilization (e.g. Compagnucci & Spigarelli, 2020; Vetenskap och Allmänhet, n.d.-b; see also Compagnucci & Spigarelli, 2025).

In Europe, the EU's member states agreed in 2016 to promote efforts to stimulate communication of research to experts and non-experts, within the research community and the general public (Bohlin & Bergman, 2019). This agreement specifically underscores the importance of dialogue between academia and the rest of society, for example for democracy, a point echoed in Swedish policy (Bragesjö et al., 2012). In Sweden specifically, where I have conducted my research, there is also a long tradition of both science communication and the third mission more broadly (Bragesjö et al., 2012; Hetland et al., 2020). Science dissemination has been promoted in the Swedish Higher Education Act since 1977 (Bragesjö et al., 2012; SFS 1977:218) which is early compared to other European countries, e.g., the UK, where science dissemination was only formalised in policy in the 1990s (Lebeau & Cochrane, 2015).

Importantly, while the first Swedish legislation on the third mission focused on dissemination and sharing knowledge, later additions have extended the law to also include, for example, utilisation of research (SFS 2009:45) and emphasising that the public should benefit from research conducted by higher education institutions (SFS 1992:1434). This is similar to a trend in many countries to go from "'pushing'

science" onto often undefined audiences outside of academia towards other more targeted or even dialogic or collaborative approaches to sharing and utilising science (Bielak et al., 2008). Utilisation is also promoted by the Swedish national research council (Swedish Research Council, n.d.) and a non-profit organisation called Vetenskap och Allmänhet (*English: Public and Science*), in which organisations, authorities, universities, and companies work together "to promote dialogue and openness between researchers and the public" (Vetenskap & Allmänhet, n.d.-a). Overall, there is a recognition in Sweden that the third mission can include one-way or two-way communication with different degrees of interaction, dialogue, and involvement (Vetenskap & Allmänhet, n.d.-b). Sweden thus exemplifies what Broks (2017) described as a shift in views on what the third mission and science communication is and should be. This entails a general expansion from science communication as only dissemination and monologue to a form of scholarship that also includes dialogue with and participation of various groups outside of academia, as well as knowledge brokering between academia and other parts of society (Cervin-Ellqvist, 2022)—for example in collaborations with industry (Abu Sa'a & Ystrom, 2024; Wallgren, 2007).

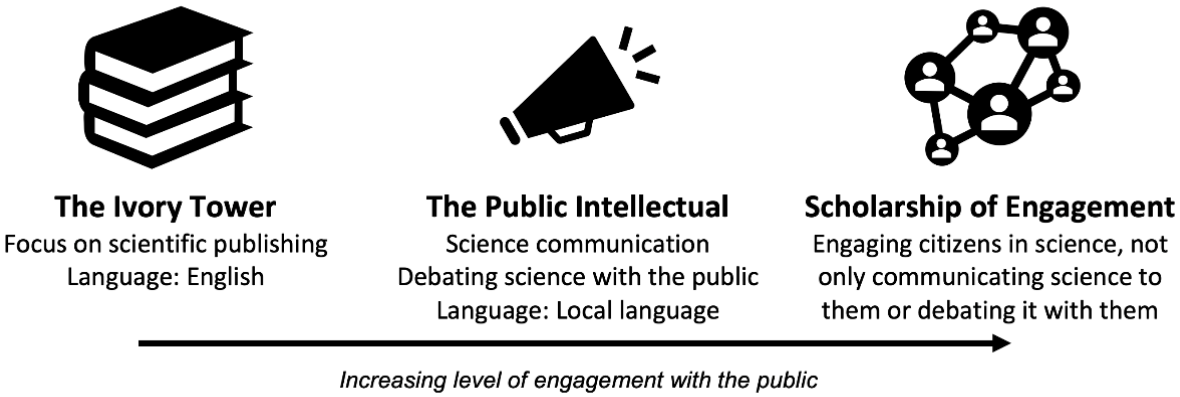
Finally, I need to clarify how I use the terms *the third mission* in relation to the term *science communication* in this thesis. While there are similarities between engaging in science communication and enacting the third mission, there may also be differences depending on how science communication is defined and what it is perceived as encompassing. For example, previous research on science communication most often assumes that academics work full time in academia, possibly with spare time engagements or interests relating to other sectors. However, this is not necessarily true for all forms of enactment of the third mission, including industrial PhDs where the student is not in academia 100 percent of their time but also is required to spend time on tasks at their industrial employer (e.g. Wallgren, 2007). Presumably, researchers who communicate to industry or the public without such a formal collaboration or employment have other pre-conditions than researchers or PhD students who are part of formal collaborations with non-academic organisations. To avoid confusion based on definitions and conceptions of what *science communication* includes, which I will elaborate on in section 2.2, in this thesis I therefore use the term *the third mission* to refer to the whole spectrum of interactions with the outside world, from outreach to close collaborations.

2.1.1. Model of what the third mission entails

As mentioned in section 2.1, the third mission consists of both science communication and knowledge brokering between academia and other parts of society (in STEM often industry). These concepts are not only related but also

intertwined and will be explained in more detail in the following sections. However, it is useful to first get an overview of how they are related. In my licentiate thesis, I conceptualised and visualised researchers' engagement with society as a continuum (see Figure 2.1), drawing on a modification of Boyer's (1990) model of academic scholarship (see Cervin-Ellqvist, 2022), Bucchi's (1996) description of science communication as a continuum, and Said's (1994) notion of the public intellectual.

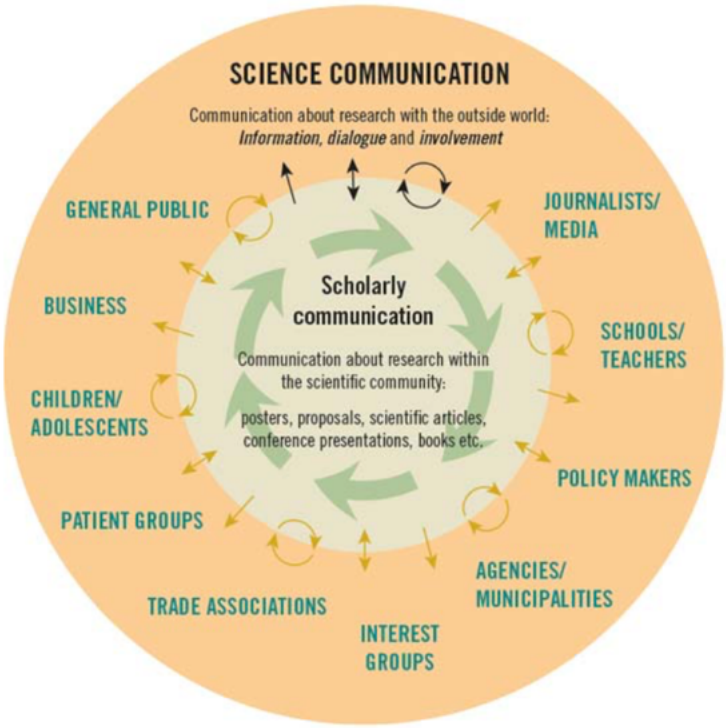
Figure 2.1. Visualisation of engagement with society as a continuum, relating science communication to theories of scholarship.

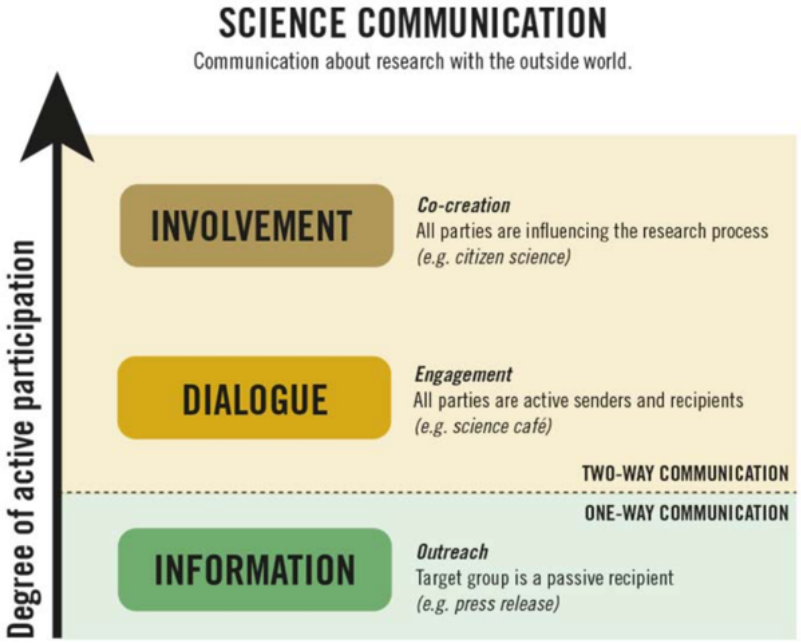


While useful to discuss science communication in the form of researchers who reach out from academia in various ways, this model does not fully capture the third mission in a broader sense, and not how it connects to knowledge brokering. Other interesting models include two from the Swedish organisation Public and Science (VA, *Vetenskap och Allmänhet*) which attempt to describe science communication in a broad sense, and in doing so capture the third mission but not how it relates to knowledge brokering. These models are shown in Figure 2.2a and 2.2b.

Figure 2.2a visualises communication of science as taking place as scholarly communication in an inner circle, academia, and as science communication in an outer circle. The outer circle includes all audiences outside of academia, including for example business. Note that there are arrows between the circles that go outwards, in both directions, and in circles, symbolising science communication entailing monologue, dialogue, and participation. Figure 2.2b complements Figure 2.2a and focuses on the degree of active participation, from information and outreach via dialogue and engagement to involvement and co-creation. While these visualisations are useful, they focus mainly on communication, and other aspects of the third mission, as well as an explicit connection to the third mission, are missing.

Figure 2.2a-b. Visualisations of science communication made by Lotta W Tomasson/VA License: CC BY-NC 2.0, https://creativecommons.org/licenses/by-nc/2.0/

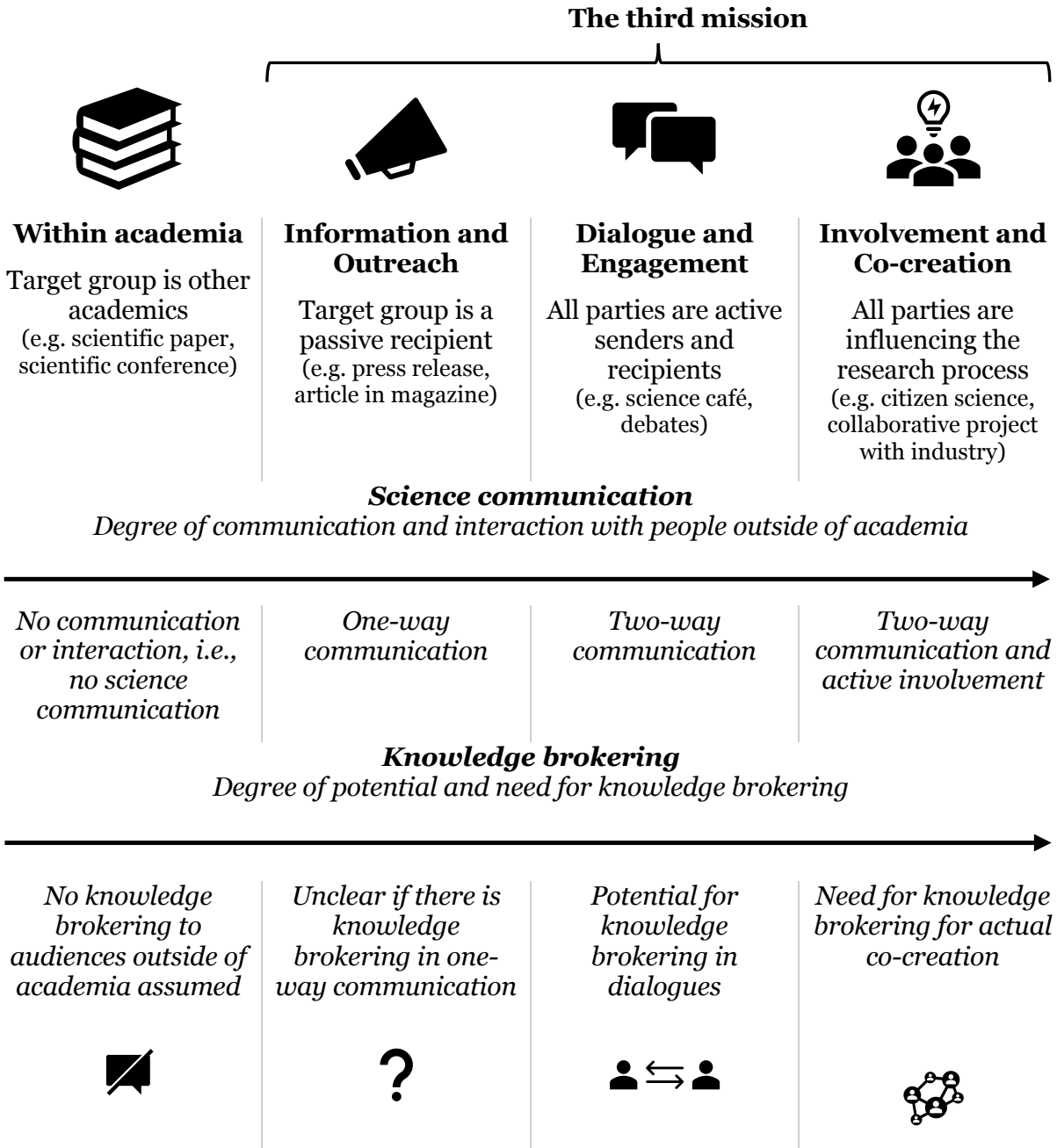




Based on my readings about the third mission (section 2.1), science communication (section 2.2) industrial PhDs (section (2.3) and Figures 2.1 and 2.2a-b, I created a visualisation that describes the third mission and its relation to various forms of communication of research (to other researchers and people outside of academia), collaborations reaching outside of academia, and knowledge brokering. This is shown in Figure 2.3 Compared to Figures 2.2a-b, I have added an explicit connection to the third mission, and I have added knowledge brokering. I motivate these expansions by the fact that only communication is not enough; knowledge brokering is needed to ensure research is useful and utilised in practice (Bulkeley & Mol, 2003; Turnhout et al., 2013). Compared to Figure 2.1, I have also added more details, but excluded language since this is not a main focus in my PhD thesis. In this thesis, I take the perspective of the researcher or industrial PhD student, which is to some extent reflected in the visualisation, but I acknowledge that communication and collaboration do not always have to be driven by a researcher who *pushes* science out to audiences outside of academia; there may also be a *pull* from those who need science, for example for applications in industry (Bielak et al., 2008).

Figure 2.3 shows how the third mission, various forms of communication of research, science communication and knowledge brokering relate to each other. For example, the first column describes communication within academia, which is not part of the third mission, contains no science communication (i.e., communication to audiences outside of academia), and no knowledge brokering to audiences outside of academia. The rightmost column, on the other hand, describes that involvement and co-creation is a form where all parties are influencing the research process (e.g., in collaborations with industry, including in industrial PhDs), there is two-way communication and active involvement, and there is a need for knowledge brokering for actual co-creation. While the categories may seem distinct, it is rather a continuum, similar to Figures 2.1 and 2.2b. Therefore, science communication and knowledge brokering have arrows showing an increase from the left to the right side of the figure. The grey lines separating each column are included for the sake of readability. Note that while science communication and knowledge brokering may seem to follow each other so that they increase at the same pace, and one level of science communication always comes with one specific level of knowledge brokering, this may not be the case in practice. For example, a collaborative project where communication occurs does not automatically mean knowledge brokering is taking place, which I elaborate on in Papers 3 and 4 as well as in later parts of this thesis.

Figure 2.3. Visualisation of what the third mission entails and how this relates to science communication and knowledge brokering. The figure builds upon Figure 2.2b, published by a Swedish non-profit organisation called Vetenskap och Allmänhet (*English: Public and Science*), in which organizations, authorities, universities, and companies work "to promote dialogue and openness between researchers and the public" (Vetenskap & Allmänhet, n.d.-a). However, the figure was developed further to provide a more comprehensive overview of what the third mission can entail by adding knowledge brokering and how various forms of the third mission and science communication relate to it.



2.1.2. Genres

The previous section describes the third mission broadly, stating that communication is important but not going into details about what communication consists of, i.e., not mentioning different *genres* and what constitutes a genre. Before going into details about previous research and theories, I thus need to give a short description of the term *genre*, which I use frequently in Papers 1, 2 and 3 and also in parts of this thesis.

Research can be communicated through many different genres, especially to non-academic audiences. Genres can be described as "abstract, socially recognised ways of using language" (Hyland, 2007, p. 149) that are "formed to carry out actions and purposes" (Tardy & Swales, 2014, p. 166; see also Heron & Corradini, 2020). Thus, a piece of writing (or other type of communication) can be recognised as belonging to a certain genre, for example, based upon similarities in content and form to other texts within the genre, and the fulfilment of the genre's socially recognised purpose and situation, as shared by authors and readers (Miller, 1984). Science communication comprises many genres, as suggested by previous research (e.g., Bucchi, 1996; Davies, 2021; Kappel & Holmen, 2019; Pérez-Llantada, 2021) and corroborated in Paper 1. An example of a genre from Paper 1 is that of opinion pieces (*Swedish: debattartiklar*), which are relatively short texts using a recognisable type of rhetoric in arguing for a specific point in a topic of public debate, most often in newspapers. In other words, opinion pieces show similarities in content and form and fulfil a specific purpose and situation, all of which are socially recognisable by both readers and authors, and they can thus be considered a genre. Paper 1 identified which genres science communication texts belonged to, summarising what kind of science communication researchers engaged in. In Paper 3, a similar mapping of genres was done by asking industrial PhD students what genres they had engaged in as industrial PhD students and what genres they had previous experience of. In both cases, genres can be used to understand the variety in and differences between different types of communication to non-academic audiences. In Paper 2, on the other hand, we investigated researchers' strategies when engaging in certain genres (concretised by examples of science communication writing chosen by the participants).

2.2. Science communication

In this section, I will elaborate on the term science communication, which connects to Papers 1 and 2 where we investigated science communication practices, and science communication writing processes, which connects to Paper 2. Specifically, I will describe what science communication is, situate my research within the

conceptualisation, provide an overview of challenges in science communication, and finally elaborate on self-regulated learning and metacognitive strategy knowledge in science communication.

2.2.1. What is science communication?

In this section, I elaborate on how science communication has been conceptualised in previous research to then define how I use the term in this thesis. Interestingly, there is no clear definition of what science communication is, possibly because it is such a broad concept and not a single genre. The Swedish organisation Vetenskap och Allmänhet *(English: Public and Science)* describes it as communication about research with audiences other than the research community (Vetenskap och Allmänhet, n.d.-b). In addition, the purpose and role of science communication in society may also vary. What is clear is that the purposes and roles are tied to higher education's functions in society as well as how higher education is managed, as suggested by the six roles of science communication described by Davies (2021):

- Contribute to the **accountability** of higher education institutions and how they use the money they get from public funding.
- Have a **pragmatic role** in which research provides practical value to societal actors, e.g., politicians that need to be well informed to make good decisions, or society provides value to the researchers, e.g., through citizen science or inspiring new research. Note that this is often dialogic to some extent.
- **Enhance democracy** by making it possible for the public to make wise, well-informed decisions, e.g., by participating in the public debate or enabling discussions on the relationship between science and society and how they should influence each other. This role is often dialogic.
- Be a part of the **culture** in a society and of shaping that culture
- Fulfil **economic purposes/values** for society, including recruiting more people into science and increasing interest in and familiarity with science and technology to prepare the workforce and the population for the technological advancements.
- Fulfil **promotion and marketing purposes**. This entails marketing specific institutions and researchers to various audiences outside of academia and often lacks critical or reflexive dimensions.

In a conceptual framework based on science communication literature, Kappel and Holmen (2019) suggested a similar set of aims of science communication, again relating to higher education's functions in society:

- Improving populations' beliefs about science
- Generating social acceptance
- Generating public epistemic and moral trust
- Collect citizens' input about acceptable/worthwhile research aims and applications of science
- Generating political support for science
- Collect and make use of local knowledge
- Make use of distributed knowledge or cognitive resources to be found in the citizenry
- Enhance the democratic legitimacy of funding, governance and application of science or specific segments of science

In addition, there is the question of who the communication is for. According to Davies (2021), science communication may either be strategic—i.e., serving the interests of the communicator—or democratic—i.e., serving the interests of democracy. There is, however, no sharp line between science communication and scientific communication, as seen in Paper 2. Bucchi (1996) underscored this lack of a clear line and described four different stages of communicating science: the *intraspecialistic stage* where the audience is other researchers within the same field; the *interspecialistic stage* where the audience is also researchers within other fields; the *pedagogical stage* where there is an educational purpose, for example in textbooks for students; and *the popular stage* where the audience includes the general public. Furthermore, the pedagogical stage and the popular stage can be divided into the dissemination paradigm and the public participation paradigm, where communication within the first typically entails monologue and within the second dialogue or even more extensive participation from people outside of academia (Kappel & Holmen, 2019). Note that these definitions concern researchers who are in academia full time and seldom mention industry-academia collaboration or in-between positions like those of industrial PhD students. Overall, what the many conceptualisations agree upon is that science communication may have many purposes and audiences and that these tend to overlap.

While *science communication* may be defined in many ways, I will use it primarily to describe the one- and two-way communication by researchers who are in academia to audiences outside of academia, in other words not including the industry-academia collaborations such as industrial PhDs. This is not a stance regarding what science communication is and should be, but a pragmatic decision to be able to distinguish my two strands of research on the third mission from each other.

