THESIS FOR THE DEGREE OF LICENTIATE OF PHILOSOPHY

(Re)harmonising the Academy

Integrating life-long learning and science communication in Swedish higher education

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Cover:
Photo illustrating the adapted version of Boyer's (1990) model of academic scholarship used in this thesis (see chapter 2, specifically Figure 2 on page 19).
Photo by Maria Cervin-Ellqvist and Göran Cervin-Ellqvist

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Abstract

Higher education today performs a complex system of functions with a variety of goals and expectations, including research, teaching, and disseminating research to the surrounding society. It is however not always clear what these functions should entail, and how they should be played out. Similarly, institutions, departments, and individual researchers' role, or roles, are multifaceted and ever-evolving and researchers are frequently expected to take on new tasks and acquire new skills as a consequence of ambitions in policy.

This licentiate thesis explores how the ambitions of Swedish higher education, as expressed in policy and regulations such as goal statements and promotion and recruitment processes, are realised in practice in two specific areas: students' life-long learning and their acquisition of learning skills—with a focus on self-regulated learning, and researchers' engagement in science communication. The aim is to investigate potential areas of disharmony between policy ambitions and practice, as well as among individual researchers' multiple roles.

The three papers included in this thesis illustrate different facets of how policy ambitions are realised in a Swedish STEM (Science, Technology, Engineering, and Mathematics) context. Paper 1 focuses on the extent to which students acquire learning skills, i.e., to what extent the ambition that students should acquire these skills is realised. This study used a questionnaire to investigate engineering students' learning skills in terms of learning strategies, self-regulated learning, and awareness of what constitutes effective learning. Paper 2 explores to what extent researchers engage in science communication i.e., to what extent the ambition that researchers should engage in dissemination of science is realised in practice. By analysing data from a publication repository along with corresponding full texts, this study mapped the science communication practices at a Swedish STEM university. Finally, Paper 3 focuses on what characterises expert scientists' writing process when addressing non-academic readers, providing input for training and eventual incentives that may promote science communication. Seven researchers in STEM with extensive experience of science communication were interviewed to pinpoint what strategies they use when writing science communication texts and how they regulate this writing process.

My thesis paints a vivid picture of how higher education in Sweden today involves a complexity of functions and practices, and faces the challenge of integrating new tasks and skills, such as learning skills and science communication writing, into teaching and into academic scholarship. Taken together, the findings from the three papers align with previous research in Sweden and internationally, and suggest that policy ambitions in these areas are realised to some extent—as shown by students' awareness of the effectiveness of various learning skills, and the fact that some researchers do engage in science communication. However, there is clearly room for improvement: students' need more scaffolding of learning skills, which in turn may require incentives and training for higher education teachers, and researchers need incentives and training in science communication. In summary, this thesis suggests that there is a shortage of both incentives and training despite policy ambitions expressed for instance in the Swedish Higher Education Act and in regulations for promotion, tenure, and recruitment processes in Swedish and internationally. Overall, disharmonies seem to be built into the system and into individual researchers' academic scholarship. Finally, my thesis provides some concrete suggestions about how to take small steps towards less disharmony, i.e., harmonising, or perhaps reharmonising, the academy.

Keywords: higher education, academic scholarship, policy, generic skills, life-long learning, self-regulated learning, metacognition, science communication

List of appended papers

This thesis is based on the following papers:

Paper 1 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.

I conceived and designed the study together with my co-authors and carried out the material preparation, data collection and analysis together with D Larsson as a part of my master's thesis project. I then reworked the analysis, improved the framing and theoretical grounding, and wrote the draft of the manuscript to Paper 1, while R. Negretti, T. Adawi and C. Stöhr supervised the work, co-wrote, and commented on the manuscript.

Paper 2 Cervin-Ellqvist, M., Johansson, S., Persson, M., Sjöberg Hawke, C., & Negretti, R. The silent tribe? Mapping the variety of researchers' science communication practices across STEM disciplines.

Submitted to ASLA:s skriftserie/ASLA studies in applied linguistics

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 3 Negretti, R., Sjöberg-Hawke, C., Persson, M., & Cervin-Ellqvist, M. Thinking outside the box: Senior scientists' metacognitive strategy knowledge (MSK) and self-regulation of writing for science communication.

Submitted to Journal of Writing Research

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.

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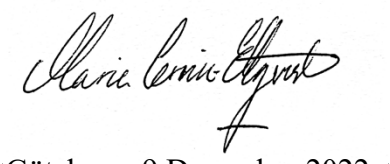

Göteborg, 9 December 2022

Preface

In the research presented in this thesis, context is important, for example for students' learning, for researchers' communication to wider audiences, and for the effects of various policies on practice. In educational research in general, context is important also in terms of who is doing the research and why. I will therefore start this thesis by describing its context: why I have done this research and where my research is going now, for the final three years of my PhD.