2.2.2. Challenges in science communication

There are several challenges relating to enacting the third mission through science communication, at individual level as well as organisational and policy levels. I will here provide an overview of such challenges, to then return to them in the discussion of my work.

Despite political ambitions, researchers internationally (Pérez-Llantada, 2021; Schimanski & Alperin, 2018), and in Sweden (Bohlin & Bergman, 2019; Dryler et al., 2022) tend to prioritise scientific publication over science communication—prioritising the first mission over the third mission—presumably because the academic system in practice promotes scientific publishing over science communication in recruitment, promotion and tenure processes. This is in line with what Swales (2004) refers to as a genre hierarchy or genre regime; some genres are valued over others and are more important for promotion and tenure than others as a consequence of policies on an international, national, institutional, and disciplinary level and of how funding is distributed (Pérez-Llantada, 2021; Swales, 2004). The existing incentives—for instance some funding bodies now require that the research they fund is communicated to wider audiences (Pérez-Llantada, 2021; Renwick et al., 2020)—seem to be insufficient to ensure the third mission is enacted in practice through science communication.

The promotion of science communication therefore needs to acknowledge that engagement in science communication requires a change of priorities within academic scholarship (cf. Boyer, 1990), in other words among academics' different tasks pertaining to the first, second and third mission, which I elaborated on in my licentiate thesis (Cervin-Ellqvist, 2022). According to previous research, researchers do believe science communication to be important (Llorente et al., 2019; Pérez-Llantada, 2021; Schimanski & Alperin, 2018). However, academic professional life poses many conflicting demands, and science communication competes for researchers' time with tasks connected to research (as described above about the genre hierarchy) and teaching (Carli et al., 2019; Defazio et al., 2022; Koryakina et al., 2015; Nygaard, 2017; Watermeyer, 2015). For example, a recent Swedish report pointed out lack of time as a key challenge for researchers who wish to engage in science communication (Bohlin & Bergman, 2019), in line with findings from other studies in Sweden and internationally (e.g., Negretti et al., 2022; Pérez-Llantada, 2021). Interestingly, researchers in the early stages of their career experience a particularly high pressure to publish in high-ranked journals and to not spend too much time on outreach (Schimanski & Alperin, 2018). They are also less positive about public outreach than their senior colleagues (Bohlin & Bergman, 2019). In a Swedish context, this is perhaps not surprising since it is not clear if, to what extent, and how science communication is valued and evaluated in recruitment processes at universities, while research and teaching are explicitly valued (Dryler

et al., 2022). Not even in Sweden, where science communication has been included in legislation for the past 35 years, are there sufficient incentives for researchers to engage in science communication in practice, and the following conclusion made by Jacobson et al. (2004) is still valid:

> 'outreach, building partnerships with non-academic organizations, and plain language communication…are not widely accepted as legitimate forms of scholarship' (Jacobson et al., 2004, p. 248)

In addition to a lack of time and incentives, individual researchers' science communication is further complicated by several other factors.

One important such factor is that science communication is difficult to measure and evaluate, and in contrast to scientific publications, there is limited data on science communication activities and practices (Besley et al., 2018; Llorente et al., 2019; Pinheiro et al., 2015). In Paper 1, we therefore mapped science communication at one university, among other things showing that researchers used a variety of genres for their science communication, and identified common genres (mainly opinion pieces, editorials in newspapers, and articles in trade magazines). Furthermore, previous research highlights the difficulty in defining what science communication quality should include (Olesk et al., 2021)—it may mean anything from trustworthiness of the science behind the communication to how many people are reached by the communication effort—which provides a barrier to evaluating science communication in recruitment processes, for example. A second complicating factor is the local institutional culture, which needs to encourage engagement with society and see such engagement as legitimate (Benneworth et al., 2015). A third complicating factor is that some topics (e.g., climate change or urban design as in Paper 1) might be more interesting to the public, and different topics might suit different audiences and genres (Ampollini & Bucchi, 2020; Jönsson et al., 2018), making it difficult to provide general advice about how to engage in science communication. A fourth complicating factor is language: for researchers working in countries where they do not fully master the local language, the language itself may constitute an obstacle to engagement (Bohlin & Bergman, 2019). In contrast to scientific publishing, where English is the main language, science communication is often conducted in the local language (Luzón, 2017; Pérez-Llantada, 2021; e.g., in Sweden McGrath, 2014), as was also corroborated by Paper 1.

Finally, lack of training is a key barrier to engagement since researchers seldom receive training in communicating to audiences beyond academia (Baram-Tsabari & Lewenstein, 2017; Besley & Tanner, 2011; Fähnrich et al., 2021), which is the case also in Sweden (Bohlin & Bergman, 2019). Moreover, science communication training is complicated by the fact that it draws on multiple disciplines, including that of the content to be communicated (Kuehne et al., 2014; Mulder et al., 2008).

It is therefore important to pinpoint what is required of researchers to make science communication successful, as a basis for designing training (e.g., Baram-Tsabari & Lewenstein, 2017; Bray et al., 2012; Mercer-Mapstone & Kuchel, 2017; Murdock, 2017). Previous attempts to identify what science communication training should focus on have taken slightly different approaches. For instance, Baram-Tsabari and Lewenstein (2017) reviewed previous research and suggested a conceptual frame for learning goals in science communication training. Mercer-Mapstone and Kuchel (2017), on the other hand, combined a review of previous literature with input from scholars doing research on science communication and summarised their findings into a list of twelve skills that are key in effective science communication. While these lists are important contributions to what science communication training should focus on, they illustrate goals and skills rather than strategies that can be applied in practice. In Paper 2, we went closer to practice and examined strategies that senior researchers use in writing science communication and how they self-regulated their writing, aiming to provide insight into what characterises expert science communication writers' writing process. This could provide input for training more concretely, as well as regarding what incentives might be effective to promote science communication and this form of enactment of the third mission in a Swedish STEM context (see chapter 4, section 4.2, where the strategies used by participants are summarised in Table 4.1).

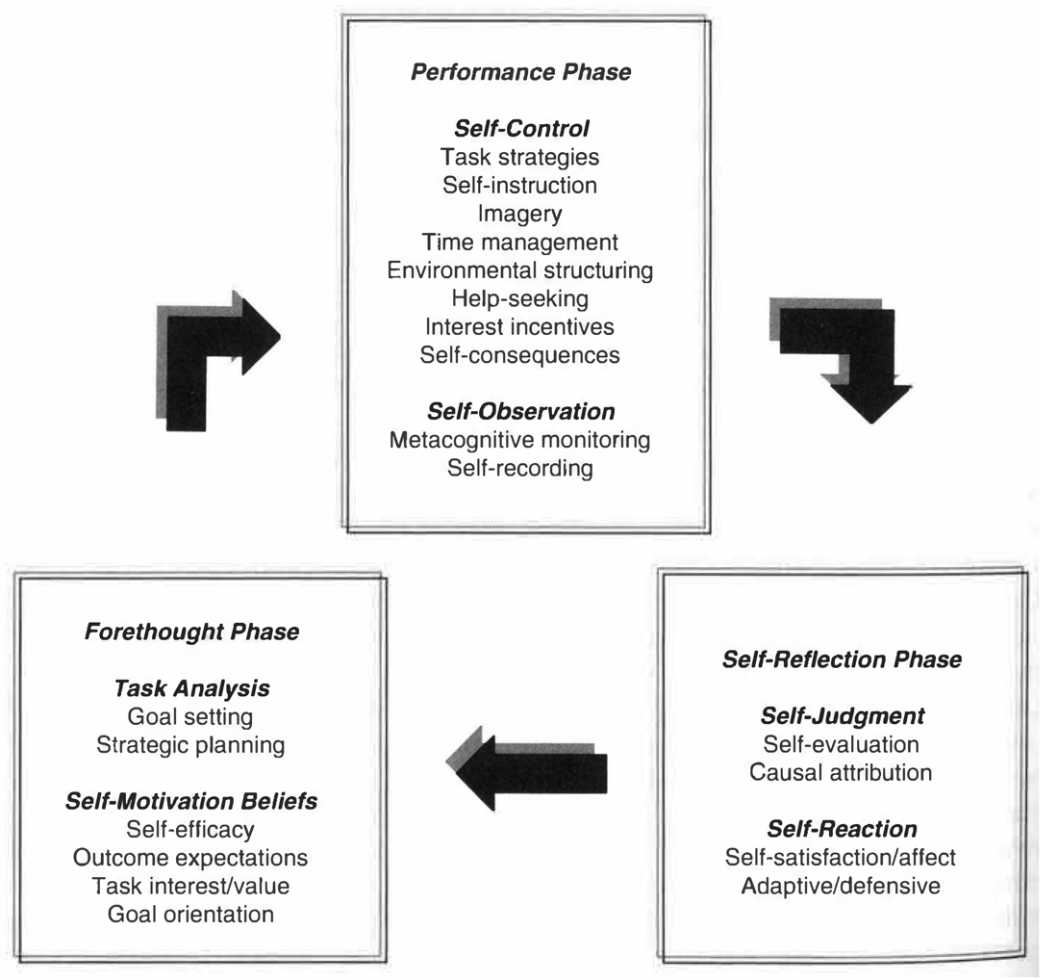
2.2.3. Self-regulated learning in science communication

In Paper 2, we draw on the theory of self-regulated learning (SRL). SRL can be described as "an active constructive process whereby students set goals for their learning and attempt to monitor, regulate, and control their cognition, motivation/affect, and behaviour guided and constrained by their goals and the contextual features" (Pintrich, 2000, p. 453). Note that *student* in this definition may refer to any learner.

There are many models describing SRL, of which we have used Zimmerman's (2000) model in the research presented in this thesis. Zimmerman's (2000) cyclical model (shown in Figure 2.4) is relatively simple and describes SRL as a process with three phases: (1) forethought (including task analysis and self-motivation beliefs), (2) performance (including self-control and self-observation), and (3) self-reflection (including self-judgement and self-reaction).

Zimmerman's cyclical model has been widely used (Panadero, 2017) and gradually improved over the years, including by Zimmerman and Moylan (2009). In Figure 3, I present Zimmerman and Moylan's (2009) version of this model. Note that the three phases do not necessarily have to happen in a particular order and that it is possible to go back and forth between the phases.

Figure 2.4. A cyclical phase model of self-regulation, Zimmerman & Moylan, Handbook of Metacognition in Education, Taylor & Francis Group © 2009. Reproduced by permission of Taylor and Francis Group through PSLClear.



In Paper 2, we used Zimmerman and Moylan's (2009) model of SRL to analyse researchers' process of writing science communication texts. SRL can be used to describe the learning process of any learner and to analyse the self-regulation (SR) of many different processes (see e.g., Schunk & Greene, 2018), including SR of writing, as described by Graham et al. (2018). Writing is "a recursive, strategic, and multi-dimensional process involving (a) planning what to say and how to say it, (b) translating ideas into written text, and (c) revising what has been written" (Graham et al., 2018, p. 139). Note the similarity between these three phases and the three phases of Zimmerman and Moylan's (2009) model (forethought, performance, and self-reflection). In Paper 2, we were interested in the process and how researchers go from planning to evaluating their science communication; i.e., what the writing processes of expert science communication writers looks like from start to finish. Therefore, we found Zimmerman and Moylan's cyclical model and its focus on the

process to be a suitable theoretical framework. In addition, this model has been used in previous studies describing writing processes in other genres and in general (e.g., Mežek et al., 2022; Roderick, 2019; Zimmerman & Kitsantas, 2007).

In Paper 2, we also examined the researchers' *metacognitive strategy knowledge* (MSK). MSK is a subcomponent of metacognition, which is a subcomponent of SR (Karlen, 2016; Pintrich, 2000), and can been used to evaluate SR of writing processes (Karlen, 2017). It encompasses "knowledge about task characteristics and requirements as well as about the appropriateness and effectiveness of … strategies with respect to the (specific) task demands" (Karlen, 2016, p. 253). This lens is particularly useful in investigations of genres that are not well defined, such as science communication, where the task requirements are often vague and presumably different to those of, for example, scientific papers (see Paper 2). Therefore, we used MSK as a complement to Zimmerman and Moylan's model in the analysis of researchers' regulation of their science communication writing processes.

Section 2.1 and its subsections have provided an overview of my conceptual and theoretical framework for the first research question, focusing on how researchers engage in science communication, and what strategies can be used to successfully self-regulate science communication writing. It is now time to turn to another aspect of the enactment of the third mission and the second research question, focusing on industrial PhDs as potential brokers between industry and academia.

2.3. Industrial PhDs

In this section, I will focus on the enactment of the third mission through industrial PhDs. I will first provide insight into and overview of what collaborative doctorates and industrial PhDs are, how they relate to other types of collaborative doctorates, previous research and industrial PhD students' communication. I will also describe knowledge brokering, communities of practices and discourse communities and how these are particularly useful as theoretical frameworks for analysing industrial PhDs. The aim is to situate my work in relation to previous research and clarify how these students' roles and conditions have been conceptualised.

While collaborative doctorates, in all their forms, are on the rise and promoted as one way to bridge research and practice (Casano, 2015; Compagnucci & Spigarelli, 2025; Grimm, 2018; Hadgraft & Kolmos, 2020; Jones, 2018; Kot & Hende, 2012; Negretti, et al., 2025), I also need to point out that collaborative doctorates and industrial PhDs have variations across countries, in both organisation and what they are called. This makes it somewhat difficult to find and provide a review of previous

research. This issue is echoed multiple times in the literature (e.g. in literature reviews such as Compagnucci & Spigarelli, 2025; Jones, 2018). It is also a research area on the rise, meaning new studies might have been published since this thesis was sent for printing.

In this thesis, I use Assbring and Nuur's (2017) definition of collaborative doctorates, defining them as:

"arrangements in which the cost, supervision and research outcomes for the PhD project and/or programme are shared by industrial actors, funding bodies and academia" (p. 185)

This definition underscores collaboration but does not specify any specifics of this sharing or how exactly the student is connected to each stakeholder, which makes it a loose definition but also one that works across national contexts.

In my thesis, I focus on one type of collaborative doctorate, namely industrial PhDs, as in Papers 3 and 4. In section 2.3.1, I will clarify what these are and what distinguishes them from other collaborative doctorates. I will then provide an overview of previous studies on industrial PhDs, and to some extent other collaborative doctorates in section 2.3.2. In sections 2.3.3 and 2.3.4 I elaborate on first knowledge brokering in industrial PhDs (2.3.3) and then communities of practice and social agents involved in industrial PhDs in (2.3.4), all of which I used to frame Paper 4. The two latter sections provide both parts of my theoretical framework and previous research relating to these. In the following section (2.3.5), I move into the communication of industrial PhDs and then discourse communities in industrial PhDs, which I used together with knowledge brokering to theorise the findings in Paper 3.

Note that the order of the sub-sections is opposite to that of the papers, where Paper 3 concerns communication and discourse communities while Paper 4 has a focus on the overall situation and communities of practice. For the sake of readability and argumentative coherence, I have decided to go from broad (the overall situation, as in Paper 4) to specific (communication practices, as in Paper 3) in this thesis. Reordering the papers would make this section seem more logical, but it would also make the connection between the papers and how Paper 4 builds on findings from Paper 3 (similar to how Paper 2 builds on Paper 1) less visible.

2.3.1. What are industrial PhDs?

As mentioned in the previous section, collaborative doctorates, and even industrial PhDs, differ in organisation and requirements, among other things, across countries and institutions. First and foremost, collaborative doctorates connect academia with an organisation outside of academia through a doctoral project (Assbring and Nuur,

2017; Compagnucci & Spigarelli, 2025). This connection may for example be a project that is almost exclusively conducted in academia but funded by industry, through a joint project where the doctoral student themself is not formally affiliated to industry, or through a project where the student is formally affiliated to both academia and industry as part of the project. "Industry" may also be a governmental agency or other organisation outside of academia. Furthermore, collaborative doctorates may certainly also have other setups, such as *triple helix* constellations where academia, industry and government are all involved (Assbring & Nuur, 2017; Thune, 2010; see also Lundberg, 2013, and Maassen & Stensaker, 2011, regarding the triple helix model in general). In my thesis, I focus on collaborative doctorates that have two main stakeholders (in addition to the student): academia and industry. However, I use the word industry in a broad sense, as it is often used for these doctorates (e.g. Compagnucci & Spigarelli, 2025, Grimm, 2018): "industry" in my thesis, as well as in Papers 3 and 4, refers to companies and other non-academic organisations, including NGOs and governmental agencies. While there might be differences between a company and a governmental agency, it still provides the dual contexts to navigate and translate between that I am focusing on in Paper 3 and 4. In addition, in the data analysis for Paper 3, the statistical tests actually did not show a difference in perceived challenges based on type of organisation. I will elaborate further on what might cause this in the discussion.

Internationally, there are two main types where the doctoral student is formally connected to both academia and some other sector in society: industrial PhDs and professional doctorates. Which type exists or is the most common varies across countries. I will therefore briefly explain their similarities and differences to avoid potential confusion across national borders. While similar in that the student is formally affiliated to both contexts, the two types of doctorates differ structurally and in terms of requirements. industrial PhD students are employed by industry and must meet the same academic requirements as traditional PhD students and result in a PhD upon graduation (Grimm, 2018). Professional doctorates have similar setup in terms of the students being employed in industry, but typically have fewer academic requirements than industrial PhDs and put stronger emphasis on practice-based outcomes (Jones, 2018). They lead to titles such as Doctor of Engineering (EngD) or Doctor of Education (EdD), and not a Doctor of Philosophy (PhD).

Despite their differences, these collaborative doctorates involve similar challenges for doctoral students in terms of navigating dual contexts and expectations, maintaining relationships across organisational boundaries, and translating and brokering knowledge (Compagnucci & Spigarelli, 2025; Jones, 2018; Wallgren, 2007). Both types are also intended to result in research that is both academically valuable and industry relevant, while preparing graduates for careers in academia, industry, and brokering between the two (Bernhard & Olsson, 2023; Borrell-

Damian et al., 2010; Cardoso et al., 2022; Mitic & Okahana, 2021). Thus, while my thesis focuses on industrial PhD students, the many similarities mean that previous research on professional doctorates has relevance as background and comparison to understand industrial PhD students' realities. It also means that the implications from my research are relevant also to professional doctorates. Studies on professional doctorates are therefore included in the overview of previous research below. Similarly, though industrial PhDs are particularly common in STEM, industrial PhDs and professional doctorates do exist in other fields. The specific projects can of course be assumed to differ across fields, and the exact setup might also vary, but the in-betweenness that characterises the doctoral students' position still seems to remain similar.

A final point to be made is that the general setup of doctorates generally and even PhDs specifically differs across countries. Therefore, I need to explain the Swedish context. In Sweden, a PhD conducted full time typically takes four years (SCB, 2024), whereof about one to one and a half years consists of courses. However, it is common to teach throughout the PhD, as part of the PhD position, which can add up to a year to the PhD. During this whole time, traditional PhDs are employed by the university. For industrial PhDs, the teaching can be replaced by work for the employer in industry, which can also be a larger portion of their time. In Paper 4, it was common to have an 80/20 divide between the PhD and other tasks (i.e., the same division as traditional PhDs can have), but time could also be divided equally between industry and academia. The latter case means the PhD would typically take eight years to complete.

2.3.2. Previous research on industrial PhDs

Research on industrial PhDs, and other collaborative doctorates, covers a number of themes, reflecting both the diversity of these doctorates and the complexity of the students' experiences. In my thesis, I take a student perspective, which is one of the strands of previous research. In a systematic literature review, Compagnucci and Spigarelli (2025) identified 5 additional strands: the perspectives of industry and academia; what industrial doctorates are; analyses of programme design; and industrial doctorates as policy tools. A seventh strand is that of the history and rise of collaborative doctorates, for example described by Jones (2018). All of these strands will come up in this thesis to some extent, and many have already done so, but I will mainly focus on the perspective of the doctoral students, as the assumed brokers in industrial PhDs. I will keep this introduction to previous research rather brief and then go into detail about knowledge brokering in industrial PhDs.

A considerable portion of previous research does focus on students' experiences, underscoring several contextual and individual factors that influence collaborative

doctoral students' experiences, learning, identities, and to some extent brokering (e.g. Abu Sa'a and Yström, 2024; Berg et al., 2026; Compagnucci & Spigarelli, 2025; Jones, 2018; Wallgren, 2007; though the term brokering is often not used explicitly). These factors include conditions at the start of the doctorate, including for example recruitment processes, division of time between contexts, relevance of the research topic in both contexts, programme organisation, and supervision. A common factor across studies seems to be students' motivation to bridge the gap between research and practice in some way, and how they thus deliberately chose to do an industrial PhD or professional doctorate rather than a traditional PhD, as also shown in Paper 4. Still, once they are conducting the doctorate, they may struggle to compose constructive connections between their two contexts in practice.

Similar to researchers who engage in science communication, industrial PhDs and other collaborative doctoral students often struggle with a lack of support, learning the skills needed, getting opportunities to broker knowledge, and dividing their time between their contexts in a sustainable way (Compagnucci & Spigarelli, 2025; Grimm, 2018; Jones, 2018; Tavares et al., 2020; Thune, 2009; Wallgren, 2007; Wallgren & Dahlgren, 2007). They also face challenges in integrating theory and practice in their project, dealing with unclear expectations and navigating dual demands and contexts, including dual cultures and institutional logics. For instance, industry reorganisations can lead to changes in both expectations and support, in terms of resources, support, and which specific people are involved in industry (e.g., switching manager or supervisor; Wallgren, 2007). This presumably complicates the journey of industrial PhDs, who need to create new relations and re-establish themselves. For example, this can entail ensuring that a new manager understands the value of the PhD and research, or a new supervisor understands and becomes active in supporting the PhD project and the student. I will elaborate further on the various social agents involved in industrial PhDs in section 2.3.3.