During my time as a university student in engineering and educational science, I was fascinated with how my peers (and I) coped with, approached, and learnt how to succeed as students in higher education (HE). In particular, it was interesting how people studied, e.g., those who always studied in a group versus those who preferred to study alone, those who spent huge amounts of time studying versus those who spent quite a lot of time on other activities than studying. Somehow, it felt like we were expected to just figure out ourselves how to do it. The same was true for our writing tasks. My background spans across disciplines, and I was exposed to numerous genres that I apparently was supposed to master, or at least master well enough to get my arguments across. There was rarely much support—we just had to figure it out well enough on our own and together with our fellow students. There seemed to be an interesting mismatch between what is expected of students and what is taught. As I learnt more—and donned a researcher hat rather than a student hat—I found it even more interesting and found similar mismatches for PhD students and faculty. (Where the expectations come from may vary, but that will be addressed further in the rest of the thesis.) This is what the research in this thesis is about, and where I think that I can contribute to research and practice. I do my research as an engineer, who tries to contribute to solving problems, and as a teacher, who wants to improve education and make sure we are teaching the knowledge and skills that students and researchers need.

The licentiate is in a sense a half-time degree for PhD students. During the first two years as a PhD student, I have built the foundation upon which the remainder of my PhD rests. In the three papers included in this thesis, I have investigated students' self-regulated learning and researchers' science communication to wider audiences and the process of learning and engaging in science communication. In this thesis, I contextualise the papers and discuss how they are connected to prioritisations and disharmonies in the HE system and academic scholarship, as well as what we can do about it. One part of the solution is to help students and academics acquire learning and communication skills, as I will come back to in the thesis. In my ongoing research, the aim is to pinpoint what training could be useful for PhD students and researchers who communicate in, to, and with industry. There is research on undergraduates' preparedness for communicating in a professional life in industry, but less research focusing on PhD students' and researchers' communication in, to, and with industry. However, many PhDs and researchers decide to quit academia at some point to work in industry, and collaborations with industry are increasingly promoted even in academia. My research focuses on a specific sub-set of the aforementioned groups: industrial PhD students (who are funded externally, by a company or governmental agency). They have an interesting in-between position, where they can reflect upon communication of research in both academia and industry as well as learning and challenges involved in communicating to both contexts. With this research, I address one gap pointed out in this thesis where my research can contribute to not only theory but also, to me most importantly, practice.

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1. Introduction

> 'To be successful nowadays, a university needs to play a number of different games. Each game has different goals and involves different rules. Some are about generating income. Others are about increasing funding through attracting greater student numbers. Some are about enhancing research, and research reputation. The goals are often incompatible, the rules are written separately, in different places by different people. And winning at one may involve compromising in others. The learning university plays to win in the games which are most significant to its survival and relative advantage. As it does so, it attempts to structure the practices of and constraints on the faculties, departments and individuals within it. … This, to apply our metaphor, can only result in *sha chi* [an old Chinese expression for disharmony].' (Trowler et al., 2005, p. 440)

In this quote, Trowler and colleagues (2005) point out how higher education (HE) today is a complex system of goals and expectations—regarding for instance research output, teaching and, disseminating research to wider audiences—and that these goals and expectations are not always compatible with each other. This complexity and incompatibility can at times result in disharmony between different goals and expectations set for students and teachers, as well as between practice and intended outcomes of HE's functions such as research and teaching or research and dissemination. HE institutions clearly have an important function in society, or rather functions, but the way HE's role is articulated and what its different functions should entail in practice, how they should be played out, is not always clear. Indeed, this issue has been debated with increasing intensity in the past decades (Brown & Carasso, 2013; Maassen & Stensaker, 2011; Tomlinson, 2018). Faculties, departments, and individual researchers all have to navigate this complex system and the changing demands stemming from their role, or roles, in HE. These varied and ever-evolving roles as researchers, learners, teachers, writers, communicators, managers etc, mean that those involved in HE are frequently expected to take on new tasks—such as engaging in collaboration and communication across disciplines and with people outside of academia—and acquire new skills—such as interdisciplinary problem-solving and skills needed to adapt research communication to a non-expert audience. Note how the new tasks also require corresponding new skills. Importantly, both students and researchers today have to learn to work across disciplines and continue learning throughout their professional lives in order to contribute to solving societal challenges as well as keep up with an ever-changing professional life and the rapid evolution of new technology (Bjork et al., 2013; Campbell et al., 2019; Hadgraft & Kolmos, 2020). Learning skills, and skills in 'communication, critical thinking, teamwork, creativity, and the like' (Moore & Morton, 2017, p. 581) are referred to as *generic skills* (Cumming, 2010). The teaching of these skills is one of the new functions of modern HE. Overall, the new tasks and skills in HE need to be implemented by faculties, departments, and individual researchers, adding to the complexity of their roles and potentially to the disharmony among these roles.