A related and reoccurring question in previous studies is that of expectations from and on the different stakeholders (meaning the student, industry and academia): What is expected of industrial PhD students and what can the students expect during and after the industrial PhD? Compagnucci and Spigarelli (2025) concluded that expectations is still a key issue to address and that industrial PhD students often "find it difficult to understand what is expected of them" (p.16), despite being highly motivated to contribute to the presumed expectation to bridge the gap between industry and academia. Moreover, expectations may not only differ between the stakeholders, but also between people within the same organisation or be unclear and not articulated (especially in industry; see e.g., Muurlink et al., 2024). This means the student has to create their own idea of what they should contribute with, as found in Paper 4.

Finally, identity and belonging are often mentioned in previous research on collaborative doctorates, even in studies that do not focus mainly on these issues (e.g. Bernhard & Olsson, 2023; Wallgren, 2007; Compagnucci & Spigarelli, 2025). This was the case also in Paper 3, where issues relating to identity and belonging (or lack of belonging) to communities in industry and academia, though it was originally not intended to be a main focus. One factor shown to be connected to a feeling of belonging and being integrated is that of having a previous connection to the organisation, especially in being employed at the organisation in industry prior to the initiation of the PhD project (as compared to being employed directly for the project; Wallgren and Dahlgren, 2007). Other factors that could affect integration and belonging in both industry and academia, as well as the students' identity, are organisational culture, access to relevant communities, and opportunities to interact, get support, and vent with colleagues in the two contexts (e.g. Abu Sa'a & Yström, 2024). Similar to the often unclear expectations, students themselves can often influence to some extent, though perhaps not fully, how integrated they are and their opportunities to provide a bridge between industry and academia (Abu Sa'a & Yström, 2024; Berg et al., 2026; see also Paper 4). Students may increase belonging by, for example, having an open attitude, trying to find ways and spaces to participate and network, and packaging knowledge in ways that make people in industry understand and see the value of their work (Abu Sa'a and Yström, 2025; Wallgren, 2007).

Overall, previous research portrays industrial PhDs and professional doctorates as responses to calls for impact and collaboration (Borrell-Damian et al., 2010; Cardoso et al., 2022; Compagnucci & Spigarelli, 2025; Mitic & Okahana, 2021). However, many questions and issues remain, including questions regarding expectations, integration in the two contexts, possibilities for brokering, support and the people, groups, and communities involved beyond supervisors (Jacobsen et al., 2025; Owens et al., 2020; Sala-Bubaré & Castelló, 2017; Solli & Muir, 2021; Tavares et al., 2020). Moreover, communication remains underexplored, with limited insight into communication practices and how to support industrial PhD students (Kihlander et al., 2011; Peters et al., 2017; Santos et al., 2021; Compagnucci & Spigarelli, 2025). As in science communication, reliance on individual initiative without adequate incentives and training means the third mission's ambitions might not be realised in practice (cf. Bohlin & Bergman, 2019; Olesk et al., 2021). These gaps motivate the focus of Papers 3 and 4, which examine communication and brokering roles in industrial PhDs, their wider network of social agents, and participation in communities.

2.3.3. Knowledge brokering in industrial PhDs

In Paper 3 and 4, as well as in this thesis, I theorise industrial PhD students as potential knowledge brokers between industry and academia. The concept, to my knowledge, has not been used extensively in research on industrial PhDs or similar doctorates, but has been on the rise in a variety of areas for some time, including brokering between policy-makers and academia, and in the health care sector (Meyer, 2010). As a reminder, knowledge brokers can be defined as "experts who interact, communicate, facilitate learning, share, and create knowledge across sectors" (Garcia-Morante et al., 2024, p. 303). Knowledge brokering involves not just moving or transferring information across contexts but actively translating, reframing, adapting, and negotiating knowledge and problems to facilitate collaboration between actors in the different contexts (Turnhout et al., 2013; Wenger, 1998). To do so, the broker needs to be familiar with both contexts and the differences between them, such as what is known, assumed, expected, and valued in the respective contexts. Skills needed include skills in understanding cultures and norms, establishing credibility, problem solving, project management, negotiating, networking, stakeholder management, mediation, and last but not least communication (Kislov et al., 2017; see also Inouye & McAlpine, 2023; and McAlpine and Inouye, 2022, on the communication of graduated PhDs in workplaces outside of academia). Finally, knowledge brokering underscores the interpretive and relational work required by those who try to compose constructive and productive connections between contexts (Wenger, 1998).

Thus, knowledge brokering is useful to analyse the realities of people in roles where they are expected to compose connections across contexts, such as industry and academia. In the literature review for Paper 3, I explored what previous research has described as success factors in industry-academia collaborations, and concluded that key factors are: support and structure, shared objectives and mutual understanding, and effective communication (Barnes, 2002; Borrell-Damian et al., 2010; Pertuz et al., 2021; Sjöö & Hellström, 2019; Starbuck, 2001; Thune, 2011). Note how these relate closely to the description of brokering above, suggesting brokering is central to boundary spanning in industry-academia collaborations (Kunttu & Kunttu, 2026). For industrial PhD students, a boundary position and need for brokering is a defining feature of their doctoral experience, as is clear from Paper 3 and especially Paper 4. Unsurprisingly, the challenges for industrial PhD students I have already mentioned earlier in this thesis (see e.g. sections 2.3.1. and 2.3.2.) aligns well with those that are typically described for knowledge brokers (cf. Kislov et al., 2017; Meyer, 2010; Meyer and Brun, 2023; Wenger, 1998). Examples include having to navigate dual organisational logics, epistemic cultures, time horizons and communication practices. Another challenge for brokers is becoming invisible by being in between, not fully belonging to either context, and conducting work that is not typical to either context. Invisible might here mean lack of inclusion,

which I will get back to, and lack of recognition (Meyer, 2010; Meyer & Brun 2023). The latter resembles the lack of recognition for science communication (see section 2.2.2.). Interestingly, like those engaging in science communication, the brokers themselves often try to make themselves and their brokering more visible (Meyer, 2010; as also seen for industrial PhD students in Paper 4). However, it may be difficult to do so while moving themselves and knowledge between contexts, and the movement may instead make them become invisible.

The challenges of knowledge brokering (Kislov et al., 2017; Meyer, 2010; Meyer and Brun, 2023; Wenger 1998) may be accentuated for industrial PhD students given their junior and apprentice role. As I theorise in Paper 4, they are students but becoming researchers, and they are often new in their role in industry but becoming experts. In addition, they are also often new at brokering and thus becoming brokers. Previous research points out that the interpretive and communicative work involved in brokering usually requires some form of guidance or support, even if this is not always acknowledged or provided in practice (Bielak et al., 2008; Meyer, 2010; Meyer & Brun, 2023; Kislov et al., 2017; Wenger, 1998). For industrial PhD students, this becomes particularly noticeable since they are still learning what is expected of them in academia, while also trying to understand the norms and priorities in industry (Compagnucci & Spigarelli, 2025). Theorising industrial PhD students as brokers could therefore be useful to pinpoint both potential challenges and what support they need.

However, brokering has only been used to analyse industrial PhDs and similar doctorates to a limited extent, whether framed through communities of practice (as in Paper 4; Bernhard & Olsson, 2023; Gustavsson et al., 2016; Wallgren & Dahlgren, 2007) or discourse communities (as in Paper 3). The related term boundary spanning is more often used (e.g. Abu Sa'a and Yström, 2024; Berg et al., 2026). Boundary spanning refers to the structural position of being located across the organisational and epistemic boundaries of academia and industry (e.g. Berg, 2025), whereas knowledge brokering refers to the interpretive and communicative work required to translate, mediate, and sometimes reframe knowledge across those boundaries (Wenger, 1998). While all industrial PhD students span boundaries, they do not necessarily broker knowledge unless they engage in the practices that link and make knowledge meaningful in both contexts. For example, Wallgren (2007) concluded industrial PhD students to not have brokering roles, while others (often not using the term brokering explicitly) report that they do have such roles (Assbring & Nuur, 2017; Berg et al., 2026; Gustavsson et al., 2016; Thune, 2009). Paper 3 and 4 further expand on this topic.

An interesting conceptualisation of industrial PhD students is made by Salminen-Karlsson and Wallgren (2008), who argue that the students should be seen as boundary subjects rather than boundary objects. In other words, they should be

seen as “human actors with whom both industrial and academic representatives have an interest in and to whom they relate as future colleagues” (Paper 4, p.1) rather than objects which satisfy “various needs for different groups, thus functioning as a physical link between the groups involved” (Salminen-Karlsson & Wallgren, 2008, p. 79; see also Star and Griesemer, 1989). This conceptual shift underscores the importance of acknowledging the individual students’ perspectives and the ways in which their brokering activities shape, and are shaped by, their experiences across contexts. It also highlights how brokers cannot be seen as neutral intermediaries but can be assumed to be affected by for instance power relations, organisational constraints, differing interests, and what support they get (Kislov et al., 2017; Meyer, 2010; Meyer and Brun, 2023; Wenger, 1998). Given that industrial PhD students are often not in a position of power or authority, much like traditional PhD students (e.g. Haley et al., 2025), such influences might be particularly important in shaping these students’ brokering and experiences, and the situation might be further complicated by a lack of support often seen in industrial PhDs (Compagnucci & Spigarelli, 2025).

I have hinted that knowledge brokering can be an individual and perhaps lonely endeavour for industrial PhD students, for example due to a lack of support. Kislov et al. (2017) suggest it is not realistic for an individual to “be expected to successfully deal with all aspects of brokering, feel at ease with various types and sources of knowledge, and maintain credibility with multiple (and often conflicting) stakeholders” (p.5). However, previous literature on industrial PhDs and similar doctorates often portray the student as the sole broker, pointing out how the student is in practice often the only link between the contexts (Bernhard & Olsson, 2023). According to Kislov et al. (2017) there is a tension between in-betweenness and embeddedness for brokers, which can contribute to a sense of loneliness or lack of belonging, a point echoed in research on collaborative doctorates (Bernhard & Olsson, 2023; Compagnucci & Spigarelli, 2025; Wallgren, 2007). Brokers belong in multiple contexts, but are perhaps not perceived as belonging in any of those contexts, which can hinder actual brokering. I will go further into industrial PhD students’ belonging, or lack of belonging, in their communities in the following section on communities of practice and social agents involved in industrial PhDs.

2.3.4. Communities of practice and social agents involved in industrial PhDs

Belonging to and participation in communities is important to have opportunities to broker knowledge. I used different theories of communities in Papers 3 and 4, since I focused on different aspects of industrial PhD students’ realities. In Paper 4, I drew on communities of practice. Communities of practice (CoPs; Wenger, 1998) offers a sociocultural lens that is particularly useful for understanding how

industrial PhD students learn, participate and broker knowledge across their two settings. A CoP can be defined as "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (Wenger et al., 2002, p. 4). In other words, they are not defined by formal organisational structures but their functions for participants (Wenger, 1998). This lens underscores learning as situated in practice, shaped through participation and connected to identity and belonging, rather than viewing learning as something that happens only through formal structures (Eraut, 2004; Fuller et al., 2005; Boden et al., 2011). Furthermore, it complements the discussion on knowledge brokering in the previous section (unsurprisingly, as the two concepts are tightly linked, see Wenger, 1998) and helps explain why industrial PhD students' position between academia and industry brings particular challenges and opportunities.

One reason why CoP fits research on industrial PhDs especially well is that it provides a way of understanding participation not as a fixed state but as something that shifts over time and across situations (Wenger, 1998). Participation in dual contexts is built into the concept of industrial PhDs, and the students thus seldom participate in only one single, coherent community (though it can happen, as seen in Paper 4). However, as explained in Paper 4, "large organisations are too diverse and diffuse, and the people too distant from each other, to constitute a single CoP". A key point is that engagement is local, which means an individual, for example an industrial PhD student, can be part of a *constellation of practices* (e.g. a company or university) but interact primarily within a smaller CoP, for example, a research group at the university and a team, unit, or professional community in industry. I need to repeat here that CoPs are not necessarily equivalent to formal structural units, which is an important point in Papers 3 and 4, but they may sometimes be. Where a PhD student ends up in an organisation may thus presumably affect their opportunities to be members of a CoP (see Paper 4).

Before going into further details about what this means for industrial PhD students, I find it necessary to introduce another CoP concept that I use in Papers 3 and 4 as well as in this thesis, namely *legitimate peripheral participation (*Wenger, 1998). Newcomers typically enter a CoP at its periphery, where they can observe, take part in limited ways, and gradually build the familiarity, competence, and relationships needed for full participation (Wenger, 1998). The periphery is not a clearly defined boundary, where you are either in or out of a community, but rather a continuum. Peripheral positions are not only a matter of limited access but also of learning opportunities and part of a trajectory to potentially move into the core of a CoP. Whether individuals eventually move further inward or remain peripheral depends on conditions such as access to resources, people, and shared routines. Instead of moving to the core of a CoP, it is also possible to remain in the periphery or instead end up in a *marginal* position. The latter is a position where the trajectory is leading

out from rather than into the CoP, one where there is less than peripheral participation and from which brokering is presumably difficult (cf. Wenger, 1998).

In Wenger's (1998) conceptualisation, *legitimate* means that newcomers are recognised, formally or informally, as having a place in the community, even if their initial participation is peripheral. Furthermore, legitimacy or the lack thereof shapes what kinds of involvement are possible and what forms of access individuals can reasonably expect. On a similar note, it is important to clarify that peripheral positions are not necessarily experienced as forced, temporary, or something one must move beyond in one direction or the other. Some individuals may instead prefer the peripheries, and even thrive in them, as suggested by Wenger (1998; and mentioned in my positionality statement). For example, full participation may require responsibilities, visibility, or commitments they do not seek, or that would take time away from brokering. Although these nuances of participation are seldom highlighted explicitly in research on industrial PhD students, previous research does underscore that industrial PhD students have to manage their time carefully and prioritise what they commit to in each context. This reasoning also connects to the students' motivation for doing an industrial PhD, for example rather than a traditional PhD: they often do seek to connect theory and practice (Compagnucci & Spigarelli, 2025), i.e., seek to prioritise brokering between their contexts (see Paper 4).

Legitimacy and peripheries provide another set of rationales for using knowledge brokering and CoPs to theorise industrial PhD students' experiences in and across their two contexts. While *boundary spanning* captures students' "ability to bridge industry and academia during PhD education" (Berg et al., 2026, p.523), peripheries and legitimacy as part of how CoP and brokering are conceptualised by Wenger (1998) make it possible to discuss varying degrees of participation in industry and academia, rather than just participation and non-participation. In addition, CoPs and brokering draw attention to the cost of being marginal or peripheral to two worlds, and, as Meyer (2010) argued, perhaps be viewed with some degree of suspicion in both.

For industrial PhD students, peripheral participation risks becoming a persistent condition rather than a short initial phase before moving further into a community. They often struggle to achieve full participation in either context, face ambiguous roles and challenges in integrating theory and practice (Compagnucci & Spigarelli, 2025; Grimm, 2018; Jones, 2018; Tavares et al., 2020; Thune, 2009; Wallgren, 2007; Wallgren & Dahlgren, 2007). As a result of these challenges, legitimacy needs to be renegotiated repeatedly, and movement toward more central participation is far from guaranteed. Other factors shown to affect the degree of participation are proximity in terms of how close the firm and university are geographically and cognitively (Berg et al., 2026), effort from managers (Abu Sa'a and Yström, 2024),

how the project was initiated, and the students' backgrounds (Berg et al., 2026). For example, industrial PhDs who were employed at a company and themselves initiated the project or those who entered through a collaborative master's thesis project can have advantages in terms of familiarity with the industry context. Previous research has pointed out the issue of potential peripheral participation implicitly, but Paper 3 and especially Paper 4 do so explicitly and theorise the issue. Furthermore, if the peripheral participation remains over time or if students move further into communities in each context remain unclear from previous research. This is addressed in Paper 4, where the initiative of the student themself is shown to be crucial for integration.

Regarding specific individuals, groups and communities, i.e., *social agents*, involved in supporting industrial PhD students and projects, previous research has primarily focused on academic and industrial supervisors (Roolaht, 2015; Salminen-Karlsson & Wallgren, 2008; Tavares et al., 2020). Supervisors' responsibilities, especially in industry, are often unclear and vary depending on prior experience, organisational expectations and individual availability (as also elaborated on in Paper 4). For example, Wallgren and Dahlgren (2007) found that some students lacked an industrial supervisor altogether, and even when supervisors were assigned in both contexts, both academic and industrial supervisors were often too busy to offer sufficient support throughout the PhD. More recently, Abu Sa'a and Yström (2024) showed that managers can create enabling conditions for knowledge dissemination in industry by recognising PhD work, facilitating interaction with colleagues, and promoting the PhD students' engagement in operations (i.e., not only traditional PhD work)—which includes encouraging training and supporting participation in relevant CoPs (cf. Papers 3 and 4).

However, studies on traditional PhDs underscore the importance of additional social agents such as peers, colleagues and research groups (Jacobsen et al., 2025; Sala-Bubaré & Castelló, 2017; Solli & Muir, 2021). Moreover, Owens et al. (2020, p. 107) emphasise the "necessity for maintaining, brokering and supporting a range of relationships" in traditional PhDs. This complexity can be assumed to be amplified for collaborative doctorates, and perhaps especially for industrial PhDs who must do so across two contexts while fulfilling the full academic requirements of a PhD (Grimm, 2018). Yet, this broader set of social agents remains understudied in research on industrial PhDs, where the focus often remains on supervisors, organisational structures, and, to some extent, managers in industry.

In summary, research needs to move beyond supervisors and consider the multiple social agents and CoPs that can be assumed to shape industrial PhD students' experiences and opportunities to participate, gain legitimacy, and broker knowledge. Understanding who "the players in the game" are (Compagnucci &

Spigarelli, 2025, p. 1097) and how students relate to them provides crucial context for analysing the knowledge brokering and participation throughout the PhD. This is a main focus of Paper 4. Another key aspect of knowledge brokering is communication, without which there cannot be brokering or belonging to communities. I will further elaborate on the communication of industrial PhD students in the following section (2.3.5), and then on discourse communities in section 2.3.6.

2.3.5. Industrial PhD students' communication

Communication underpins successful collaboration between academia and industry generally (Pertuz et al., 2021; Sjöö & Hellström, 2019) and is also highlighted in studies on industrial PhDs specifically (Kihlander et al., 2011). Industrial PhD students must not only communicate within each context—mastering academic writing and presentations as well as industrial genres—but also learn to navigate the interface between the two, translating knowledge, goals, and expectations so that their communication works in both settings and for brokering (Paper 3; see also Granata & Dochy, 2016; Kihlander et al., 2011; Santos & Patrício, 2020). Many industrial PhD students have also been in industry for some time before starting the PhD, which may make challenges in academic communication more pronounced (Peters et al., 2017), and previous research also shows challenges in communication and specifically academic writing for traditional PhD students generally (Calle-Arango & Ávila Reyes, 2022; Duff, 2010; Kaufhold, 2025; Sala-Bubaré et al., 2018). Furthermore, genre differences add complexity to industrial PhD students' communication practices compared to those of traditional PhDs. For example, previous research broadly suggests that academic communication is dominated by scientific articles, while industry often prefers oral presentations and to some extent technical reports (Kihlander et al., 2011; Santos et al., 2021). Note that the communication and genres differ not only linguistically but also epistemically, for example, regarding what counts as relevant or credible communication in each context. However, the full repertoire of genres used by industrial PhD students remains under-described and communication overall has, to my knowledge, received less attention in previous research than other issues such as expectations from different stakeholders, supervision, or programme design. This gap is addressed in Paper 3 where I provide a more comprehensive picture of industrial PhD students' communication practices, including what genres they use.

Previous research does offer some insight into how students navigate communication in collaborative doctorates, and how they find opportunities to communicate within their industrial organisations. Abu Sa'a and Yström (2024) show that industrial PhD students may facilitate knowledge dissemination in their industrial context by maintaining an open attitude to learning, participating and

building relationships beyond the immediate project, and packaging knowledge for different audiences, including acting as translators within the organisation. A particularly useful aspect of Abu Sa'a and Ystrom's study is the distinction they make between the co-creation of knowledge within the immediate project team and the dissemination of knowledge to broader groups in the organisation. When I first encountered their use of the term dissemination, it seemed somewhat unexpected in the context of a collaborative doctorate, but their distinction is helpful and adds nuance. Knowledge is not necessarily co-created with the wider organisation and communication directed at colleagues outside the people closest to the project is, as Sa'a and Ystrom argue, more appropriately described as dissemination (cf. Kihlander et al., 2011). They also highlight that even surface-level dissemination has value, as it can increase visibility, make the PhD project appear more accessible, and help the student connect with colleagues who may have related interests. Although such communication may remain relatively limited in depth, it can still make the project more visible and known in the organisation and show its relevance for others in the organisation, possibly contributing to recognition.

Moving beyond surface-level communication, to deeper engagement with other social agents in the involved organisations, however, requires trust and sustained interaction, particularly because much of the knowledge industrial PhD students work with is tacit or highly contextual (Abu Sa'a & Ystrom, 2024). This is presumably true for both the industrial (more applied) and academic (more theoretical) aspects of their work. Tacit knowledge is difficult to articulate and "requires socialisation to be transferred" (Abu Sa'a and Ystrom, 2024, p. 533). In other words, meaningful and useful communication is not just a matter of presenting information but of engaging with colleagues in industry and academia in ways that allow tacit insights to become meaningful and useful in each context (cf. Figure 2.3 on the third mission, science communication and knowledge brokering). This is why, in Paper 4, I explored what connections industrial PhD students have to various social agents in their two contexts.