Policies at an international, national, and university level that regulate what the functions of HE should be, as well as what is valued in promotion, tenure, and recruitment processes (e.g. Brown & Carasso, 2013; Dryler et al., 2022; Entradas et al. 2020; Maassen & Stensaker, 2011; Pérez-Llantada, 2021; Tomlinson, 2018; Trowler et al., 2005). In this thesis, *policies* refers to the system of regulations that articulate universities' goals and practices in general, typically for education management purposes. *Policy ambitions* then refer to the intended, desirable outcomes of HE that emerge from different policies, for example in institutions' mission statements and strategic plans, appointment regulations, and at the national/international level documents such as the *Swedish Higher Education Act*, and EU regulations. The term *disharmonies* in this thesis is tightly linked to Trowler and colleagues (2005) description of complexity in HE, and the incompatibility that this complexity at times creates between goals and expectations attached to

different university functions. In other words, the metaphor of disharmony is used to describe various mismatches, including differing expectations between policies, mismatches between policy ambitions and what is measured and valued in practice, mismatches between policy ambitions and training opportunities for researchers and students, and mismatches among different roles within individual researchers' academic scholarship. The concepts described in this paragraph will be further conceptualised in chapter 2.

Specifically, in this thesis, I use the concept of disharmony to explore the challenges of implementing new tasks and skills into HE within two comparatively new functions of the academy: 1) helping students and researchers develop skills to regulate their own learning and continue to learn throughout their professional lives; and 2) communicating research to society. I investigate whether in practice the addition of these and other new tasks and skills cause difficulties for academics to prioritise among different parts of their scholarship, such as research, teaching, and engaging with audiences outside of academia. In this thesis, *academic scholarship* refers to the combination of different roles of researchers within higher education, including different dimensions of scholarship relating to research, teaching and engaging with society (Boyer, 1990; which will be further elaborated on in the theoretical framework, chapter 3). In other words, the aim of this thesis is to explore the potential disharmonies described by Trowler and colleagues (2005), not only within universities but also within individual academics' scholarship (Boyer, 1990; Pérez-Llantada, 2021; Trowler et al., 2005). Are the missions of HE reflected in practice? Where can we find misalignments between policy and practice? Specifically, is there a disharmony between policy and practice in Sweden and at Swedish STEM (Science, Technology, Engineering, and Mathematics) institutions? If so, what are the consequences for individual STEM researchers and students?

One example of potential disharmony is in the domain of life-long learning. Both previous research and Swedish policy point out that HE students should acquire the ability to keep on learning independently after graduation (Bjork et al., 2013; Hadgraft & Kolmos, 2020; SFS 1992:1434; SFS 2021:317). To do so, students need to self-regulate their own learning, which includes planning, monitoring, and evaluating their learning (Zimmerman, 2002) and choosing appropriate and effective learning strategies (Dunlosky et al., 2013) based on cognitive factors as well as their motivation, behaviour and context (Pintrich, 2000). Even though students have been found to be unaware of which learning strategies are effective (e.g., Carrier, 2003; Dunlosky et al., 2013; Gurung, 2005; Karpicke et al., 2009), and may therefore need scaffolding of learning skills (Bjork et al., 2013; Kornell & Bjork, 2007), it is nonetheless often left to the students themselves to learn these skills (Bjork et al., 2013). Interestingly, although research suggest that teaching interventions promoting self-regulated learning (SRL) are most often effective (Jansen et al., 2019), HE teachers' themselves (especially teachers in other disciplines than educational science) often lack training in how to integrate scaffolding into their teaching, as well as incentives to implement it (MacMahon et al., 2022; Vrieling et al., 2018).

The acquisition of adequate learning skills is especially important for STEM students, since the challenges they face in their professional life will inevitably evolve alongside rapid societal and technological development (Hadgraft & Kolmos, 2020; McDowell, 2019; Wallin & Adawi, 2018; Zheng et al., 2020). SRL and the use of effective learning strategies has been shown to affect students' performance in STEM courses (Grohs et al., 2018; Ko & Hayes, 1994; Litzinger et al., 2010; Meyer et al., 2015), but more research is still needed in an authentic STEM HE context as well as into potential barriers for integration of learning skills into STEM HE. In Paper 1, we thus investigated engineering students' learning and regulation of their learning in different courses at a large Swedish STEM university, to see if the findings of previous research regarding students' skills, awareness, and need for scaffolding were also valid in this context.