To understand these communicative environments and the challenges industrial PhD students encounter, I draw on the concept of discourse communities (DCs), as elaborated in section 2.3.6. DCs highlight the communicative norms, expectations, and genres that characterise different communities and therefore help explain why industrial PhD students must adapt their communication across contexts. When used together with knowledge brokering, DCs provide a framework for analysing not only *how* students communicate within and across their two contexts, but also *what kinds of support* they may need to do so sustainably.

2.3.6. Discourse Communities

The concept of discourse communities (DCs) is useful for understanding the communicative environments industrial PhD students engage with. Drawing on Swales' (2016) and Johns' (1997) work, DCs brings attention to the communicative norms, expectations, and preferred genres that characterise different groups, and thus help explain why and how students must adapt their communication when moving between academia and industry. Using DCs alongside knowledge brokering makes it possible to analyse both how students communicate within and across their two contexts, and what kinds of support they may need to do so.

The focus of the concept is on "texts and language, the genres and lexis that enable members… to maintain their goals, regulate their membership, and communicate efficiently with one another" (Johns, 1997, p. 500). Specifically, each DC has its own 1) set of goals, 2) internal communication, 3) participatory mechanisms, 4) genres, 5) terminology, 6) hierarchies, 7) silential relations, and 8) expectations. They can, for example, be recognised through the texts they produce, the conventions they uphold, and the language choices that signal membership or expertise (Johns, 1997; Swales, 2016). In summary, DCs foreground the linguistic and rhetorical features that hold a community together, whereas CoPs emphasise shared practices, identities and forms of participation (cf. Wenger, 1998). Both concepts focus on what communities do, but DCs highlight how they *communicate*. This distinction is helpful for analysing industrial PhD students' communication realities, because their work involves navigating two DCs that differ in form, function, and communicative expectations, as I elaborate in Paper 3.

A DC perspective also helps clarify how communicative expectations are shaped by what different communities value and pay attention to. In academic settings, emphasis often lies on disciplinary conventions and theoretical contribution, while in industry communication tends to be guided by organisational aims and practical needs (Compagnucci & Spigarelli, 2025; Kihlander et al., 2011). Rather than restating specific genre differences (see section 2.3.5 and Paper 3), the key point here is that the norms and assumptions embedded in each DC influence what kinds of knowledge are considered valuable, what forms of evidence carry weight, and how messages need to be framed. For industrial PhDs, this underscores that communication across industry and academia, theorised as DCs, involves navigating underlying assumptions about relevance and purpose, and not just adjusting surface-level features of text or talk. Moreover, Meyer (2010) argues that brokers' communication across communities involves not just moving knowledge, but also transforming it. To transform and negotiate knowledge between stakeholders, and in this process "de- and reassemble" it (Meyer, 2010, p. 123) shapes not only the communication but can also make the produced knowledge more robust and useful across DCs.

However, DCs should not be understood as uniform or fixed entities. Large organisations often contain several overlapping DCs, and communication practices can vary considerably across teams, functions, and professional groups (Bazerman & Prior, 2005; Swales, 2016). The same applies to academia, where disciplinary traditions, research groups and methodological orientations shape discourse in different ways. For industrial PhD students, this means there is no single "academic" or "industrial" discourse to adapt to. Instead, they encounter multiple and sometimes shifting expectations, and DCs as a theoretical lens risk oversimplifying the communicative landscapes that industrial PhD students navigate. I argue that this does not undermine the usefulness of DCs, but it does point to the need to apply the concept with attention to variation and overlap between communities. In previous research in academic settings, DCs have for example been used to explore how students are socialised into disciplinary writing norms and research practices (e.g., Basturkmen et al., 2014; Zhang et al., 2018; Kamler, 2008). In professional environments, the concept has been applied to analyse workplace communication, genre use, and the coordination of specialised knowledge (Pogner, 2003; Singh et al., 2019). These studies suggest that DCs still remains a valuable lens for examining how individuals learn to communicate within and across different contexts.

Finally, DCs offer a way of identifying support needs, which is a main point made in Paper 3. If communication across DCs requires students to recognise and adapt to different norms and assumptions (Swales, 2016), then training and supervision also need to take these differences into account (see Paper 3). DCs therefore complement the brokering perspective by highlighting the communicative dimension of brokering: what students must say, write, translate and transform to make knowledge meaningful in both settings (Wenger, 1998; Meyer, 2010). In this thesis, DCs are used together with knowledge brokering to theorise industrial PhD students' communication practices described in Paper 3, and to outline what kinds of support might be needed to help students communicate effectively within and across their two contexts.

In this chapter, I have provided an overview of the conceptual and theoretical framework of this thesis and the appended papers, situated my research in relation to previous research and theories, and motivated my choices of theoretical frameworks. As a reminder, the chapter has included the broader picture of the third mission (section 2.1) as well as the two aspects that I focus on in this thesis: 1) researchers' engagement in science communication and self-regulation of science communication writing (Papers 1 and 2; section 2.2), and 2) industrial PhD students' brokering between industry and academia, including challenges and enablers in this process as well as their participation in communities (Papers 3 and 4; section 2.3). Specific theories for science communication include metacognitive strategy knowledge and self-regulated learning as well as different conceptualisations of science communication and researchers' roles (see section

2.2). For industrial PhD students, specific theories and concepts include knowledge brokering, communities of practice and discourse communities (see section 2.3).

3. Methodology

The aim of this chapter is to explain the methodological decisions made in this thesis. In the investigations of how the third mission is enacted through science communication and industrial PhDs, I have used several methodological approaches. The first three papers included in this thesis are co-authored, and my role varied in regard to the methodological design, collection and analysis of data in these three studies. Papers 1 and 2 were part of a research project led by my main supervisor, called "Scientific communication and metacognition: Thinking outside the box". I collaborated in this project first as an amanuensis (a form of research assistant), and then as main author and co-author in two studies (Papers 1 and 2 in my thesis). Papers 3 and 4 are part of another project, which can be seen as my main PhD project and was run by me. Further details about my contributions can be found in Table 3.1, which provides an overview of the methodology for each of the four papers.

Before diving further into the details of the methods for each paper, I will elaborate on the research philosophy that lies behind the methodological choices in my research. I will also elaborate on how my research can often be considered mixed methods research, what parts cannot be considered mixed methods research, and motivate why I have combined so many different methods.

3.1. Research philosophy

As an engineer, my focus is on solving problems: identifying a problem and trying to figure out possible ways to solve it. As a social scientist, I am still greatly influenced by this mindset. Though "solving" a problem is often not as straightforward when doing research within educational sciences, educational psychology, and applied linguistics as it is in engineering, I always aim to clearly connect to a problem in practice and provide a piece of the puzzle in solving this problem. My research approach is therefore best described by pragmatism, a paradigm which focuses on the research problem at hand and what methods and theories work best to address it (Creswell & Plano Clark, 2011; Feilzer, 2010; Morgan, 2014; Robson & McCartan, 2016).

Pragmatism is "almost an 'anti-philosophical' philosophy which advocates getting on with the research rather than philosophizing—hence providing a welcome antidote to a stultifying over-concern with matters such as ontology and epistemology" (Robson & McCartan, 2016, p. 30), in which pluralism is endorsed

Table 3.1. An overview of the methodology of the four papers included in this thesis

Paper	1. Science communication	2. Self-regulation and science communication	3. Industrial PhD students' communication	4. Industrial PhD students' networks
Purpose of approach	Map science communication practices	Illustrate the metacognitive strategy knowledge (MSK) and self-regulation (SR) of researchers who are experienced in writing science communication genres when they write in these genres	Investigate in what ways industrial PhD students broker knowledge between academic and industrial contexts, theorised as discourse communities (DCs), what challenges they face in doing so, and what support they need.	Further investigating the knowledge brokering of industrial PhD students between academic and industrial contexts, focusing on the roles of various social agents in the industrial PhD.
Methods	• Analysis of metadata for publications • Qualitative content analysis • Aspects of genre analysis	• Narrative/episodic interviews • Sampling based on findings from Paper 1	Questionnaire • Closed and open questions • Qualitative content analysis	• Semi-structured interviews • Community plots • Participants from Paper 3 who volunteered • Inductive thematic analysis
Objects of enquiry	506 publications • Metadata • Full texts	7 researchers experienced in writing science communication genres	152 industrial PhD students from 5 Swedish STEM universities	12 industrial PhD students from 2 Swedish STEM universities
Data source	• Metadata from a publication repository • Full texts available online	One interview with each participant, specific questions targeting MSK and SR	Questionnaire sent to 535 industrial PhD students by email, linking to Microsoft Forms	One interview per participant, using community plots as a visual tool and scaffold
My contribution to methodology	Co-authored paper. We collaboratively designed the study, and I took the main role in data collection and analysis, in addition to authoring the paper.	Co-authored paper. I was involved in the initial phase of the design, that overlapped with the analysis in Paper 1, but not in the continuation of the design or in the data collection. I contributed to the analysis and interpretation of the data.	Co-authored paper. I did the majority of the work and my supervisors advised and gave valuable feedback in all stages of the process. Material preparation, data collection and analysis were performed by me.	Single-authored paper. My supervisors naturally provided feedback, but to a lesser extent than for Paper 3.

(Creswell & Plano Clark, 2011). Unsurprisingly, a common critique against pragmatism is that it is an easy way out for those who do not care about research philosophy (Donmoyer & Gage, 2008). While Robson and McCartan's (2016) quote may be interpreted this way, I would instead argue that pragmatism entails an understanding that the world's complexity cannot easily be described by one worldview, neither by one objective reality nor by several subjective realities (see Creswell & Plano Clark, 2011; Donmoyer & Gage, 2008). Broadly, pragmatism can be considered mainly an ontological construct (Donmoyer & Gage, 2008), where the general ontological assumption is that there is both a natural/physical world and a social/psychological world (Robson & McCartan, 2016) and where both a purely objective and a purely subjective worldview are seen as insufficient for understanding the nature of reality (Donmoyer & Gage, 2008). Similarly, the epistemological assumptions combine the traditionally opposing views of knowledge as either based on reality or constructed (in e.g., post-positivism versus interpretivism, the critical/emancipatory paradigm, and post-modernism), and recognises both, as well as that both truth and knowledge change over time and space (i.e., between people; Donmoyer & Gage, 2008; Robson & McCartan, 2016). While it may seem like "anything goes" in this paradigm, or that it is a paradigm for those who do not care about research philosophy (Donmoyer & Gage, 2008), researchers adhering to pragmatism still motivate their choices of theories and methods, especially in relation to their research question, hypothesis, or the problem they try to solve. The pluralism of pragmatism, and thus its openness to various methods and theories, makes these rationales particularly important.

Based on the above description and my reading of literature on different research paradigms, I argue that pragmatism has much to offer in its orientation towards real-world problems and informing practice (cf. Robson & McCartan, 2016). In my research, a pragmatist approach is especially useful due to its compatibility with mixed methods. Though mixed methods may be used in research with other philosophical perspectives, a mixed methods approach is often associated with pragmatism as both pragmatism and mixed methods emphasise choosing methods (and theories) that are appropriate for addressing a particular research problem (Creswell & Plano Clark, 2011; Morgan, 2014).

I will elaborate on my methodological choices in the following section, but first a note on how my choices of paradigm and methods are linked to my background. Researchers' values may influence their choice of paradigm as well as theoretical framework and methods, as mentioned in the preface (Greenbank, 2003). This influence is recognised, even central, within pragmatism (Donmoyer & Gage, 2008; Robson & McCartan, 2016). I therefore acknowledge that a pragmatist approach aligns well with my engineering, problem-solving-focused background. I also recognise that my background has undoubtedly affected my methodological choices,

while my approach and methodological choices have also evolved throughout the course of my PhD.

3.2. Mixed methods research and mixing methods

There are various definitions of mixed methods research, and I will therefore elaborate briefly on this before moving on to describing how I have used, and not used, mixed methods in the four papers. As summarised by Creswell and Plano Clark (2011), some definitions focus on methods and quantitative/qualitative research while other definitions focus more on methodology, research design, or even philosophy. Based on these definitions, Creswell and Plano Clark (2011, p. 5) identified the following core characteristics of mixed methods research:

1. Both quantitative and qualitative data is collected and analysed (persuasively and rigorously)
2. The two types of data are mixed/linked/integrated
3. One or both types of data are given priority/being emphasized
4. The procedures are used in one study or different phases of a larger study
5. The procedures are framed within philosophical worldviews and theoretical lenses
6. The procedures are combined into "specific research designs that direct the plan for conducting the study"

Importantly, the use of mixed methods must be justified by the research problem, for example, a research problem that cannot be answered sufficiently using only qualitative or quantitative data.

In two out of the four studies, Paper 1 and 3, the research problem warranted the directed use of both quantitative and qualitative methods. Drawing on a pragmatist worldview, I therefore mixed methods to provide sufficient answers to the research questions. The design of each of these two studies also fulfils all six characteristics described by Creswell and Plano Clark (2011). I will briefly describe the design of Papers 1 and 3 below to justify this statement. I will also comment on the overall methodology in the project that Paper 1 and 2 were part of, to then reflect upon if Paper 4 can be considered a mixed methods study or not, given that it collected both qualitative and visual data.

Paper 1 used a convergent design (Creswell & Plano Clark, 2018). In a convergent design, quantitative and qualitative data are collected during the same time period and not sequentially one after the other (Creswell & Plano Clark, 2018). Quantitative

and qualitative data were obtained from a database on publications and additional qualitative data in the form of full texts of articles were then added from other sources. The convergent design in Paper 1 was used due to the fact that the data was already available, and the data collection only consisted of downloading data from a publication repository, organising it in a metadata file, and finding and downloading the full texts.

Paper 3 used the questionnaire variant of convergent design (Creswell & Plano Clark, 2018) where quantitative and qualitative data were collected simultaneously through a questionnaire with open and closed questions. While I deemed quantitative data interesting and valuable in relation to the research questions, there was a need for a deeper understanding than could be provided by a purely quantitative method. Therefore, in line with my worldview and focus on the problem at hand, I used mixed methods in this study. In both Paper 1 and 3, the data was analysed both quantitatively (partly after inductive coding of qualitative data) and qualitatively, whereafter the results from the qualitative and quantitative analyses were compared and merged to provide a better understanding of the research questions.

In summary, in both Papers 1 and 3, both quantitative and qualitative data were collected and analysed (characteristic number 1) as well as integrated and linked (characteristic number 2) in analyses where both types of data were given priority (characteristic number 3) in one study (characteristic number 4). The two studies used established theoretical frameworks and were framed within a pragmatist worldview, where the problem at hand was in focus (characteristic number 5). Finally, both Papers 1 and 3 combined qualitative and quantitative data collection in specific designs to fulfil the aims of the studies (characteristic number 6). Thus, both studies show all the core characteristics of mixed methods research described by Creswell and Plano Clark (2011).

In Paper 4, I collected and analysed several types of data (visual data and qualitative interview transcripts). The visual data were used as elicitation tools during the interviews, supporting participants in recalling and articulating their experiences across contexts, but also as data in themselves (cf. Thille et al., 2021). While I mixed methods, collecting two types of data, it does not count as mixed methods research according to Creswell and Plano Clark's (2011) characteristics, since I did neither collect nor generate quantitative data (except for basic background information about each participant). How to characterise visual and other art-based methods in relation to mixed methods research has been debated (Shannon-Baker & Edwards, 2018), similar to the overall debate on mixed methods that Creswell and Plano Clark tried to summarise into core characteristics of mixed methods. Their characterisation does not include art-based methods, nor is it positioned in relation to such methods, which has been critiqued as it may limit "methodological

innovations that might characterize another approach as its own strand" (Shannon-Baker & Edwards, 2018, p. 937). Visual methods are instead more common in ethnographic and ethnographically oriented work, where visual cues are used to support the recollection and articulation of lived experience (van den Scott, 2018). Paper 4 could thus be considered taking on an ethnographically oriented approach. To be consistent with the discourse on mixed methods, I will, as advised by Shannon-Baker and Edwards (2018), not define Paper 4 as mixed methods research. I instead describe it as a study using multiple methods that are used both together during data collection and to complement and triangulate each other in the analysis process—i.e., as a study mixing methods. This is similar to mixed methods research, but instead of quantitative and qualitative methods, I used qualitative and visual methods. Note that except for using visual rather than quantitative data, Paper 4 fulfils the other criteria for mixed methods research by linking and integrating two types of data (criterion 2), emphasising both in the analysis though priority was given to the qualitative data in the written paper (criterion 3), being used in one study (criterion 4), being framed within philosophical worldviews and theoretical lenses (pragmatism, learning as social and situated; and communities of practice; criterion 5) and being combined intentionally into a research design (criterion 6).

In contrast, the study written up in Paper 2 was a qualitative narrative inquiry study. It clearly does not fulfil the six core characteristics of mixed methods research, since we used only one qualitative method: interviews (not fulfilling characteristic number 1). Note, however, that Papers 1 and 2 were part of one larger research project, and Papers 3 and 4 were part of another larger research project. These two larger studies overall fulfil the criteria of mixed methods (see characteristic number 4), both of them with an explanatory design. An explanatory design typically entails a first quantitative phase followed by a qualitative phase aiming to explain or elaborate on the findings from the quantitative phase (Creswell & Plano Clark, 2011). In my research, Paper 1 served a mapping purpose and Paper 2 elaborated on the findings from Paper 1 and aimed to provide an understanding of what lay behind them through episodic/narrative interviews. Similarly, Paper 3 served a mapping purpose, though more elaborate than the mapping in Paper 1, and Paper 4 then followed up on some of the most interesting aspects emerging in Paper 3.

3.3. Methods used for each paper

My methodological choices have been guided by the research problem at hand, as explained in the previous sections of chapter 3 (see also Pears et al., 2012). These choices resulted not only in a mixed methods approach in two papers and multiple

methods in another paper, but also in the use of different methods in the different papers, as summarised in Table 3.1, where I provided an overview of the four articles from a methodological perspective. In the following sub-sections, I will present the methods used in the four papers and why I found them suitable to address the research problems. Note that the methods are presented in the order of the papers, first for Paper 1 (qualitative content analysis and genre analysis, also including the qualitative content analysis for Paper 3) and then for Paper 3 (questionnaire) followed by Papers 2 and 4 (interviews) and then the visual method used in Paper 4 before describing thematic analysis as used in Papers 2 and 4.

Before moving on to the specific methods used, I however find it important to make three points. First, a PhD is an education in conducting research, and though my methodological choices have been guided by the aim and research questions for each study, I think it is beneficial from an educational perspective that I ended up using, and thus practicing using, many different methods. Second, there was originally also a statistical analysis in Paper 3, but the reviewers did not find the findings from that analysis sufficiently interesting for international journal publication. I therefore decided to remove that aspect in the revision process. That method, which was binary logistic regression (Osborne, 2017), is therefore not included in this thesis, though I did use it as part of this PhD. The binary logistic regression analysed correlations among whether industrial PhD students perceived challenges in communicating their research and several other factors: whether or not participants had taken a course in communication; length of time between most recent degree and the start of the PhD; university affiliation; languages they had used in professional contexts (Swedish, English, or both); and type of employing organisation (governmental agency, research institute, large company, or small to medium sized company with fewer than 250 employees)[4]. More to the point, choosing methods has not only been about selecting which methods to use, but also about selecting which methods not to use, and be pragmatic about what in the end contributes to answering the research questions—throughout the whole research process—and telling a story, rather than one too many stories, in the written papers. Third, I conducted the data analysis alone for Papers 3 and 4, and partially Paper 1. However, alone is an imperfect word to describe a process where I did the data analysis but where I could discuss any concerns with my coauthors and supervisors at any point, did so whenever needed, and kept a continuous dialogue during the whole process of designing and conducting data collection, data analysis, and

[4] The findings are not part of Paper 3 or this thesis but could be summarised briefly that the overall model was significant but only one independent variable was significant: those with previous experience of only Swedish and those with experience of both Swedish and English were more likely to experience challenges than those with previous experience of only English. It was in other words beneficial to have previous experience of using English in a professional setting, but not more beneficial to also have previous experience of Swedish.

writing the papers. In other words, I used parts of my community to make the research process as trustworthy as possible.

3.3.1. Qualitative content analysis (Papers 1 and 3) and genre analysis (Paper 1)

Qualitative content analysis (Cho & Lee, 2014; Schreier, 2012) aims to describe the meaning of the material in a systematic way, rather than identifying relationships between materials or building theory as in grounded theory. It was used to identify the main topics in the publications in Paper 1 and to systematically describe the meaning of the answers to open questions in the questionnaire used in Paper 3. In Paper 1, I combined qualitative content analysis with genre analysis, and in Paper 3 I used several types of qualitative content analysis, which I will get into further below where I first focus on Paper 1 and then Paper 3.

In Paper 1, we aimed to map the science communication practices at the university in a way that gave justice to the complexity of these practices. To do so, we combined methods from within and across fields. While the data collection for this study was fairly straightforward, the data analysis was more complex. First, I made an initial statistical description of the dataset, for example including how many publications different authors had been involved in and how many publications were connected to each department at the university. Thereafter, I analysed all the full texts, which were available online for the vast majority of the publications, using qualitative content analysis (Cho & Lee, 2014; Schreier, 2012) and aspects of genre analysis (Miller, 1984; Swales, 1990) to identify topics, audiences, and purposes. In the meantime, one of my co-authors, a bibliometrician, used network analysis to explore co-authoring patterns.

For the qualitative content analysis in both Paper 1 and 3, I used an inductive approach where the topics were derived progressively from the data. In Paper 1, I did so by looking at both manifest characteristics of the texts—such as title, abstract, and where it was published—and latent meaning as interpreted from the text—for example the type of content presented (Cho & Lee, 2014). The topics were later categorised into themes to provide a better overview of the main themes at a larger scale rather than specific topics on a micro scale. Note that I here used the word themes, though categories is perhaps the preferred word to use in qualitative content analysis (Kuckartz and Rädiker, 2023). Since it refers to the same thing and is used in Paper 1, I continue to use the term here, but I acknowledge that, looking back, categories would be a more correct term and categories and is therefore also the word I use for it in Paper 3.

Similar to qualitative content analysis, genre analysis is an inductive process. Following Miller (1984), in Paper 1, I took three requisites of genre into account in

the analysis of the texts, considering their: 1) systematic similarities in content and form, 2) fulfilment of socially recognised purposes and situations, and 3) function as social action rather than as created to fulfil requirements stated in policy.

In Paper 1, we also used network analysis to explore the co-authoring patterns in our dataset. This analysis was mainly conducted by one of my co-authors, which is why I will not go into details here. In short, network analysis is a method from bibliometrics used to study authoring patterns in research fields (Schreier, 2012). This method can for instance reveal who the key authors in a field are, what different groups there are (and what they are writing about), if there are authors who link different groups together, etc. See Paper 1 for further details.

In Paper 3, many of the survey questions were designed to enable inductive qualitative content analysis of different aspects of industrial PhD students' communication realities. This approach, to design survey questions to enable analysis within certain main categories, is common in qualitative content analysis (Kuckartz & Rädiker, 2023). As is common in qualitative content analysis, the main categories were decided on based on previous research and the aim of the study. Within each main category, I coded the data into sub-categories using an inductive approach. I chose an inductive approach, within the main categories, to maintain the exploratory nature of the study within the identified aspects of industrial PhD students' communication realities (cf. Kuckartz & Rädiker, 2023).

Most of the main categories in Paper 3 are thematic (Kuckartz & Rädiker, 2023), meaning that they mainly describe manifest meaning of participants' answers to the questions (Graneheim et al., 2017). However, one main category was derived inductively from the data and can rather be considered an analytical category (Kuckartz & Rädiker, 2023). Its sub-categories are broader and more analytical than those for the other main categories and the coding was based on both latent and manifest meaning. This is somewhat similar to what would be described as themes in thematic analysis (Braun & Clarke, 2006, 2022), a data analysis method which I used in Papers 2 and 4.

3.3.2. Questionnaire (Paper 3)

In Paper 3, we collected data through a questionnaire. The design was based on our research questions and a number of previous studies using questionnaires to explore researchers' communication practices, including Bohlin & Bergman (2019), Emerson (2017), Entradas et al. (2020), and Pérez-Llantada (2021). The rationale behind using a questionnaire was an ambition to get input from as many industrial PhD students as possible. Originally, I intended to distribute the questionnaire to one or two universities. However, I subsequently decided to include five universities to provide a more comprehensive picture of industrial PhD students'

communication practices. By distributing the questionnaire to these five large STEM universities in a digital format, I gathered the perspectives of 152 industrial PhD students across Sweden. This corresponds to a response rate of 28.4 percent of industrial PhD students at the five STEM universities who were at least one year into their PhD. The one-year limit was set to ensure participants actually had experience of communicating research as PhD students.

Questionnaires are effective tools to get an overview of a phenomenon in a large population—if designed carefully and interpreted cautiously—and require comparatively little time and effort from the researcher compared to the amount of collected data (Robson & McCartan, 2016; Dörnyei and Taguchi, 2010). However, designing, testing, and improving a questionnaire is very time-consuming. For Paper 3, considerable time and effort were indeed put into the questionnaire design to ensure it targeted the research questions properly and that questions would not be misinterpreted. Using previous studies for inspiration provided a base for what questions could generate interesting data and how they could be phrased. The questionnaire was also piloted with five PhD students with a similar background to industrial PhD students, though the pilot participants were doing their PhDs in educational science or closely related disciplines.

Another challenge in using questionnaires, as with any other self-report data, is that such data cannot be seen as entirely objective (Iwaniec, 2011), and participants may answer inaccurately as a result of self-deception (answering what they would like the truth to be, not what it is), acquiescence bias (answering positively when they are not sure what to answer) or the halo effect (overgeneralising based on an overall impression). In Paper 3, I tried to capture the perceptions and experiences of the participants, both of which are not objective in themselves (cf. Iwaniec, 2019). Some questions were more fact-oriented, for example if they had taken a course in communication and in that case what kind of course. I could perhaps have tried to triangulate that data, but on the other hand using students' reports was sufficient for the purpose of the study and there is no reason to believe they would misreport consciously or even to any high extent unconsciously. For example, the questions did not focus on details that might be difficult to remember but had a comparatively low resolution.

Responses to closed questionnaire questions can be analysed quantitatively using statistical methods while responses to open-ended questions can be analysed both qualitatively, and after quantification, quantitatively. In Paper 3, the responses to the closed questions were analysed with descriptive statistics while the responses to the open-ended questions were analysed both qualitatively and quantitatively, after having been coded using qualitative content analysis (see section 3.3.1). As mentioned in section 3.3, I also tried using binary logistic regression (Osborne, 2017) for some of the quantitative data to identify potential correlations between if

participants experienced challenges in communicating their research and a number of factors such as university and type of organisation.

3.3.3. Interviews (Papers 2 and 4)

In Paper 2 and 4, interviews were used to generate in-depth data to be able to answer the research questions for each of these papers. Both papers had been preceded by a mapping study and were the second phase in their respective research projects, now aiming to examine specific aspects more in depth.

In Paper 2, we used interviews to capture researchers' metacognitive strategy knowledge (MSK) and self-regulation (SR) in relation to writing science communication. The data used for Paper 2 was part of a larger dataset from these interviews. The interviews used in Paper 2 are best described as episodic narrative interviews, meaning interviews that focus on the narratives of episodes and involve some prompting in relation to the episode (Flick, 2000; Mueller, 2019). The parts of the interviews that Paper 2 are based upon also involved some prompting in relation to the theoretical concepts, for example to the different phases of self-regulation, including planning, monitoring, and evaluating. This type of interview combines aspects of both narrative and episodic interviews. Narrative interviews are semi-structured interviews aiming to capture the bibliographical dimensions of a lived phenomenon, as described by Barkhuizen (2015). This type of interview allows for lengthy answers and was for example used by Emerson (2017) in her book on researchers' experiences of and reflections about themselves as writers, a book that inspired Papers 1 and 2. However, we wanted to focus on a specific part of our participants' writing and dig deeper into their science communication and what was behind the publications we had discovered in Paper 1. (Note that some of the participants in Paper 2 were also included in the dataset in Paper 1.) The participants were therefore asked to bring examples of their science communication with them to the interviews. These examples aimed to prompt a discussion about certain episodes of writing and the process for writing the texts the participants had brought. Focusing on episodes can make it easier for the interviewees to remember what they did and thought compared to a more open approach with no prompt or link to a concrete experience that they can recall. To make sure the participant actually remembered the episode, they picked their example texts themselves, as advised by Flick (2000). In line with Flick's (2000) description of what constitutes an episodic interview, questions about the specific episode were combined with more general questions relating to science communication overall and to our theoretical framework.

Some of the questions in the interview protocol for Paper 2 were designed to elicit responses about different parts of MSK and SR. The answers to these questions were

compiled and analysed both inductively, using thematic analysis (see section 4.3.4), and deductively, framing the emergent themes within the self-regulated learning theoretical model by Zimmerman & Moylan (2009).

In Paper 4, I used semi-structured interviews (Rowley, 2012) to further examine the realities of PhD students, and specifically examine what expectations the students, as presumed knowledge brokers, face, and social agents and communities of practice involved in industrial PhDs. The interviews, however, also included questions about the PhD project and setup, research communication practices and support, and overall reflections on the industrial PhD experience. The first and last of these topics also informed Paper 4, while the data regarding communication has not yet been used for academic publications. The part about communication was inspired by the results from Paper 3 as well as Paper 2 regarding communication and learning to communicate. I also showed the participants their responses to the survey used for Paper 3, asking them to explain and elaborate on their communication practices. I however found the results regarding the industrial PhD experience overall, and who is involved in an industrial PhD, more interesting and important for practice, which is why these are the parts of the interviews I analysed in Paper 4. More details about the specific questions can be found in Paper 4. A first version of the interview guide was piloted with a PhD student who had previously had an industrial PhD setup, but in educational sciences rather than STEM. This pilot resulted in minor adjustments of the interview guide. I will go into further details about the visual method used in Paper 4, community plots, below.

3.3.4. Visual methods (Paper 4)

In Paper 4, the interviews included an element called community plots, which was originally designed by Sala-Bubaré and Castello (2017). In this part of the interview, participants were asked to make plots representing people, groups, and communities who had a role in their PhD and how those related to each other and the PhD student. *Communities* was not defined, which means not necessarily interpreted as CoPs but as groups of some sort, formal or informal, that the participants felt were important for the PhD. This visual method was used to get a better understanding of industrial PhD students' networks than could be achieved through more traditional interview questions. Visual methods can be described as "series of research approaches in which visualizations are developed, analysed, and/or disseminated to examine a specific phenomenon" (Shannon-Baker & Edwards, 2018, p. 937). In Paper 4, the plots were used as data in themselves and as prompts during the interviews for explaining, for instance, the composition of their networks, what roles various social agents played, which actors were the most important, and if the composition of their plots would have been different at different points in their PhD.

Note that the plots were created by the participants during the interviews. They had got information regarding what topics the interview was going to include but not the exact questions or information about community plots. What this method captured was thus their perception of the social agents involved in their PhD at the moment of the interview. Other options would have been to send the instruction for community plots beforehand so they could start thinking, or even asking them to complete the plots beforehand. However, an important part of this method was to capture participants' thinking around the plot when trying to decide how it should look to best represent their reality. Their reasoning around the creation of the plots is thus an important part of the interview data that would have been excluded if they had not created the plots during the interviews. As for the other papers, the goal was not objective descriptions of reality but rather to capture the participants' perceptions and experiences, in this case of doing an industrial PhD, and to ultimately give suggestions for practice, policy and future research. The generated data was subjective and that was in line with the aim of the study and in line with my research philosophy (see section 3.1). Finally, the participants' reactions to this exercise are worth mentioning. Several commented that it was an interesting exercise to make them reflect ofnthese matters, sometimes at a deeper level than they had before or seeing all parts of their network more holistically and how they fit together rather than seeing parts more separately (e.g., industry and academia separately).

3.3.5. Thematic analysis (Papers 2 and 4)

Thematic analysis can be described as "a method for identifying, analysing, and reporting patterns (themes) within data" (Braun & Clarke, 2006, p. 79, see also Braun & Clarke, 2022). The data is coded into different *categories*, or *themes*. Each theme should capture "something important about the data in relation to the research question and represents some level of patterned response or meaning within the data set" (Braun & Clarke, 2006, p. 82). Typically, thematic analysis includes the following steps (adapted from Braun & Clarke, 2006, p. 87):

- Familiarising yourself with your data
- Generating initial codes
- Searching for themes
- Reviewing themes
- Defining and naming themes
- Producing the report

In inductive thematic analysis, the themes are created from the data, while in theoretical/deductive thematic analysis the themes are created based on a theoretical framework.

In Paper 2, we scanned the interview data for parts that related to our theoretical framework: metacognitive strategy knowledge (MSK) and self-regulation (SR). Within these themes, we then identified specific strategies, roughly following the steps described by Braun and Clarke (2006). The approach in Paper 2 was partly deductive, since the overall categories of MSK and SR were based on theory. Within each category, the strategies were not predefined but followed the principles of inductive thematic analysis (Braun & Clarke, 2006). Note that in the qualitative content analysis in Papers 1 and 3, I quantified the data as part of the analysis, while we in Paper 2 were interested only in the qualitative aspects of our data and what that could tell us in relation to our research questions.

In Paper 4, the data analysis process was more complicated since I combined qualitative and visual data. After transcribing data and anonymising all 12 community plots, I first curated the transcribed data into a large table to be able to familiarise myself with the data also across participants. Similar to Paper 2, the exploratory and qualitative nature of the study warranted the use of inductive thematic analysis to identify categories as well as themes within these categories across participants. The process roughly followed the steps laid out by Braun & Clarke (2006) with adaptations to accommodate for the number of participants and nature of the data—i.e., the fact that there was both visual and qualitative data. The initial table was updated along the way to represent not only the qualitative but also the visual data. As described in more detail in Paper 4, the categories included several different aspects of the PhD and several different social agents described by the participants. If certain social agents, e.g. an industrial supervisor or colleagues in academia, were absent from the data (plots and transcripts), this was also treated as meaningful data, indicating that the participant did not perceive the absent actor as playing a role in their PhD. After having identified themes within each of the categories, a summary was written for each participant and category, to theorise it and include it in Paper 4. I revisited the transcripts and plots when needed along the way to check interpretations. Note that compared to the steps in thematic analysis described by Braun and Clarke (2006), the data analysis for Paper 4 included additional steps. This was needed to properly include the rich visual data.

3.4. Ethical aspects

None of the studies included in this thesis have dealt with sensitive personal information, and the studies therefore did not require ethical approval according to

Swedish law. However, ethical aspects have been taken into account and the studies have followed the four fundamental principles of conducting research ethically (Swedish Research Council, 2024): 1) reliability in terms of quality; 2) honesty in all parts of the research process; 3) respect for participants, society, colleagues, etc; 4) and accountability throughout the research process and for consequences relating to the project.

In terms of quality, the four studies presented in the four papers are all carefully designed to answer their research questions, or, as in Paper 1 which has no explicit research questions, fulfil their aim. The studies were designed to address the questions or aim as appropriately as possible. In this process, I have had experienced co-authors whose knowledge of methods, theory, and previous research have further assured the quality of the studies. In Papers 2, 3 and 4, the questionnaire and the interview protocols were developed both based on the research questions and on previous research, as described in each paper. Piloting then further assured the quality of the research designs. All four studies have been presented at conferences, and Papers 1, 2 and 3 are published in peer-reviewed journals.

In terms of honesty, there have been no conflicts of interest for the authors for any of the papers. For each paper, all authors contributed to the studies and all who contributed to the design, data collection, analysis, and/or writing of the papers are included as authors. In Paper 4, which is single-authored, feedback from supervisors is recognised in the acknowledgements section of the paper and further described in the list of appended papers in this thesis. The research has been communicated as transparently as possible, while not compromising the respect for the participants.

In terms of respect for the participants and accountability throughout the research process, anonymity has been important in all four studies. In Paper 3, data that could identify participants were not collected unless they voluntarily left contact details to participate in the next stage of the project. This data was only used to contact potential participants for the interviews that resulted in Paper 4. In Papers 1, 2 and 4, the participants' identities were known to us or me during the studies, but anonymised in the papers. For Paper 4, my supervisors never knew the identities of the participants. Importantly, I had no prior connection involving power relations (for example through teaching) to the participants in the studies. In all four papers, we have tried to provide an as detailed account as possible of the research process to ensure accountability, as have I done in this thesis. The project which Papers 1 and 2 are a part of was also funded by a specific initiative at Chalmers University of Technology, Genie: Gender Initiative for Excellence, and therefore had to report back to the organisation of this initiative, adding to the accountability of Papers 1 and 2. Note that while I have also been involved in this initiative, Genie, during my

PhD, I did not become engaged in it until several years after the funding for the research project was secured and had no conflict of interests there.

Regarding accountability for wider impacts of the research, one goal of the research presented in this thesis is indeed to have wider impact. Therefore, I have tried to communicate this research beyond researchers within my field(s), and will continue to do so, for example by discussing it with academics in STEM. However, it is important to note that researchers have multiple roles and conflicting demands, as described in this thesis, and to respect academics' realities in discussing potential changes to their practices.

4. Summary of appended papers

In this chapter, I summarise the four papers appended to this thesis, focusing on the results of each paper (sections 4.1-4.4).

4.1. Paper 1

The silent tribe? Mapping the variety of researchers' science communication practices across STEM disciplines

In Paper 1, we explored the science communication practices at a large STEM university in Sweden through science communication publications registered in the university's publication repository. As described in section 2.2, science communication has received increasing recognition as an important role of the higher education system and an activity that researchers should engage in (Bragesjö et al., 2012; Entradas et al., 2020; Pinheiro et al., 2015; Watermeyer, 2015), but there still seems to be a lack of incentives for researchers to engage in science communication (Llorente et al., 2019; Pérez-Llantada, 2021; Schimanski & Alperin, 2018) and overall limited knowledge about what is actually going on under the umbrella of science communication. Thus, mappings like ours are important to provide a starting point for discussing, evaluating, and supporting science communication in relation to researchers' professional life, academic scholarship, and career, as well as in relation to policies and incentives.

By combining methods from applied linguistics and bibliometrics, as described in chapter 3, we found a complex picture of science communication practices. Our dataset contained numerous genres, with opinion pieces being the most common of the genres that we could clearly identify. There were also, for example, articles in trade magazines and editorials in newspapers. A majority of the publications were intended for the general public—such as most of the opinion pieces—but almost as many were intended for professionals—for example texts published in trade magazines. Interestingly, there were clear overlaps between audiences for some publications. Articles in architecture magazines are one such example, where the audience could be assumed to comprise both professionals and researchers. In our analysis, we compared this to the different stages in Bucchi's (1996) model of science communication and found that the aforementioned architecture articles as well as some other types of publications spanned across several stages in the model and communicated to several audiences.

Two themes of topics were by far the most common: 1) architecture, civil engineering, urban design and similar and 2) global warming, renewable energy sources and similar. These themes correspond to the two departments with the highest number of publications in our dataset. However, this overrepresentation could largely be explained by 15 researchers who had written comparatively many texts each. Notably, all but one of these 15 researchers were senior and tenured when writing their texts. This is in line with previous research suggesting that junior researchers feel that they have to prioritise according to traditional genre hierarchies even more than senior researchers, since the junior researchers want to optimise their chances of tenure and promotion (e.g., Bohlin & Bergman, 2019; Schimanski & Alperin, 2018). This finding was thus not surprising. In addition, all 15 were fluent speakers of Swedish, and almost all publications intended for the general public or professionals were written in Swedish. Finally, the network analysis showed that there were different collaboration patterns in the two most active departments as well as among the 15 researchers who were particularly active, where some researchers always wrote alone and some always co-authored their texts—possibly illustrating differences in local culture.

Overall, the mapping resulting from Paper 1 provides one piece of the puzzle of how science communication fits into the role of higher education and in researchers' professional life. It also shows how methods can be combined to better capture the complexity of science communication practices. In addition, it has similarities to Paper 1 in that it can potentially inform practice. For example, the two most active departments have shown interest in our research, what science communication is happening at their department, and, by extension, how they can support it better. This exemplifies how the difficulty of measuring science communication has implications not only for the evaluation of it (for example in promotion processes) but also for the support of it. Both practice and research need a concrete starting point, a map of where we are—to know what to do next. In Paper 1, we contributed to this starting point.

4.2. Paper 2

Thinking outside the box: senior scientists' metacognitive strategy knowledge (MSK) and self-regulation of writing for science communication

In Paper 2, we investigated the self-regulation (SR) and metacognitive strategy knowledge (MSK) of seven senior researchers who regularly and actively engage with writing science communication. However, the question remains how to best

prepare future researchers for writing in science communication genres. It is thus interesting to investigate practices of senior researchers who have expertise and extensive experience in writing such texts. Paper 2 addressed the following research questions:

1. What is senior scientists' metacognitive strategy knowledge (MSK) of writing for science communication, and what strategies do they use?
2. How do they self-regulate (SR) their writing for science communication?

In our analysis, we used MSK (Karlen, 2016) and SR (Zimmerman & Moylan, 2009) as our theoretical lenses (see chapter 2 Conceptual and theoretical framework). MSK allowed for an analysis of how the researchers chose and adapted strategies based on task conditions and the rhetorical situation, and SR allowed for an analysis of strategies used in different phases of the writing process, i.e., the forethought, performance control, and evaluation and self-reflection phases (cf. Zimmerman & Moylan, 2009).

The data in this paper came from an ethnographic interview study on science communication, and the data presented in Paper 2 is a cross-section of narrative interview data (Barkhuizen, 2015), as described in chapter 3. The seven participating researchers were from various disciplines within STEM and were all employed at one large university of technology in Sweden.

We compiled our findings into a list of metacognitive strategies used in different phases of SR of science communication writing, as shown in Table 4.1 on the next page, which is originally from Paper 2.

In the forethought phase, our participants used various strategies to analyse and conceptualise their task, including considering the purpose, message, and audience of the text. The participants also set goals for their communication—relating to purpose, content, and rhetoric—and planned for how to reach their goals, for example by creating a structure for the text. In the performance control phase, the metacognitive strategies included thinking about the readers' expectations, calibrating stylistic and linguistic choices to the audience, and considering the relationship between the text's genre and academic genres. In the evaluation and self-reflection phase, the participants explained how they trusted their gut feeling and/or experience, sought feedback—from colleagues, family members, editors, or people in the intended audience—and dealt with positive and negative reactions to their texts. There were thus instances of social regulation (Hadwin et al., 2018).

Overall, our participants based their strategies on knowledge of the task and individual preferences. The strategies emerged from experience rather than training, which is not surprising given the general lack of training in science communication, as found by Bohlin and Bergman (2019).