Another example where there is potential disharmony is that of communicating science to audiences outside of academia. Both previous research and Swedish policy point out that it is important to communicate research beyond academia and that researchers engage with society, i.e., engage in *science communication* (Bucchi, 1996; Davies, 2021; Entradas et al., 2020; Hetland et al., 2020; Kappel & Holmen, 2019; Renwick et al., 2020; SFS 1992:1434). Internationally, research has pointed out that while policies may be well intended, there is a lack of incentives for researchers to engage in science communication in practice (Pérez-Llantada, 2021; Schimanski & Alperin, 2018). Specifically in Sweden, science communication has been included in law since 1977, which is early from an international perspective (Hetland et al., 2020). However, Swedish researchers still perceive a lack of incentives to engage in science communication and that they themselves lack the time and training needed despite being overall positive to 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, there are differences in how much researchers engage in science communication across disciplines and topics (Bohlin & Bergman, 2019) as well as in how interested the public is (Ampollini & Bucchi, 2020; Bucchi, 1996; Jönsson et al., 2018). This variation as well as the fact that science communication is an umbrella term for many different types of communication with non-researchers (Davies, 2021; Kappel & Holmen, 2019) makes science communication difficult to measure, evaluate and teach (Baram-Tsabari & Lewenstein, 2017; Olesk et al., 2021; Pinheiro et al., 2015). In Paper 2, we explored science communication output at a large Swedish STEM university, as a starting point to better support and promote researchers' science communication. To further investigate what characterises active and successful science communication practices at the large Swedish STEM university, in Paper 3 we examined strategies that senior researchers use in writing science communication and how they self-regulated their writing. Paper 2 and 3 were part of a larger study on science communication.

Overall, especially in a Swedish context, there is an ambition from policymakers (see the Swedish Edcuation Act) and universities to integrate life-long learning and science communication into HE. However, research still seems to be valued over teaching (including the scaffolding of learning skills) and engagement with society (MacMahon et al., 2022; Schimanski & Alperin, 2018; Tomlinson, 2018). In addition, there is lack of training on science communication for students as well as teachers/researchers (Bjork et al., 2013; Bohlin & Bergman, 2019; MacMahon et al., 2022). The overarching aim of my thesis is therefore to explore how the ambitions of Swedish HE are realised in terms of students' acquisition of learning skills (specifically focusing on self-regulated learning) and researchers' engagement in science communication, and if there seems to be a disharmony between ambitions and practice as well as between individual researchers' multiple roles. An overview of the foci of the included papers is shown in Figure 1 (see page 4). The specific research questions for each study and additional research questions for this thesis are described in Table 1 (see page 5), 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 chapter 2, I first present an overview of the evolving landscape of HE, including marketisation, performativity, and the Swedish context. Then, I continue with an overview of previous research related to generic skills and specifically self-regulation skills. Finally, I present previous research on science communication in academic scholarship and on learning to communicate to audiences beyond academia. In chapter 3, I introduce the multiple theories I draw on and how they relate to each other. I present theories on academic scholarship, and then focus specifically on theories on self-regulation and the scholarship of teaching, and finally science communication and the scholarship of application and engagement. In chapter 4, I describe my methodology, including the philosophical

underpinning as well as the methodologies for each paper. In chapter 5, I summarise the findings of my three papers. In chapter 6, I discuss my findings and what they together with previous research suggest about how ambitions in HE policy are realised in terms of students' acquisition of learning skills and researchers' engagement in science communication. I also discuss potential disharmonies between ambitions and practice as well as among individual researchers' multiple roles. Finally in chapter 7, I come back to my main conclusions.

Figure 1.
Visualisation of the focus of this thesis and how the different parts (and thus papers) relate to each other as well as to the larger project on science communication that Paper 2 and 3 are a part of.