Table 4.1. MSK in science communication writing according to SR phases

SR Phase	Strategies (themes) from out data
Forethought	<u>Task analysis (conceptualization)</u> • Think about the argument and the story you wish to tell • Consider the purpose of the text • Consider the differences between science communication and scientific articles • Think about the audience and how to translate complex scientific phenomena for this audience <u>Planning and goal setting</u> • Convey scientific knowledge and a clear message • Set content-related and rhetorically related goals • Planning: Deciding on the message (discussion with co-authors) • Planning: Create a structure related to the goal
Performance control	• Monitoring: Consider the relationship with academic genres and adapt strategies • Monitoring: "The reader's mind", i.e., think of the readers' expectations and reactions to how the text is written • Monitoring/control: Considering audience, carefully calibrate your linguistic and stylistic choices
Evaluation and elf-reflection	• Evaluation/self-reflection: Trust gut feeling and/or experience about whether the initial goal is accomplished • Evaluation: Seek feedback from others • Self-reaction: Potential negative reactions to feedback, and potential negative reaction from audience response

With Paper 2, we contribute to increased knowledge about how effective science communication can be fostered by illuminating the self-regulatory and metacognitive mechanisms that underlie science communication writing. We also provide a theoretical contribution in showing the transfer of writing knowledge, strategies, and expertise across genres. Overall, our findings point to the importance of MSK and SR in science communication writing, and that metacognitive strategy training could potentially be beneficial for developing expertise in this writing, as previous research has pointed out for other forms of writing (Harris et al., 2010; Qin & Zhang, 2019; Zhang & Zhang, 2019). This suggestion aligns with previous studies on what should be included in science communication training (Baram-Tsabari & Lewenstein, 2017; Mercer-Mapstone & Kuchel, 2017).

4.3. Paper 3

The industrial PhD: Student perspectives on learning, communicating and knowledge brokering

In Paper 3, I examined the experiences of industrial PhD students in Sweden, focusing on their communication practices, challenges, and support needs as they navigate their dual contexts. As outlined in section 2.3, industrial PhDs have gained attention as a way to strengthen collaboration between universities and industry and to produce societally relevant research (Compagnucci & Spigarelli, 2025; Grimm, 2018; Thune, 2009). However, previous research has painted the picture of industrial PhD students' communication realities with broad brush strokes, leaving gaps in the understanding of industrial PhD students' specific challenges and support required. Paper 3 addresses the following research questions:

1. What are industrial PhD students' experiences of communication within and across discourse communities?
2. What are industrial PhD students' training and support needs regarding communication?

In the theoretical framing of Paper 3, I combined discourse communities (DCs; Swales, 2016) with the concept of knowledge brokering (Wenger, 1998), enabling me to analyse students' experiences of communicating in and across their two contexts with differing goals, genres, and expectations. Using a survey distributed to 152 industrial PhD students across five major Swedish STEM universities, I explored four areas: communication practices, challenges, learning strategies, and experiences of dual discourse community membership.

The findings revealed that most participants communicated their research to both academic (93 percent) and industrial audiences (87 percent), using multiple genres such as scientific papers, in-house reports, and presentations. Many participants (76 percent) had previous experience of communicating within industry, while fewer (41 percent) had previous experience of communicating with researchers in their field. Over half of the respondents (53 percent) reported challenges with communicating their research, primarily related to adapting to different audiences—such as adjusting to different levels of knowledge, language, and detail—rather than academic writing alone. Strategies for overcoming these challenges included learning by doing, taking courses, and seeking supervisor support. However, most of the external support focused on academic writing. Two thirds of the participants (66 percent) had taken communication courses, but similar to other external support, these were almost exclusively aimed at academic writing; very few had received training in communicating with industry or "bridging between research

and practice" (participant Paper 3). Furthermore, 16 percent even reported little to no support except for courses or felt alone in facing their challenges. Overall, students expressed a need for tailored support addressing the specific challenges industrial PhD students face.

Beyond communication, participants highlighted both opportunities and challenges of belonging to two DCs. Benefits included opportunities to conduct research that is relevant to industry and to communicate with industry, as well as to learn communication skills needed not only in academia. Challenges involved negotiating expectations, managing time, and dealing with issues regarding identity and belonging—e.g. peripheral participation rather than full inclusion in both contexts. These findings underscore that while industrial PhDs offer a boundary-spanning function, this potential cannot be fully realised without adequate support structures.

Paper 3 contributes a more nuanced and detailed understanding of industrial PhD students' realities, specifying what it means in practice to "speak both academia and practitionese" (Kihlander et al., 2011) and to act as knowledge brokers—enabling the design of better support for industrial PhD students. Our results highlight several gaps in training and support, particularly for industrial communication and brokering, and resonate with previous research on industry-academia collaborations generally in emphasising the importance of shared objectives, mutual understanding, and effective communication in university–industry collaborations (Pertuz et al., 2021; Sjöö & Hellström, 2019). In addition, Paper 3 points to how DCs and knowledge brokering as theoretical lenses can inform practical strategies for improving collaborative doctoral education. The implications for practice are a particularly important part of the paper—one that was appreciated by reviewers and editors—and include structured planning phases, continuous follow-up, supervisor and manager training, and evidence-based communication courses focusing on genre awareness and adaptation across contexts.

4.4. Paper 4

Being, becoming and brokering: Industrial PhD students' positioning within industrial and academic communities

In Paper 4, I explored industrial PhD students' perspectives on the social agents (communities, groups and, individuals) involved in their doctoral journey—who is involved, how they relate to each other and the PhD student, what roles they play, and what they expect from the project and PhD student. A key motivation for having industrial PhDs is, as described in section 2.3 and its subsections, to bridge the gap between industry and academia, a boundary-spanning function that is often carried

out by the student as the main or only knowledge broker (e.g. Assbring & Nuur, 2017; Bernhard & Olsson, 2023; Gustavsson et al., 2016; Thune, 2009; Wallgren, 2007). However, previous research has provided limited insight into what communities and individuals actually play a role in these projects and how students experience their participation and brokering role. My study addressed this gap by examining industrial PhD students' perspectives on their academic and industrial contexts and the expectations they perceive from each. My research questions were:

1. What expectations do they, as presumed knowledge brokers, face?
2. What social agents and communities of practice are involved and what are their roles?

In Paper 4, I used a community of practice lens (Wenger, 1998) to analyse and theorise industrial PhD students' participation in their two contexts, including whether it is peripheral, their presumed brokering role, and how industrial PhD students themselves shape their participation. I interviewed 12 industrial PhD students from two large Swedish STEM universities, and used a visual mapping tool called *community plots* (Sala-Bubaré & Castelló, 2017) as a scaffold in the interviews (see section 3.3.4.). These students had participated in the questionnaire in Paper 3 and there volunteered to be interviewed.

The findings revealed differences between the academic and industrial contexts. Academia was consistently described as stable and predictable, with clear expectations such as coursework, publications, and thesis writing. Supervisors were central figures in students' academic communities, often placed at the core of their plots and described as guides, mentors, and discussion partners. Other PhD students and colleagues also played important roles, providing informal support and a sense of belonging. In most cases, academia offered a clear pathway for participation—from legitimate peripheral participation as newcomers to deeper involvement over time. However, some students still felt somewhat peripheral or excluded, often due to physical distance or cultural barriers. In contrast, the industrial context was characterised by variability in expectations, support, and organisational structures. While funding was secure, expectations were often unclear, but could include research outputs and competence development. Industrial supervisors' roles varied widely, from active engagement and co-authorship to no practical role. The participants' managers in industry emerged as key figures by either being enablers through providing resources and visibility or creating barriers due to lack of understanding, limited funding or resources, or similar. Organisational changes were common and posed challenges in rebuilding relationships and understanding. Colleagues in industry were important for some students, particularly when they provided practical insights or shared research interests, but limited time spent on non-PhD tasks often hindered integration.

Overall, several participants described feeling peripheral in industry, and some lacked an identifiable industrial CoP altogether.

The analysis of brokering revealed that seven participants perceived themselves as the sole link between their academic and industrial contexts, while five mentioned additional brokers or structures, such as collaborative projects or competence centres. Most participants acknowledged a gap between academia and industry, often tied to differing priorities and epistemologies—academia's long-term focus versus industry's short-term goals. Despite these challenges, many students actively shaped their research to align with industrial interests, demonstrating agency in their brokering role. Interestingly, while brokering is often theorised as occurring in and emerging from the peripheries, my findings suggest that meaningful brokering requires participation in CoPs in both contexts—something that was often lacking in industry.

Overall, Paper 4 contributes a deeper understanding of the relational and structural dimensions of industrial PhDs, highlighting how participation and brokering are shaped by the presence or absence of CoPs, by the students themselves, and by the roles of key social agents such as supervisors, managers, and peers. A key message is that brokering does not happen automatically; it requires relationships, participation, and support. In addition, Paper 4 problematises the notion of industrial PhDs as brokers as it contains "a paradox in that new industrial PhDs *are* newcomers and learners and *are becoming* brokers between industry and academia, but also *becoming* experts in each of the contexts, all at once" (Paper 4, p.12). For instance, brokering is often described as happening from the peripheries, while learning and becoming an expert typically entails moving further into CoPs (Wenger, 1998). It can thus be questioned if a sustained peripheral participation, as was often the case in particular in industry, is desirable and constructive in an industrial PhD.

My findings underscore the need to establish clear expectations among stakeholders and stronger support structures (particularly in industry), to support brokering as a skill through mentoring and training, to create opportunities for peer interaction to reduce isolation, and to make deliberate efforts to foster inclusive CoPs in both contexts. Finally, and interestingly, despite all the challenges and barriers they described, most participants expressed that they wished to remain connected to both academia and industry after graduation and somehow retain a brokering role. This underscores the participants' strong motivation for bringing practice and research closer, but importantly the potential of industrial PhDs to train brokers who increase collaboration also in a long-term perspective.

5. Discussion

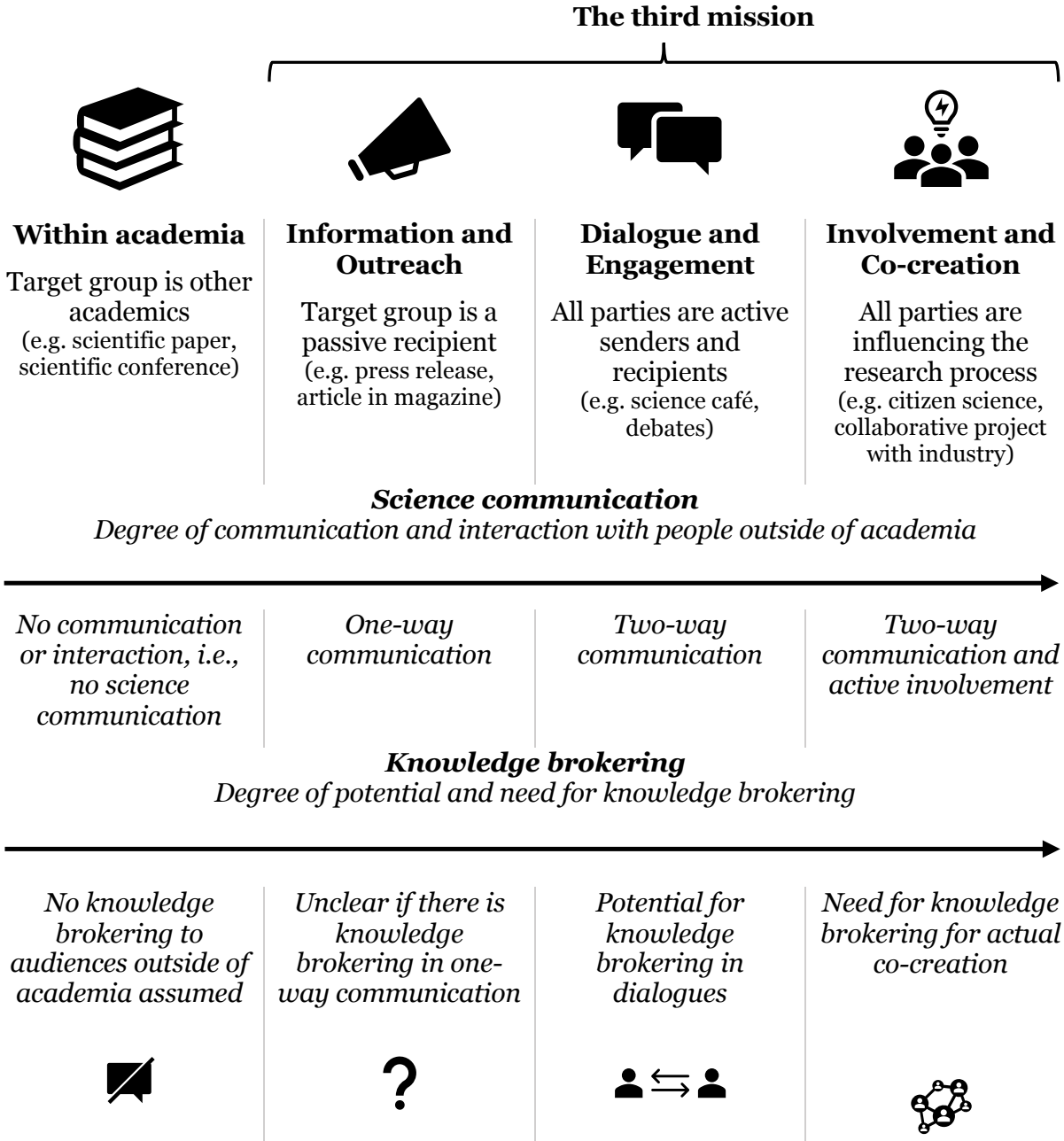
This chapter brings together the findings from the four papers to develop an overarching understanding of how academia's third mission is enacted in practice in a Swedish STEM context. While the third mission is often articulated at policy and institutional levels (e.g. Bohlin & Bergman, 2019; Compagnucci & Spigarelli, 2020; Perkmann et al., 2021; Pinheiro et al., 2015; Tomlinson, 2018), it is in practice enacted by people, such as my participants, who compose connections between academia and society through communication and participation. Regarding both science communication (Perkmann et al., 2021) and industrial PhDs (Compagnucci & Spigarelli, 2025), there have been calls for more research on the individual level, examining the perspectives of those who enact the third mission and the social agents surrounding them.

As a reminder, the aim of my thesis was to explore how the third mission is enacted through science communication and industrial PhDs in STEM, with a particular focus on the roles, practices, and challenges of individuals presumably enacting the third mission and the implications for support, training, and policy. Based on the overarching aim, the two research questions are:

1. How do researchers engage in science communication, and what strategies can be used to successfully self-regulate science communication writing? (Papers 1 & 2)
2. In what ways do industrial PhD students broker knowledge between academic and industrial contexts, and what challenges influence this process? (Papers 3 & 4)

In this chapter, I will discuss the research questions in the order above, before discussing these in relation to the enactment of the third mission more broadly, including enablers and barriers. These sections (5.1 to 5.3) also include implications and future research integrated into the discussions. I will then discuss some limitations (section 5.4) before summarising the main implications and directions for future research (section 5.5). Finally, I summarise the contributions I make in this thesis in section 5.6 before providing a condensed conclusion in the next chapter (chapter 6). Since I will refer to my model for the enactment of the third mission (Figure 2.3), this figure is repeated as Figure 5.1.

Figure 5.1. Visualisation of what the third mission entails and how this relates to science communication and knowledge brokering, identical to Figure 2.3. The figure builds upon Figure 2.2b, published by a Swedish non-profit organisation called Vetenskap och Allmänhet (*English: Public and Science*), in which organizations, authorities, universities, and companies work "to promote dialogue and openness between researchers and the public" (Vetenskap & Allmänhet, n.d.-a). However, this figure was developed further to provide a more comprehensive overview of what the third mission can entail by adding knowledge brokering and how various forms of the third mission and science communication relate to it.



5.1. Enacting the third mission through science communication (RQ1)

In Papers 1 and 2, I focused on science communication: how researchers engage in it and what strategies can be used to successfully self-regulate science communication writing (RQ1 in this thesis). Overall, our results show a complex picture of what types of science communication researchers engage in and what science communication is, including different genres, purposes, and practices (cf. Davies, 2021; Kappel & Holmen, 2019). The science communication publications included in Paper 1 belonged to many different genres, whereof some genres were more common for certain topics. Topics relating to urban design, civil engineering, and architecture together with topics relating to climate change were by far the most common. These topics corresponded to two departments at the university which had the highest number of science communication publications in our dataset. The findings regarding topics and genres are in line with previous research suggesting that some topics are more interesting to the public and that different topics suit different audiences and genres (Ampollini & Bucchi, 2020; Bucchi, 1996; Jönsson et al., 2018). For example, there is a tradition in architecture to publish in trade magazines, magazines that are read by architects, researchers and perhaps sometimes also the public. It is possible that the two departments corresponding to the most common themes of topics have a culture that encourages science communication, which is important for engagement according to previous research (Benneworth et al., 2015). These findings raise the question of whether all topics and disciplines are suited to be communicated to broader audiences, thus suggesting science communication may fall more on individuals conducting research on topics of interest to the public. However, note that I have focused on science communication targeting broader audiences such as the general public or professionals in open channels. The question of how the third mission is enacted through science communication in other forms, for example in one-to-one contact with companies or reports and briefs for policymakers, remains.

Another aspect of how researchers engage in science communication is *who* engages. We found that a few senior and tenured researchers had authored a majority of the registered science communication publications at the university (Paper 1). Given previous research on how junior researchers experience pressure to prioritise scientific publishing (Bohlin & Bergman, 2019; Schimanski & Alperin, 2018), this finding was not surprising. Senior researchers presumably have more experience and scientific ethos, possibly making it easier for them to take on the role of a public intellectual, and be seen as such by their audiences (see section 2.1.1; see also Said, 1994). Indeed, the most active researchers in our dataset in Paper 1 could mainly be placed somewhere around the public intellectual in the continuum of

engagement with society that I suggested in my licentiate thesis (see Figure 2.1). In my model for the enactment of the third mission (Figure 5.1), this corresponds to the *information and outreach* category. This was further corroborated in Paper 2, when the participants talked about the purpose of their science communication texts and how they thought carefully about what message they wanted to convey. The focus was here on communicating science *to*, rather than *with*, audiences outside of academia and on educating and informing rather than mutual benefit or brokering knowledge in terms of linking knowledge production and use (cf. Turnhout et al., 2013; Wenger, 1998). Many texts were part of a dialogue—for example responding to an opinion piece by providing a scientific perspective—but still seemingly not aiming to be beneficial for the researchers themselves in their research or otherwise. However, we only included written science communication, which could possibly be the tip of an iceberg of various forms of engagement with society whereof not all result in written outputs, and it is thus possible that some of our participants in Papers 1 and 2 should be placed further towards the right side of the model—i.e., going more towards dialogue, brokering, and participation—if also other written and in particular oral science communication is considered.

Still, our findings provide an important indication of what type of science communication is being conducted and to what extent (Paper 1). The mixed methods approach of this Paper 1 is important since science communication is difficult to measure and there is limited data available (Pinheiro et al., 2015; Schultz et al., 2020; Thelwall, 2021). To summarise, we found that science communication is happening, but the vast majority of researchers seem not to engage in science communication at all; of those who did engage most only authored one science communication publication. The question is then who should realise the ambition regarding science communication in practice. Do all researchers really have to engage in science communication, or more broadly speaking have to engage in the third mission? Is it a mission for higher education institutions overall, or is it a role of each individual researcher, or perhaps both? While answering these questions should be the objective of future research, institutions, and policy-makers, it is clear from previous research and Papers 1 and 2 that there is room for improvement in the support of researchers who wish to engage, including in training opportunities (Baram-Tsabari & Lewenstein, 2017; Besley & Tanner, 2011; Bohlin & Bergman, 2019; Fähnrich et al., 2021), and in providing sufficient incentives for researchers (Alperin et al., 2019; Baram-Tsabari & Lewenstein, 2017; Bohlin & Bergman, 2019; Dryler et al., 2022; Fähnrich et al., 2021; Llorente et al., 2019; Pérez-Llantada, 2021; Schimanski & Alperin, 2018).

Regarding what strategies can be used to successfully self-regulate science communication writing, we investigated what characterises expert science communication writers' writing process and compiled our findings into a list of strategies (Paper 2), divided into the three phases of self-regulation (SR) described

by Zimmerman and Moylan (2009). Importantly, we found that our participants adapted their writing strategies to the specific text they were writing, considering for example genre, how the genre compared to scientific articles, and what message they wanted to convey to whom. Interestingly, they related their science communication practices to their scientific communication practices, i.e., their communication within the first mission (research) and the third mission. Overall, the findings underscore the importance of metacognitive strategy knowledge (MSK) and SR in science communication writing (Paper 2). Consequently, Paper 2 suggests that metacognitive strategy training could potentially be beneficial to develop expertise in such writing. This is in line with what previous research has pointed out for other forms of writing (Graham et al., 2018; Harris et al., 2010; Qin & Zhang, 2019; Teng & Zhang, 2020; Zhang & Zhang, 2019; Zimmerman & Kitsantas, 2007; Zimmerman & Risemberg, 1997) and in a few studies also for science communication efforts (Baram-Tsabari & Lewenstein, 2017; Fähnrich et al., 2021). In addition, our findings align with previous research suggesting that expert writers can adapt their writing strategies as well as content, rhetoric, and linguistic choices across genres—i.e., exhibit genre awareness (Tardy et al., 2020)—but expand it to science communication.

The question is then how to train researchers in science communication and thereby promote engagement in science communication. Importantly, training should be evidence-based, which is currently difficult to achieve due to several complicating factors. For instance, difficulties in measuring science communication practices (Pinheiro et al., 2015; Schultz et al., 2020; Thelwall, 2021) and quality (Olesk et al., 2021) result in difficulties both in defining what should be included in science communication training (Baram-Tsabari & Lewenstein, 2017) and in evaluating the effect of specific training efforts (see for example efforts to evaluate training by Murdock, 2017; Rodgers et al., 2020; Rubega et al., 2021). With Paper 2, we added to the limited evidence about training effectiveness by taking a slightly different perspective than previous studies and identifying what expert science communication writing entails. In section 2.2.2, I described two ambitious previous attempts to define what science communication training should include: those of Baram-Tsabari and Lewenstein (2017), who suggested a framework summarised as a list of learning goals, and Mercer-Mapstone and Kuchel (2017), who identified and listed key skills for effective science communication. Both the learning goals and the list of skills are relatively comprehensive and could be used in designing training. While they are slightly different, both lists focus on *what* is needed for effective science communication. Our focus in Paper 2 makes an original contribution in that it lies closer to *how* effective science communication can be conducted in terms of strategies in the writing process. We provide a set of relatively concrete strategies, used by expert science communication writers, that can be taught in training and/or

inspire individual researchers who wish to start engaging in or become better at science communication.

Moreover, Paper 2 uses MSK and SR as lenses to analyse science communication writing processes, a theoretical lens that to my knowledge has not been explicitly used in similar studies on science communication before. Both Baram-Tsabari and Lewenstein (2017) and Mercer-Mapstone and Kuchel (2017) touch upon aspects of MSK and SR, but do not explicitly use these concepts. For example, one of Baram-Tsabari and Lewenstein's (2017) learning goals concerns reflection, including reflection on one's own learning and science communication writing process—i.e., SR of science communication and of learning to do science communication. Two other learning goals describe an adaptation to the audience and genre, an adaptation that presumably entails SR and genre awareness (cf. Tardy et al., 2020, see also Donaghue & Adams, 2025, on embedded genre-based writing pedagogy). Similarly, Mercer-Mapstone and Kuchel's (2017) list of skills includes several aspects of adaptions to audience and genre that implicitly points to using genre awareness in SR of science communication. Finally, in Paper 2, it was clear that analysing the task and its purpose is very important in science communication, which is also specifically highlighted in Mercer-Mapstone and Kuchel's list of skills. Overall, Paper 2 partly aligns with previous research on science communication training, but also adds new dimensions by the focus on the *how* of writing science communication and on MSK and SR.

Our participants seemed to have built their science communication confidence and expertise over time (Paper 2), and since they were senior researchers, they can be assumed to have the scientific authority that follows from seniority—they were public intellectuals (Said, 1994). They seemed to see themselves as someone who can contribute to society through science communication—which relates to the identity goal of Baram-Tsabari and Lewenstein's (2017) framework of learning goals—and be motivated to engage—which relates to both the affect goal of Baram-Tsabari and Lewenstein's framework and the motivation/affect area of SR (cf. Pintrich, 2000)—despite a lack of incentives to do so (Bohlin & Bergman, 2019). In Paper 2, identity and possibly also motivation seemed to have developed over time, with increasing experience as researchers. There were examples of external motivation in the interviews, but overall, our participants seemed to engage because they found it intrinsically important. In section 6.1, I asked the question of who should engage in science communication, but here the question is rather which researchers feel themselves like they should and could engage. The findings in Paper 2 suggest that one way of promoting the enactment of the third mission through science communication could be to design training that address identity and motivation/affect, since this could make more researchers feel like they can engage in science communication and have something to contribute. In summary, my main advice for future research is thus to design, conduct, and evaluate science

communication training taking genre, genre awareness, MSK, SR, identity, and motivation into account.

5.2. Enacting the third mission through industrial PhDs (RQ2)

In Papers 3 and 4, I focused on industrial PhD students: in what ways they broker knowledge between academic and industrial contexts and what challenges influence this process (RQ2 in this thesis). My findings illuminate in what ways industrial PhD students broker knowledge from two perspectives. First, my research nuances what communication across academic and industrial contexts involves in practice, from the students' perspective, and what the fact that industrial PhD students have to speak "academia and practitionese" (Kihlander et al., 2011) actually means (Paper 3). Second, it explores what industrial PhD students' brokering role entails in practice, including which social agents are involved and how, what expectations students perceive in their two contexts, what support students get, and what support is needed for industrial PhD students and their brokering role (Paper 4).

Regarding communication, industrial PhD students use a wide range of genres in both academia and industry. Academic writing and presentations in industry—both mentioned in previous research (Kihlander et al., 2011; Santos et al., 2021)—are only two examples of a more complex repertoire of genres through which industrial PhD students report, present, explain, and adapt research for their different audiences (Paper 3). By theorising industry and academia as different discourse communities (DCs; Swales, 2016), it is possible to pinpoint where the differences between the communication in the two contexts actually lie, and why. As I put it in Paper 3, adaptation across industry and academia include accounting for differences in many of the defining features of DCs (cf. Swales, 2016), including goals and expectations; how research knowledge is shared within the communities; which genres are used; and language choices, both in terms of Swedish versus English and the level or detail of the language. This understanding offers advice on what may be needed for students to develop skills in communicating in and across academia and industry, somewhat similar to how Papers 1 and 2 do so for researchers' science communication, which can then be used to design training and support. Studying and further developing such training are then topics for future research. Based on my findings, I also suggest that training of communication for collaborative doctorates should be designed, conducted, and further developed together with representatives from industry and academia, as well as doctoral students to make sure it is actually useful in each context as well as for brokering. While additional training seems to mainly be needed relating to industry and brokering, including

stakeholders from academia could foster an understanding of industrial PhD students' communication realities in industry and brokering among the stakeholders in academia, thereby potentially improving support from, and collaboration with, academia.

Interestingly, the findings suggest that both communication and belonging might be more challenging in industry than in academia for industrial PhD students. This was somewhat surprising given that many of them have worked in industry after graduation, previous research has pointed to challenges of coming back to academia to do a doctorate after some years outside of academia (e.g. Peters, 2017), and traditional PhD students may struggle with these issues in academia (Calle-Arango & Ávila Reyes, 2022; Sala-Bubaré et al., 2018). Participatory mechanisms (a criteria for DCs; Swales, 2016), feedback, and support varied across the DCs and participants brought up both knowledge brokering and issues relating to belonging and identity (Paper 3). The findings from Paper 3 also suggest that industrial PhD students may remain peripheral in one or both their DCs instead of moving further into the DCs. Note that whether industry and academia are actually two distinct DCs can be debated, but Paper 3 showed differences tied to the criteria of DCs despite that some things, like the area of interest in a broader sense, can be assumed to be somewhat similar, given that both contexts are involved in the same PhD project.

A clear difference across DCs was how participants described it as difficult to make the PhD project interesting to communities in industry (Paper 3), or find communities that were interested (Paper 4). A possible explanation lies in the fact that an industrial PhD is a PhD, with the academic requirements that come with that, and that the academic side of the project thus often has priority (Compagnucci & Spigarelli, 2025; Grimm, 2018). The industrial context understands and respects this, but perhaps too much, resulting in the student struggling with communication, brokering, and belonging in the larger industrial organisation, or even their own division (Paper 4). Abu Sa'a & Ystrom (2024) made an important point about how the nature of communication related to industry-academia collaborations can vary to different parts of the industrial organisation: at least in many cases, it seemed rather easy to find, communicate, and discuss with a small number of close industry colleagues who were genuinely interested in the project, but much more difficult to find ways to reach other or broader audiences in the industrial organisation. The second type of communication indeed seemed more similar to dissemination (as in Paper 3) and the student tried to find ways to create an interest and in a sense push the communication onto people, rather than those people requesting the communication ("pulling", cf. Bielak et al., 2008). Finding people and groups who were interested was often challenging and required extensive initiative and agency from the PhD students themselves, i.e., the PhD students themselves had to actively find or create communities and opportunities for both disseminating and brokering knowledge. This is especially interesting given that the industrial employer is

funding the PhD. It ties back to the unclear expectations found in Paper 4, to how academia and industry operated on different time scales and how industrial interest often, though not always, seems to decrease over time if the students themselves do not succeed in finding opportunities for dissemination and brokering.

The discussion above, based on findings from Paper 3 and to some extent Paper 4, provides new insights compared to previous research but also raises many questions regarding how brokering happens in industrial PhDs. Some of the questions concern communication, and further research could investigate actual texts, presentations and so on to get an even better insight into what communication in industrial PhDs entails and what differs between industry and academia, when theorised as different DCs. However, my findings from Paper 3 also raised other questions, such as who is actually involved in an industrial PhD, how the students are connected to their two contexts, and finally whether they are part of communities in both their contexts. Based on the findings in Paper 3 and what seemed to be missing in previous research (e.g. Compagnucci & Spigarelli, 2025; Jones, 2018), I deemed the latter set of questions, concerning social agents and communities in industrial PhDs, the most pressing. Consequently, I addressed the latter set of questions in Paper 4 and have left for future research to address the further questions concerning communication in industrial PhDs.

If and how brokering happens is inevitably tied to the people and communities surrounding the broker, and dialogue or participation is needed to ensure brokering: that an industrial PhD is a form of enactment of the third mission (see Figure 5.1 and chapter 2). Regarding who is involved in an industrial PhD, roles and expectations, there is, unsurprisingly, variation but also patterns across industrial PhD students (Paper 4). Academia was perceived as a comparatively stable environment by the participants in Paper 4, with little change, clear expectations and academic supervisors having clear roles. Industry, on the other hand, was less stable, with support and structures varying both across participants and during the course of individual participants' PhDs. Expectations were most often not clear and the roles of and support from industrial supervisors and managers varied. In academia, supervisors act as guides and mentors, while in industry it is not given that the industrial supervisor has the same function—they could do anything from having no role at all to having a similar role as academic supervisors or providing important network opportunities within industry.

While the differences in supervisors' role across contexts are somewhat similar to findings from some previous research (Roolaht, 2015; Salminen-Karlsson & Wallgren, 2008; Tavares et al., 2018), Paper 4 moves beyond these descriptions and elaborates on how the supervisors and student are connected, and importantly what other social agents are involved and to what extent the PhD students participate in communities of practice (CoPs). As a reminder, CoP refers to "groups of people who

share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (Wenger et al. 2002, p. 4). In industry, managers could be enablers or create barriers, similar to findings by Abu Sa'a and Yström (2024) who focused specifically on managers rather than all involved social agents. CoPs could often, though not always, be found in academia and even within formal units within academia (e.g. research group or colleagues at the division). They could also be found in industry but not for all participants. In industry, CoPs could consist of colleagues, other PhD students, and sometimes also supervisors, but they did not correspond to formal units as often as in academia. Importantly, there was not always a clear CoP in industry. Based on these findings, it would be interesting to examine in more detail how and with whom collaborative doctoral students interact in their academic and especially industrial environment. For example, an ethnographic approach, for instance including fieldwork (Gobo & Molle, 2017) and/or the students writing diaries (Alaszewski, 2006), could be very useful to get more insight into what connections these doctoral students have in industry, who they interact with, what the interactions result in, and to what extent they belong to and participate in CoPs. I believe that such an approach could help in further identifying what is needed to compose constructive connections in industry, for example in terms of training, networking, and other support structures.

Another aspect of how industrial PhD students broker knowledge and the challenges they face is that they were sometimes the only brokers between industry and academia (Paper 4), similar to what Bernhard and Olson (2023) found, but sometimes there were other links. Having a group engaged in the project, with people who understand both industry and academia (though not necessarily themselves being formally tied to both) seemed constructive for brokering, as did connections to other people who were acting or had acted as brokers, such as supervisors with experience from the other context, other industrial PhD students, or industrial colleagues with PhDs. Students most often perceived a gap between industry and academia, and people or groups (e.g. CoPs) with experience of brokering were described as helpful in providing support in navigating the dual contexts and brokering. Two key points from Paper 3 and 4 are here that brokering does not happen automatically by having an industrial PhD—the surrounding people and support matter—and that participation in CoPs is important both for opportunities for brokering and for support in brokering.

This may explain why previous research has come to different conclusions regarding the brokering or boundary spanning function of industrial PhDs, for example if they act as brokers in practice or not (e.g. Assbring & Nuur, 2017; Berg et al., 2026; Gustavsson et al., 2016; Thune, 2009; Wallgren, 2007). These findings also underscore the need for people, structures, and agreements between the involved parties that enable brokering (Paper 3 and 4). To ensure that brokering happens in

practice, in a sustainable way, there should be agreements on who should be involved in each context and what their roles should be to make sure brokering is enabled rather than hindered, and make sure the doctoral student is not left alone to figure out how to broker between their two contexts. I have made suggestions in this direction in both Paper 3 and 4, but I leave to future research to examine to what extent there are such agreements or how they could be designed and implemented if they are not in place. A key point to consider is that planning and agreements in the planning phase of a collaborative doctorate, i.e., before or in the very beginning of the project, are important, but regular follow-ups throughout the project are equally important.

On a similar note, I have also argued that industrial PhD students risk having sustained peripheral participation, or even a marginalised position, in CoPs in both industry and academia (Paper 4; cf. literature on brokering generally, such as Wenger, 1998; Meyer, 2010; Meyer & Brun, 2023). For example, differences described in previous research (see section 2.3.2) and seen in Papers 3 and 4 in terms of epistemologies, time frames, expectations, and interest in the PhD student and project seemed to pose challenges specifically for moving further into CoPs in both contexts. Academia often offered clearer pathways for participation, similar to those for traditional PhDs, while industry's understanding of the priority of the academic requirements sometimes seemed to be a barrier for inclusion and for moving further into CoPs in industry. Importantly, as argued in Paper 4, new industrial PhD students *are* newcomers and learners, but they are also *becoming* brokers between industry and academia. At the same time, they *are becoming* experts in each of the contexts, all at once. As brokers, according to Wenger (1998), they should stay close to the peripheries, while as newcomers they can be theorised as entering their contexts "through *peripheral* but *legitimate participation*, on their route to move further into the CoPs as they increase their expertise" (Paper 4, p. 12; see also Sala-Bubaré & Castelló, 2017). By actively finding or creating CoPs in industry, participants found ways of moving in from the peripheries into CoPs that were constructive for them as researchers, learners, employees, and brokers. Furthermore, peripheral participation and lack of CoPs especially in industry may be an explanation for why previous research has sometimes found that industrial PhD students do act as brokers and sometimes that they do not (Compagnucci & Spigarelli, 2025; Wallgren, 2007).

The implications I have already suggested in previous paragraphs concern issues relating to peripheral participation, being, and becoming to some extent, and I will return to the question of support and training in the next paragraph. However, I believe it is important to first highlight the value of theorising and its importance for implications here. Theorising industrial PhD students as potential brokers between communities (in this case specifically CoPs), and elaborating on their being and becoming and participation in CoPs, makes it possible to identify tensions,

challenges, and enablers that may have remained hidden otherwise. In previous research, there is often more of an empirical focus, and less focus on theory and especially theorising. The theorising in my research is thus a contribution in itself to this research area. Based on my pragmatist approach to research and drive to contribute to improvements in practice, I therefore encourage future research into collaborative doctorates to engage more extensively with theory to increase our understanding of these doctorates and suggest useful implications.

In the discussion of science communication, I highlighted a lack of support and training in academia for science communication. For industrial PhDs, the support relating to academia seemed sufficient and there was generally an understanding in academia of the importance of also contributing in industry. In the industrial context, support and training were instead often lacking, for example with the industrial supervisor having varied, unclear or even no roles in the PhD (similar to findings on industrial supervisors by Roolaht, 2015; Salminen-Karlsson & Wallgren, 2008). Most participants in Papers 3 and 4 mentioned no formal training targeting the industrial context or the presumed brokering role. Learning was instead described as informal, social, and situated, which is not problematic per se but an issue if there is a lack of supporting and interested people to learn from and with (cf. Wenger, 1998). However, I do not argue that the responsibility for providing support relating to industry and brokering lies only in industry. Academia could be assumed to have more experience in what support might be needed in PhDs in general. Though their insight into exactly what is needed in industry may be limited, they are used to PhD education, to PhD courses and supervision, and to discussing how to communicate research—some researchers might even have collaborated with industry before or have experience from other forms of enacting the third mission, as seen in Paper 4. Thus, academia has a crucial role in facilitating and maintaining a dialogue with industry and the student to ensure the PhD as a whole includes sufficient support, conditions that enable brokering, and a sustainable situation for the industrial PhD student.

5.3. Enactment of the third mission—enablers and challenges (Overarching aim)

I began this thesis by referring to the old metaphor of academia as an ivory tower (cf. Hancock & Walsh, 2016). My research adds to the rather extensive line of research examining how academia is no longer an ivory tower, but still sometimes struggle to compose connections to the rest of society (e.g. Bohlin & Bergman, 2019). Importantly, my papers add granularity in some aspects of how the third mission is enacted in practice, at the individual level. Specifically, my work adds to the

understanding of how the third mission is and can be enacted through science communication and industrial PhDs. In this section, I will bring the two aspects together and discuss enablers and challenges for researchers and PhD students who try or are assumed to enact the third mission. There are some main themes that reappear across my papers and previous research with similar foci, namely 1) incentives, 2) training and support, and 3) communities.

Regarding *incentives*, the third mission is portrayed as an important task for universities in various policies at national and international level (Hetland et al., 2020; Perkmann et al., 2021; Pertuz et al., 2021; Sjöö & Hellström, 2019; SFS 1992:1434; Tomlinson, 2018; Thune 2009) and as a way forward to address some of today's societal challenges, especially in STEM (Grimm, 2018; Hadgraft & Kolmos, 2020; Hancock & Walsh, 2016; Mitic & Okahana, 2021; Pertuz et al., 2021). Previous research has pointed to lacking incentives for regarding science communication, and this issue appeared also in my studies. As elaborated in this thesis and extensively in my licentiate thesis, there is still a lack of incentives for engaging in science communication (Schimanski & Alperin, 2018). This is true even in STEM, where there is a presumed pull for it (Bielak et al., 2008; Grimm, 2018; Hadgraft & Kolmos, 2020; Pertuz et al., 2021), and in Sweden with its long-standing tradition of science communication (Bohlin & Bergman, 2019; Hetland et al., 2020). While the second mission, teaching, is increasingly taken into account in promotion and tenure (Perkmann et al., 2021), the third mission is still very difficult to measure and evaluate and not prioritised in recruitment and promotion processes (see my licentiate thesis, Cervin-Ellqvist, 2022; and Papers 1 and 2).

The question of *incentives* becomes even more complex when discussing industrial PhDs: their dual contexts also entail dual sets of incentives and priorities. However, Papers 3 and 4 suggest that the priorities remain fairly the same overall, i.e., that the academic requirements, i.e. the first mission, get priority in both contexts. The fact that the students are employed in industry, but academia is prioritised in the PhD, creates tension between what is prioritised and what is valued in practice in the employing organisation, for example in salary revision. For instance, participants in Paper 4 reported that while industry did not have clear expectations regarding contribution, they still often tried to evaluate the students' performance as employees using the similar criteria as for other employees who were not doing a PhD. In other words, in salary revision, industry valued practical contribution, for example, through completing similar tasks as any other employee or as part of the third mission more than academic contribution, though they at the same time encouraged the student to focus primarily on the academic side (see also Abu Sa'a and Yström, 2024, on managers' roles as enablers or barriers in industrial PhDs). Incentives for the third mission beyond individuals' own interests and motivations are not completely absent, as there are funding bodies and employers in industry who do provide incentives for communicating beyond academia but, taken together

with previous research, my research suggests that the incentives are not in parity with the third mission ambitions in policies. In addition, it is perhaps not clear who should enact the third mission: is it every researcher, some selected or interested researchers, or universities through more central efforts? The answer or answers to this question certainly affect what additional incentives there should be.

Training and support was another reoccurring theme across science communication (Papers 1 and 2) and industrial PhDs (Papers 3 and 4), echoing previous research (e.g. Bohlin & Bergman, 2019; Compagnucci & Spigarelli, 2025; Jones, 2018; Llorente et al., 2019; Pérez-Llantada, 2021; Wallgren, 2007). Note how support for science communication was lacking in academia and support for industrial PhDs was lacking in industry. The common denominator was that it was for the third mission (conducted from academia for science communication and in industry for industrial PhDs) that support was lacking. For researchers engaging in science communication, it is the university who could provide support for their enactment of the third mission. For industrial PhD students, it can be assumed to mainly fall on industry to support the students' enactment of the third mission in connection to industry, though this can be problematised and academia could have a more prominent role in supporting the students' brokering, as I argued in section 5.2.

All appended papers point to the possibilities of training as an enabler for enacting the third mission at an individual level. Paper 1 and 3 clarify what communicating research to audiences outside of academia entails in practice, and thereby what to focus on for example in courses or other training and support. Paper 2 instead focuses on the process of communicating to non-academic audiences, showing what strategies researchers who have become experts at science communication use when they write or prepare science communication. These strategies were theorised through the lens of self-regulation and metacognitive strategy knowledge (Karlén, 2016; Zimmerman and Moylan, 2009). While self-regulation was not used as a theoretical lens for industrial PhDs, aspects of self-regulation emerged in the data used for Paper 3 and 4 and in additional data from the interviews (not included in this thesis). The individual industrial PhD student's navigation of, deliberate modulation of, and attempts to create meaningful connections in the environments they are in entails having an idea of what they want to do (a goal), trying to do something to reach that goal while monitoring how they are doing, and then evaluating and continuing to try, possibly altering their goal along the way. In other words, they need to self-regulate their way through the challenges of the industrial PhD, in terms of communication and more broadly in terms of personal development. However, I argue that this self-regulation can be challenging as a newcomer and learner in industry, academia, and brokering all at once, which further strengthens my suggestion about continuous support and follow-up for industrial PhD students, concerning the situation in both contexts as well as in

between contexts. Self-regulation could also be used as a theoretical lens in future research, to further theorise collaborative doctorates and to provide useful implications for practice.