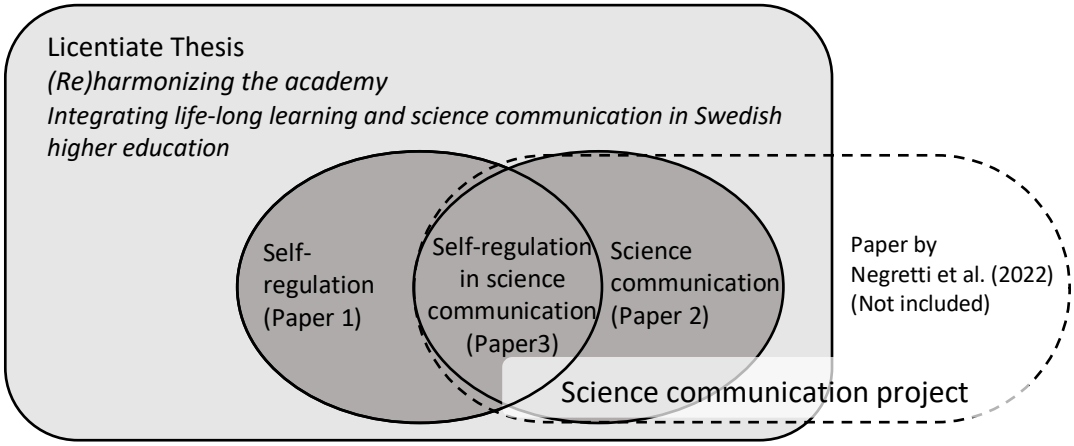


Table 1.
My specific research questions for each study and additional research questions for this thesis, as well as description of how each study links to the overarching aim of the thesis.

Title	Research questions or aim	Link to overarching aim
Paper 1: Metacognitive illusion or self-regulated learning? Assessing engineering students' learning strategies against the backdrop of recent advances in cognitive science	• What learning strategies do engineering students report for studying outside the classroom? • How do the learning strategies that students apply outside the classroom differ between engineering programs and types of courses? • How aware are students of the effectiveness of their learning strategies? • Why do students use their specific learning strategies?	Investigating to what extent students acquire learning skills, i.e., to what extent the ambition that student should acquire these skills is realised
Paper 2: 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 to what extent researchers engage in science communication i.e., to what extent the ambition that researchers should engage is realised
Paper 3: 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
Licentiate thesis: (Re)harmonizing the academy: Integrating life-long learning and science communication in Swedish higher education	1. How are the ambitions of Swedish HE realised in terms of students' acquisition of learning skills (specifically self-regulated learning)? 2. How are the ambitions of Swedish HE realised in terms of researchers' engagement in science communication? 3. In relation to both questions 1 and 2, is there a disharmony between the ambitions of Swedish HE and the multiple roles researchers take on in their everyday practice?	Concluding what the three papers together with previous research suggests about how ambitions of Swedish HE in relation to learning skills and science communication are realised, as exemplified in a Swedish STEM university.

2 Contextual background and previous research

The aim of this thesis is to explore how the ambitions of Swedish HE are realised in terms of students' acquisition of learning skills (specifically focusing on self-regulated learning, SRL); researchers' engagement in science communication; and if there seems to be a disharmony between ambitions and practice, and among individual researchers' multiple roles. The three papers provide concrete examples of practice. In order to achieve this aim, I contextualise the three papers, and broaden the discussion to focus on similarities and differences in how ambitions are realised and the challenges to implementing policy in practice, for universities and individual researchers. To broaden the discussion, it is important to understand the international trends towards marketisation of the HE system that may affect whether, and how, the addition of new tasks and skills into HE may cause disharmony for universities and, in particular, individual researchers. In section 2.1, I will therefore first provide an overview of these trends and connect them to Swedish HE as well as to learning skills and researchers' communication to /with society. Thereafter, I will provide an overview of previous research on generic skills and SRL in section 2.2 and on science communication in section 2.3.

2.1 The evolving landscape of HE: Marketisation, performativity and Sweden

Universities have been an important cornerstone of society for a long time, but their function, or functions, have evolved over time. This evolution of HE and its function(s)—also referred to as missions—are tightly linked to that of society and what society at a given point in time demands from HE, as pointed out by, among others, Knafo (2020b) and below by Austin and Jones (2016, p. 7):

> 'Universities' missions are crafted at different times to reflect the need to meet the challenges facing higher education, specifically, and society in general. The mission is also driven by the philosophy of what a university ought to be at the time.'

To provide an overview of current trends, it is important to see how those trends are a continuation of a modernisation of HE that started about 75 years ago. Historically, the sole function of HE was tied to knowledge generation and education, for example educating people for bureaucratic and similar roles in society (Maassen & Stensaker, 2011). Since then, the functions and management of HE have changed in three phases of reform (Maassen & Stensaker, 2011). The first phase of reform was caused by an increasing number of students—referred to as the massification of HE—and concerns about increasing costs. This reform aimed to make universities themselves tune in to the demands of the students—their 'customers'—and thus started the marketisation of HE—a gradual process in which HE has become increasingly similar to a market. The second phase of reform aimed to make the HE system more responsive, agile, flexible, operationally efficient, and effective (Austin & Jones, 2016; Currie et al., 2003; Kezar, 2004) by introducing performance-based steering and thus trying to make sure HE kept up with society (Maassen & Stensaker, 2011). Finally, the third phase of reform focused on internationalisation and on common issues rather than local variety, for example making it easier for students and faculty to move within Europe and creating new policies on quality assurance in HE on a national and European level. Important driving forces, especially for the third phase of reforms, were 'the philosophical prescriptions of globalization and the new economy' (Austin & Jones, 2016, p. 3), neoliberalism, and global organisations such as OECD, the World Bank and the World Trade Organisation. Overall, universities have gradually turned into increasingly complex institutions, and HE into a system resembling a market tied to national and international economic growth (Austin & Jones, 2016), where students are consumers of education (Brown & Carasso, 2013; Tomlinson, 2018); where institutions compete for funding and are evaluated and compared based on quantitative measures of their research output (Maassen & Stensaker, 2011); and from which government