The second and third themes, *training and support* and *communities*, were connected to each other across the papers. In Paper 4, I specifically examined the social and situated dimensions of support and learning in industrial PhDs rather than formal courses or other training. Both Paper 3 and 4 show the importance of people to learn from and with, such as colleagues and supervisors, and how this more informal learning is particularly important in industrial PhDs, somewhat similar to other professional settings (Boden et al., 2011; Eraut, 2004; Fuller et al., 2005). Similar findings regarding learning were made for science communication in Papers 1 and 2. Taken together, my papers show that there is often a lack of formal and structured training, which can be compensated by other support and informal learning from e.g., colleagues. However, my papers also suggest that this creates a dependency on the environment, colleagues, and for PhD students also supervisors, which leads to large variation in—and often lacking—support. Thus, adding, for example, courses to compensate for the lack of training and support is not enough (cf. Sin et al., 2021). Instead, formal training needs to be combined with a supportive environment to learn from and together with.

Participation in *communities* could also be seen as an enabler for the third mission in all appended papers. In Papers 3 and 4, as well as in section 5.2, I explicitly argue for the importance of communities in industrial PhDs. In Paper 1, we saw that while some researchers engage in science communication as single individuals and public intellectuals, many engage in science communication as a collaborative effort with colleagues, suggesting that it might be encouraged more in these environments than in others, in line with the importance of the environment suggested by Benneworth et al. (2015) and Perkmann et al. (2021). Some participants in Paper 2 further elaborated on the importance of the environment and also described how input from others, perhaps people who are not in academia, is especially useful for science communication. Overall, many of the participants in my four papers had found communities where their enactment of the third mission was valued or encouraged, either because they happened to end up in such a community or because they actively tried to find such a community. An example of the latter is the participants in Paper 4 who moved themselves within their employing organisation, or in one case even initiated a larger reorganisation, to find a community where they could act as brokers. However, the road to find a community was often challenging and not everyone succeeded (e.g., Paper 4). In summary, the value of communities for discussions, input, validation, and support of various kinds runs as a theme throughout my papers, but so does the issue of finding communities where the third mission is recognised. The question is then how to create environments and communities where the third mission is encouraged. Future research on the

enactment of the third mission should prioritise this question, given its potential to promote engagement but also to minimise frustration, challenges, and feelings of loneliness among the individuals involved in this mission. Concretely, future research could examine examples of environments that are particularly successful in this regard, like the clusters of researchers engaged in science communication in Paper 1 or the contexts of the industrial PhD students in Paper 4 who found their industrial community especially supportive of and constructive for their industrial PhD. Note that this does not mean that all the responsibility for engagement should fall on communities: incentives at all levels, sufficient training and support, and communities are all needed to promote the third mission in practice.

Another aspect of *communities* is that of peripheral participation (Paper 3 and 4), as described by Wenger (1998) and Meyer (2010). The industrial PhD students are clearly in-between contexts, where at least a part of their work does not fit into the norms—an issue mainly in industry but also to some extent in academia. The researchers engaging in science communication are not between contexts in the same way, but they are also trying to connect academia with other parts of society, while working in a context where other tasks are recognised more. Norms, including what is valued and recognised in a community, are described as key in the research addressing discourse communities and communities of practice (Meyer, 2010; Swales, 2016; Wenger, 1998). Engaging in activities that fall outside of what is valued by a community and perhaps seen as legitimate may result in peripheral participation in the community. In more extreme cases, it may result in a trajectory that is not leading further into the community but outwards, to marginality. While industrial PhD students and researchers engaging in science communication cannot be assumed to always end up in peripheral or marginal positions, time is clearly a limiting factor in both science communication and industrial PhDs: Individuals must prioritise between activities pertaining to the different missions of higher education (e.g. Bohlin & Bergman, 2019), and in the case of industrial PhDs also tasks from the employer (e.g. Compagnucci & Spigarelli, 2025). By engaging in activities that are not core activities of a community, individuals enacting the third mission might risk becoming invisible in the community (cf. Wenger, 1998), which could be seen in Paper 4. In contrast to many of the PhD students, participants in Papers 1 and 2 were instead often senior researchers, presumably already holding positions within one or several communities based on other merits, which meant they could afford spending time on tasks outside the core activities with less risk of peripherality or marginality (cf. Schimanski & Alperin, 2018, on the pressure to publish scientific articles rather than engage in outreach for junior researchers). However, similar patterns could be seen based on seniority in industry for the industrial PhD students (Paper 4, data not published in the paper to not compromise anonymity). In other words, both communities and incentives seem to be more important to people who are more junior, and the inclusion of newcomers

into communities where the third mission is presumably enacted is thus particularly important to address in practice and to investigate further.

As a final note on peripheral participation, it is particularly interesting that the participants in my studies had often actively chosen to try to compose connections between academia and society, and in the case of industrial PhD students actively chosen to participate in dual contexts. While participants across Papers 2-4 sometimes expressed frustration about peripheral participation or lacking incentives and understanding in their communities, they somehow still seemed to thrive in bridging communities and reaching out to people in other contexts (cf. Wenger, 1998, on how brokers may thrive bridging contexts from the peripheries).

An additional aspect of *participation* and *communities* is that of how the person enacting the third mission is connected to their audience and what opportunities this gives for composing connections across contexts in terms of communication and brokering. Researchers engaging in more outreach type science communication might not have a clear audience to communicate with and cannot be assumed to engage in knowledge brokering. For example, participants in Paper 2 identified challenges in evaluating their science communication since they were often not in dialogue with their audiences. Industrial PhD students on the other hand participate in two contexts, optimally in communities, and can thus be assumed to have the possibility to broker knowledge to a higher extent. This was also something the participants in Papers 3 and 4 underscored themselves. While their participation was often quite peripheral, in almost all cases it felt legitimate, and it did create opportunities to enact the third mission. In other words, connections and participation are enablers of the third mission. For support, this implies that universities who wish to promote the third mission could provide active support in finding communities and audiences who could be interested in getting to know about, discussing, or even collaborating on various research topics.

Before summarising the implications, a final point to be made is how *incentives*, *training and support*, and *communities* are multi-layered and how my research and previous research (see chapter 2) taken together show that these multiple layers are important in enabling individuals to enact the third mission. While the third mission is encouraged in policy, my papers and previous research (see chapter 2) show that this encouragement is often not present as incentives on an individual level. Between policy and the individual level, there are, for example, several factors that pose challenges at the individual level. These include norms within academia both internationally and nationally, funding bodies' expectations, priorities and rules for promotion and recruitments at universities, strategies at institution or department level, interpretations by managers in salary revisions, and what is valued by communities (theorised as CoPs or DCs). In terms of training and support, there are also several layers, for example, what courses or training is required nationally and

locally at universities for faculty and PhD students, how many credits PhD students should take and what fits into those credits, and the quality and applicability of courses (see e.g., Paper 3 on applicability of communication courses for industrial PhD students). Other factors relevant for training include what knowledge there is in academia to base courses and other training on, what should be included in formal versus informal training, as well as what roles different people have in supporting both the learning to enact and the actual enactment of the third mission. Another main point about the roles of different people and communities is that they do not exist in a vacuum: communities exist in *constellations of practice* and other larger systems that affect them, they interact with other communities, and they change over time. Even though a community values the third mission and supports those who try to compose connections between academia and society, it does not mean this is recognised at other levels/layers.

Overall, my thesis challenges understandings of third mission-related activities as peripheral or optional add-ons to other roles of academics, by showing that science communication and knowledge brokering are closely intertwined with academic or doctoral work itself. The enactment of the third mission can be an integral part of how research is organised and carried out in practice, as shown particularly in industrial PhDs (see Papers 3 and 4) but also to some extent in researchers' engagement in science communication (see Paper 2). In collaborative doctorates, the enactment of the third mission, and communication related to this, are embedded in everyday doctoral work as students navigate and link academic and industrial contexts. This work involves ongoing adjustment, negotiation, and translation, and most often requires sustaining participation in multiple communities with different expectations and priorities. This implies that it is important to recognise third mission-related activities as legitimate, and consequently as activities for which time and support are needed. When science communication and brokering remain implicit or are taken for granted, there is a risk that responsibility for the third mission falls too much on individuals, which can be especially true for those positioned at boundaries between contexts, and especially troublesome for those who are junior in their roles. This is an implication for policy, to ensure that third mission activities are not only goals stated in policy but also incentivised, recognised, and supported (and for research to further investigate how to realise in practice). To achieve this, policy-makers nationally and internationally as well as individual universities have important roles to play.

5.4. Limitations

As with any research, there are a number of limitations both to the papers and this thesis. First, since all my studies have been conducted in Sweden, it is important to note that variation in policies, incentives, structures, training, and cultures, among other things, may affect the enactment of the third mission through science communication and industrial PhDs across national borders. I have elaborated on this in chapter 2, and I would here like to encourage studies in other contexts, especially across countries and in countries outside the EU and countries that are not anglophone. One example of such research, though on traditional doctorates, to be inspired by is the research carried out within the lab Researcher Identity Development and their papers on PhD holders' career trajectories beyond academia in various countries[5]. Second, an issue across all papers and this thesis is terminology: both science communication and collaborative doctorates (even industrial PhDs) may be defined in a number of different ways and be called different things in different settings. It is thus difficult to get and provide a comprehensive picture of how they are enacted according to previous research. I have tried to mitigate the issue in my thesis by being clear and explicit about terminology and the issues surrounding it, but it remains a limitation.

Third, I have argued that the theories I use help illuminate important aspects of science communication and industrial PhDs. However, no theory is perfect, and I acknowledge that by highlighting some aspects by using certain theories, others are inevitably hidden. For example, regarding communities, they are not always cohesive or harmonious, and power dynamics, competing interests, and organisational politics can shape access to core practices (Fuller et al., 2005), and both DCs and CoPs inevitably simplify the complexities of communities. The concepts can also be difficult to apply in large, fragmented organisations where practices are loosely connected, discourses overlap, DCs and CoPs are difficult to identify, and membership is fluid. These factors are particularly salient for industrial PhD students, who are often in junior positions in both their contexts and may thus also lack the authority or network needed to gain access to core practices. In other words, CoPs, DCs, and knowledge brokering provide valuable insights into learning, participation, communication, and how knowledge is brokered across contexts, but these concepts must be used with an awareness of the structural and organisational conditions that shape how communities function in practice. Based on how theories highlight some aspects and hide others, using a multitude of theories to examine and theorise a phenomenon (e.g., both DCs and CoPs) is not only possible but also desirable. While I have tried to do so to some extent, further

[5] See Researcher Identity Development's webpage for a list of publications: https://www.researcher-identity.com

theoretical lenses could provide important additional and complementary insights, particularly into collaborative doctorates where more theorising is generally needed.

Fourth, I have not accounted for new technologies, such as Artificial Intelligence (AI) and specifically large language models (LLMs) that have developed rapidly during my time as a PhD student. As shown in a study I conducted together with three colleagues, AI can provide information to be used in writing in PhDs, but for orientation in communication and social contexts, people (e.g., peers) are needed (Khuder et al., 2026). Therefore, AI could be useful in learning to navigate different genres tied to the third mission and this is an interesting question to address in future research. However, the findings by Khuder et al. (2026) suggest that the importance of communities remains.

Fifth, there are limitations based on the methods I have used. While chosen carefully to fit as well as possible with my research question, there are inevitably things they do not capture and in Papers 2-4 there are the general limitations of self-report data (see chapter 3.3.2). However, Papers 2-4 focused on the individuals' perspectives and thus subjectivity is both inevitable and desired. Future research could complement the self-report data for example with observations and perspectives of other stakeholders (e.g., audiences of science communication, employers in industry, academic supervisors and so on). In Paper 1, a main methodological limitation is that we only examined science communication publications in written form in a publication repository to which researchers themselves add their publications. This is connected to the difficulty of tracking and measuring science communication already discussed, but it is something that could certainly be addressed in future research. For example, a similar approach to that of Paper 3 (i.e., using a questionnaire) could be employed.

5.5. Summary of implications and directions for future research

I have integrated implications and directions for future research into the discussion in sections 5.1-5.3 and the limitations in section 5.4. For convenience, I have summarised the main implications of this thesis in Table 5.1 and the main directions for future research in Table 5.2. In Table 5.1, I have also tried to pinpoint whom each implication concerns.

Table 5.1. Summary of implications, as stated in sections 5.1-5.4

Connection to third mission	**This thesis suggests that…**	**Whom it concerns**
Third mission (overall)	…the third mission needs to be recognised and incentivised as part of academic work (e.g. in promotion and recruitment), rather than treated as an add-on. In addition to disadvantages in relation to their careers, individuals engaging in the third mission also otherwise risk ending up at the periphery of their primary communities.	Policymakers, universities, departments
Third mission (overall)	…time should be allocated for third mission activities, e.g., in workload models, rather than relying on individual initiative.	Universities, managers in academia and industry
Third mission (overall)	…training and support should include relevant and applicable courses but also go beyond these and include access to people, feedback, and supportive environments where the third mission can be both enacted and learnt.	Universities, industry
Third mission (overall)	… access to relevant audiences and communities needs to be actively facilitated to promote communication and knowledge brokering, instead of relying on each individual to figure out how to compose connections on their own.	Universities, industry (for industrial PhD students)
Third mission (overall)	…communities that support and encourage the enactment of the third mission are key and should thus be encouraged, supported, and something to work towards to increase engagement.	Universities, departments
Science communication (RQ1)	…support and incentives for science communication need to be stronger especially for junior researchers, who typically prioritise scientific publishing since this is what counts the most to get a position or a promotion.	Universities, departments
Science communication (RQ1)	…training should focus on *how* to communicate, including task analysis, audience adaptation, and writing strategies. Genre awareness, self-regulation, and metacognitive strategy knowledge can be used to structure such training.	Universities
Science communication (RQ1)	…identity and motivation should be addressed and included in training to support researchers' engagement in science communication.	Universities

Industrial PhDs (RQ2)	…communication across academia and industry requires explicit support for adaptation to each context and for communication across contexts (e.g. including genres, expectations, and language). Discourse communities can be a useful lens to identify where support and training might be needed, and what to focus on in such training.	Universities, industry
Industrial PhDs (RQ2)	…more training for industrial PhDs is particularly needed for the industrial context and brokering, but training should be co-designed with academia and industry to be relevant across contexts (e.g., ensuring an academic course in communication in industry is actually useful in industry).	Universities, industry
Industrial PhDs (RQ2)	…knowledge brokering needs to be actively supported through access to people and to communities of practice to become a member of. Brokering may sometimes occur automatically in industrial PhDs, but this is not a guarantee. In addition, supporting interaction and inclusion in communities of practice can prevent industrial PhD students from feeling alone or feeling a lack of belonging.	Universities, industry
Industrial PhDs (RQ2)	… expectations, roles, and responsibilities across contexts should be clarified in the very first stages of an industrial PhD and followed up throughout the PhD. This is similar to how traditional PhDs are followed up, but for industrial PhDs this needs to take into account not only the academic context but the whole context of the PhD (including also industry and brokering).	Policymakers, universities, industry
Industrial PhDs (RQ2)	…participation and inclusion of industrial PhD students should be supported actively, particularly in industry contexts.	Universities, industry

Table 5.2. Summary of directions for future research, as stated in sections 5.1-5.4

Connection to the third mission	**Future research could…**
Third mission (overall)	…examine how responsibility for the third mission is distributed between individuals and institutions, how this shapes incentives and engagement.
Third mission (overall)	…explore how alignment between policy ambitions and everyday academic practices can be achieved across levels (policy, universities, departments, and communities).
Third mission (overall)	…study how environments and communities that support engagement in the third mission can be created and sustained.
Third mission (overall)	…complement self-report data from individuals enacting the third mission with other methods (e.g., using digital tools or more ethnographically oriented approaches) and perspectives (e.g., from supervisors and managers).
Third mission (overall)	…explore how AI can support learning and communication related to the third mission, while considering the continued role of communities.
Science communication (RQ1)	…design and evaluate training that focuses on the *process* of communication (e.g., drawing on genre awareness, self-regulation, and metacognitive strategy knowledge).
Science communication (RQ1)	…investigate how researchers' identities and motivation related to science communication develop over time and how they influence engagement.
Science communication (RQ1)	…develop methods that better capture science communication practices, including forms beyond written outputs.
Industrial PhDs (RQ2)	…analyse communication practices across academia and industry in more detail, for example through analysing the composition of texts and oral communication.
Industrial PhDs (RQ2)	…study how expectations, roles, and agreements in industrial PhDs are designed, implemented, and followed up in practice.
Industrial PhDs (RQ2)	…conduct longitudinal and/or ethnographic studies of participation, communication, and knowledge brokering in industrial PhDs.
Industrial PhDs (RQ2)	…develop and evaluate training and support structures, preferably co-designed with academia and industry to ensure applicability.

5.6. Contributions

In this thesis, I contribute to research on universities' third mission by providing an empirically grounded and practice-oriented account of how the third mission is enacted through science communication and industrial PhDs. The contributions of the thesis lie both in the individual studies and in how their findings are brought together and interpreted in this thesis (*Swedish: kappa*).

At an empirical level, my thesis contributes with detailed insights into how the third mission is enacted in practice in two forms. Across the included studies, science communication and knowledge brokering are shown to be positioned in different ways: they are often treated as peripheral at the level of expectations or incentives, while at the same time being closely intertwined with academic and doctoral work in practice, especially for industrial PhDs. By examining communication practices and industrial PhD students' experiences, the thesis documents how the enactment of the third mission is shaped by incentives, access to training and support, and opportunities for participation.

Conceptually, my thesis contributes with a practice-based perspective on the third mission. Rather than treating science communication and brokering as roles, skills, or outputs, the thesis conceptualises them as forms of work that develop over time and often through participation. This contribution lies in linking research on science communication, doctoral education, and communities of practice in a way that foregrounds learning, positioning, and participation as central to how the third mission is enacted. In the studies on industrial PhD students specifically, I show the usefulness of discourse communities and communities of practice to theorise and understand the social and situated dimensions of the enactment of the third mission. Moreover, my thesis exemplifies the need for and value of several different theoretical lenses, including discourse communities and communities of practice but also self-regulated learning and metacognitive strategy knowledge, to provide a comprehensive picture that goes beyond painting with broad brush strokes what realising the third mission entails (as I put it in Paper 3) and can offer useful advice for practice (see Papers 1-4).

The thesis contributes to research on science communication partly by providing a more detailed description of what it may entail and partly by illuminating what strategies can be used during actual engagement in science communication writing and writing for industrial audiences (Paper 2 and 3). Given that a lack of training is a recurring finding in previous research, these strategies provide important advice both for individual scientists who wish to engage in science communication but need advice on how to do so and to those designing much-needed practically-oriented training for science communication.

The thesis contributes to research on doctoral education by foregrounding industrial PhDs as an example of where the third mission is enacted in everyday work. Through its focus on industrial PhD students' experiences and connections to various social agents, the thesis shows how doctoral education carried out across academic and industrial contexts shapes learning, positioning, and identities, and how expectations related to research, communication, and collaboration are negotiated in practice. This is certainly a contribution to research on industrial doctorates, but can also be valuable for doctoral research more broadly, especially for doctoral projects done in collaboration with several stakeholders (within academia or also including collaborators in industry). In addition, my thesis contributes to research on and conceptualisation of brokering by providing empirically grounded illustrations of brokering as communicative and relational work. Specifically, Papers 3 and 4 show how brokering is enacted in practice rather than being built into, or automatically resulting from, organisational structures or formal roles.

Methodologically, my thesis contributes by combining different types of empirical material and analytical approaches within and across the studies. Similarly to how my use of several theoretical lenses, my use of several methods has contributed to a more comprehensive picture. The combination of qualitative content analysis and network analysis (a bibliometric method) in Paper 1 as well as the combination of interviews and community plots in Paper 4 are especially important contributions. These two examples also show the value of using plots to visualise relationships in research on the third mission, to capture the social and situated dimensions. Community plots, to my knowledge, had been used only to examine traditional doctorates before Paper 4, but proved very useful in generating data relating to brokering and communities.

Finally, my conceptualisation of the enactment of the third mission and its relation to brokering and science communication is a contribution in itself, combining several lines of research in which definitions are often unclear and distinctions between concepts vague. While I do not claim it to be perfect, it provides a starting point for discussions of various aspects of the third mission and how they relate as well as for developing even better models and conceptualisations.

6. Conclusion

The third mission is important for many reasons, and has over the years been increasingly promoted in university and governmental policies. However, while policies at international, national, funding-agency, and institutional levels frequently emphasise the importance of the third mission and need for increased engagement with society, they often provide limited guidance on how these activities can be enacted and supported in practice. Two key questions are thus how the third mission is enacted in practice, at the individual level as part of academics' everyday work, and how to promote it.

In this thesis, I have examined and discussed how individuals compose connections between academia and society and how to support them in doing so. Specifically, I have focused on science communication and industrial PhDs, exploring communication practices, learning, and the communities these individuals engage with. These two aspects of the third mission may seem different at first, and there are indeed differences between them, for example, in terms of type of communication, the extent to which they involve knowledge brokering, the type of connection with audiences or communities outside of academia, and the seniority of the academic who engages in it, to mention a few. However, my findings together with previous literature suggest that both science communication and industrial PhDs share a set of enablers and barriers that seem to be common for activities relating to the third mission: a need for, but also too often a lack of, incentives, training and support, and communities where the third mission is encouraged, supported, and valued. By adding much-needed detail on practices, learning, and communities at the level of individuals who enact the third mission, combining methods to provide a nuanced understanding, and integrating several aspects of the third mission that are often studied and theorised separately, this thesis provides a foundation for designing and further developing training and support structures to promote the third mission.

As a final note, I want to encourage discussions and actions at all levels about the third mission and how to ensure it is enacted—internationally, nationally, at institutional level, in divisions/units, communities, and generally among colleagues. One key finding in Papers 2-4 was an appreciation of discussing with colleagues and other interested people and how that could be inspiring and provide support and learning. For individuals, I stress that composing connections to society and enacting the third mission is not something you (should) have to do alone if you do not wish to or know how to; it can be a collaborative effort where you encourage, support, and learn from each other along the way.

7. References

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