and employers expect graduates that are highly employable (Campbell et al., 2019; Cumming, 2010). In addition, HE is today expected to provide solutions to increasingly complex and interdisciplinary challenges—such as the climate crisis and the integration of technology in all areas of life and society (Hadgraft & Kolmos, 2020)—in collaboration with other actors in society (Brooks & Everett, 2008; Hadgraft & Kolmos, 2020). It is important to keep this gradually developing complexity of HE in mind when discussing how to further evolve the functions of HE and implementing new tasks and skills for students and researchers.

Variation across countries of course exists in terms of when, how and to what extent the reforms described above have been carried out (Maassen & Stensaker, 2011). For instance, how performance-based steering was implemented in the second phase of reform varied across countries, with one common example being the creation of various agencies and intermediate bodies to control funding based on output (Maassen & Stensaker, 2011). In Sweden, for example, the base funding for research has decreased over time and funding from intermediate bodies become more important (Åmossa, 2021). To what extent HE is a proper market also varies across countries. In general, HE is in practice a quasi-market rather than an ideal self-regulated market (Knafo, 2020a; Tomlinson, 2018), since it is still regulated by policies written by the government and thus not entirely self-regulated (Tomlinson, 2018). This is even more true for countries such as Sweden where students do not have to pay tuition fees as university education is funded by government (Tomlinson, 2018). In such countries, government invest money and students invest time, and they both expect to get value out of this investment/cost; in other words, both could be considered consumers of HE. However, students could also be considered investors in their education for the future rather than consumers of education, especially in countries without tuition fees. Overall, it is therefore important to consider the national context in research relating to HE policy and management, including in my research.

One potential cause of disharmony is that marketisation has brought corporate governance and managerialism, which refers to the increased influence of and control by policymakers and managers on academic work (Austin & Jones, 2016; Eagleton-Pierce & Knafo, 2020; Poutanen et al., 2020). Academia however has a long tradition on self-governance, which on an institutional and departmental level is based on the assumption that academics know their discipline and how it is linked to goals of the university better than for example managers from outside the discipline or higher up in the hierarchy of academic governance such as a vice-chancellor (Austin & Jones, 2016; Trakman, 2008). Consequently, universities have difficulties adapting to a more marketised and corporate approach to governance (Austin & Jones, 2016; Christopher, 2012; Marginson & Considine, 2000). Furthermore, Poutanen et al. (2020) argue that increased managerialism has led to a de-democratisation of HE and that changes towards managerialism have been introduced despite resistance and explicit preference for democratic self-governance and academic freedom from academic communities. (Note that democratic here refers to academic democracy rather than the democracy in society as a whole, and that it could be considered democratic from a societal perspective to have more influence from democratically elected policymakers.) While the new approach to governance is connected to quantitative quality assurance and extrinsic rewards, the traditional self-governance typically entails a more trusting environment among colleagues with more intrinsic rewards and less monitoring (Austin & Jones, 2016). This results in a clash of values that may contribute to disharmony at both institutional and individual level, if what institutions and/or individuals believe is important is not awarded by the marketised and corporatised HE system.

As mentioned above, quality in HE today is often measured based on performance or output—reducing and simplifying complex phenomena in HE to quantitative measurements of certain selected outputs. The focus of management on quantified outcome can also be referred to as performativity (Tomlinson, 2018) or ‘governance by numbers’ (Ball, 2015). Performativity is

clearly connected to the functions of HE and how academics prioritise between different parts of their scholarship (e.g., between research and teaching or communicating their research to society); Tomlinson (2018) described the effect of performativity as followed:

> 'The preponderance of measurement and measurability within higher education is clearly prevalent in the managed market environment and is used to incentivise behaviours which serve the end goals of favourable market positioning. The attainment of desired outcomes—e.g. research ranking, student satisfaction, teaching quality, graduate employment outcomes—becomes a driving incentive and can marginalise other areas of institutional life which cannot be quantified into set units of production.' (p. 721)

In other words, performativity affects what institutions prioritise, and thus the focus of the whole HE system. For both teachers and students, performativity may lead to a focus on measurable performance and instrumental values rather than intrinsic values as well as for example actual learning, development of self-regulated learning skills, and intellectual contributions (Tomlinson, 2018). Consequently, performativity can affect what students learn from HE, whether they learn skills that are difficult to quantify but yet important, such as generic skills, and how researchers prioritise within their academic scholarship. For example, researchers who engage in science communication are often driven by strong intrinsic motivation to do so (Koswatta et al., 2022; in a Swedish STEM context Negretti et al., 2022), but in a performative and managerialist system, the extrinsic motivation to engage with what is measured and quantitatively evaluated—i.e., research and teaching—may overpower an intrinsic motivation to engage in activities like science communication that are not measured and quantitatively evaluated. Interestingly, this seems to be the case in Sweden, where promotion and recruitment regulations are unclear about the weight of science communication, prioritising instead research and teaching activities (Dryler et al., 2022). A second example is how teaching is quantitatively evaluated in terms of for example time spent studying, student satisfaction with specific courses, the time it takes for students to complete their programs, and employment rates some time after graduation, measurements that do not capture the complexity of student learning or readiness for the job market (Campbell et al., 2019; Kelly et al., 2017; Sin et al., 2019)—e.g., students' development of important generic skills. Note that I am pointing to organisational factors that affect individuals, rather than putting the responsibility solely on the individuals. I thus echo Jacobson et al.'s (2004) point of who should be responsible for how scholars in HE prioritise, in this case in relation to science communication and transferring knowledge to others:

> 'Focusing only on promotion and tenure guidelines risks turning knowledge transfer into a matter of individual-level motivation rather than organizational-level commitment.' (p. 248)

For individual researchers, the more evident consequences of marketisation, managerialism and performativity include changes to funding of research, teaching workload (e.g., with more students per teacher and less time per student), and what work is prioritized, as well as an increased internal and external surveillance of academics' performance (Deem & Brehony, 2005). Managerialism emphasises research and sourcing external funding and large grants to advance in academia (White et al., 2011), which together with performance-based evaluations affects what academics who wish to climb the career ladder should prioritise in their academic scholarship. Overall, it is not surprising that researchers often prioritise research and scientific publications over tasks that matter less for their academic career, such as teaching—and especially teaching of generic skills—and engaging with society, in line with what is favoured in the academic system and culture (Chalmers, 2011; Pérez-Llantada, 2021; Schimanski & Alperin, 2018; Tomlinson, 2018). In addition, the way that different activities in HE are measured, evaluated and valued suggest that expectations from society, policies, and steering

tools sometimes lacks coherence (e.g., Trowler et al., 2005). Policies mention different activities—pertaining to different parts of academic scholarship such as research, teaching and engagement with society—but the question remains as to how they can properly be put into practice and fit into the scholarship of individual researchers.

While internationally, much of the research on HE policy and how it is implemented in practice currently stems from a few countries such as the UK and Australia, the research included in this thesis has been carried out in Sweden. It is important to expand the research to different countries since policies, traditions and culture vary. Countries may also learn from each other how to, for example, create HE policies that truly encourage what they intend to encourage, or pinpoint challenges in the implementation. Swedish policy includes clear ambitions regarding both science communication and life-long learning, as described in the introduction to this thesis (chapter 1). Swedish policy also states that teaching and research should be assigned equal value in recruitment and promotion processes, but not how engagement with society should be valued in comparison to research and teaching (Dryler et al., 2022). Moreover, it is largely up to the universities themselves to design the process for how to evaluate research, teaching, and engagement with society in recruitment processes. In a recent national investigation by the Swedish Higher Education Authority (Dryler et al., 2022), Swedish universities report having requirements regarding both research and teaching in recruitment processes, suggesting that teaching is valued in practice to a higher extent than suggested by previous research in other countries. The weight of research versus teaching varies depending on the position (i.e., if it is a senior research-heavy position or a junior teaching-heavy position), yet the norm is for both research and teaching to be included in most positions. However, while there is a long tradition and widespread knowledge on how to evaluate research, Swedish universities are still today in the process of designing models for how to evaluate teaching in recruitment processes (Dryler et al., 2022). It is still unclear exactly what parts of teaching should be evaluated, e.g., if this evaluation includes other aspects than students content knowledge or student satisfaction by the end of a course. Moreover, The Swedish Higher Education Agency (Dryler et al., 2022) concludes that while some universities report valuing engagement with society in recruitment processes, it is unclear to what extent they do so and exactly what type of engagement they value. As pointed out in the introduction, Swedish researchers themselves report that they do not have time for science communication (Bohlin & Bergman, 2019), a point that is echoed by The Swedish Higher Education Agency in their report (Dryler et al., 2022).

In relation to how academic positions are composed and funded, Swedish universities find that the need for external funding from intermediate bodies and other funders causes instability and constitutes an issue for institutions (Dryler et al., 2022). In recent years, the base funding of universities has decreased and the need for external funding increased, a trend that has given rise to recurrent debates about whether this change is actually beneficial or not for the quality of research and the work environment of Swedish researchers (e.g., Åmossa, 2021). Overall, the evaluation of academic activities—such as research, teaching, and engagement with society—have developed in a similar way in Sweden as in the rest of Europe, towards a system where quantitative evaluation and efficiency are important (Austin & Jones, 2016; Maassen & Stensaker, 2011; Tomlinson, 2018). However, I have in this section and in the introduction (chapter 1) highlighted several factors that distinguish Sweden, including for instance the long tradition of science communication, the lack of tuition fees, and the fact that teaching should be valued in recruitment processes according to policy. Given these contextual features, it is interesting to explore what challenges there might be in Sweden for modernising HE and implementing new tasks and skills, and what potential disharmony this modernisation might cause for Swedish universities and individual researchers. Clearly contextualised research from

different countries can provide insights into both what common challenges and disharmonies there may be, but also into potential differences and ways forward.

Overall, the HE environment of today can be described as dynamic, shifting, turbulent, and increasingly complex (Austin & Jones, 2016). Moreover, while policies separately may be well intended, the overall bundle of interacting policies on HE often contains 'policy paradoxes, shaping practices in contradictory ways and setting up incommensurable goals' (Trowler et al., 2005, p. 439), a point that is echoed by many, including Maassen and Stensaker (2011) in their analysis of how external pressure regarding education, research and innovation affect universities. In addition, HE policy often downplays the complexity of the relationship between the different parts of academic scholarship, for example between research and teaching, and between research and engagement with society (Tomlinson, 2018), also in a Swedish context (Bohlin & Bergman, 2019; Dryler et al., 2022). It is perhaps not surprising if this complex and shifting HE system creates disharmonies for both universities and individual researchers. In the following sections, I will zoom in on some aspects of academics' and students' practices where the complexity is particularly apparent, namely self-regulated learning skills and science communication.

2.2 Learning in HE: Generic skills and self-regulated learning

In this section, I will present previous research on generic skills in relation to learning in HE and more specifically, to self-regulated learning (SRL). This overview of previous research provides a background mainly to Paper 1—where we examined engineering students' learning strategies and SRL—and partly to Paper 3—where we examined senior researchers' strategies for and self-regulation (SR) of science communication. It also provides a background to the overall discussion on the realisation of policy ambitions relating to new tasks and skills in HE.

Previous research indicates that graduates often lack generic skills (such as skills in learning, communication, critical thinking, teamwork, and creativity) or more specifically that employers' perceptions are that graduates are less skilled than the employers would like them to be (Cumming, 2010; Moore & Morton, 2017). Governments have contributed to bridging this supposed gap between students' skills and the employers' expectations by trying to strengthen the link between HE and economic growth, incorporating generic skills in policy, and measuring and assessing for example graduate skills and employability. A global example is the UN's Sustainable Development Goal number 4, which concerns the quality of education and promoting lifelong learning opportunities for all, and sub goal 4.7 that gives specific attention to acquiring knowledge and skills needed to contribute to a sustainable development (*Goal 4: Quality Education*, 2022). However, measuring generic skills is difficult and large quantitative studies have failed to pinpoint what exactly the deficiencies are, and even if they actually are deficiencies (Moore & Morton, 2017). For instance, Moore and Morton (2017) found that graduates' challenge with writing in a professional setting is not the writing skills in themselves, but rather that the context and communication practices differ between HE and industry, concluding that instead of just becoming better at writing in academic genres, students need to become more aware of differences between genres and at adapting their writing to different genres. Inouye and McAlpine (2022) made the same conclusion in a more recent study, where they found that an understanding of genres acquired during doctoral education allows PhDs to adjust to writing in new genres in industry.

Another important aspect of generic skills is who defines what is deficient and what is sufficient, as well as which generic skills students should acquire. It is perhaps not surprising that whether students have acquired sufficient generic skills is often measured in terms of what employers think, since it is to employers that universities 'market' their students. Perhaps in this sense, also employers are consumers of HE. However, what a sufficient level of generic skills is could

also/instead be defined by governments and society on various levels (as suggested by the interest from the UN), HE itself (e.g., at an institutional level), students, or all of these stakeholders. In Moore and Morton's (2017) description of generic skills, the focus is not on what employers or governments think, but on the students and their development to competent, critical, and creative learners, thinkers, and team players. How exactly generic skills are best taught—whether it is through separate interventions or integrated into regular courses—is also unclear (Cumming, 2010). Overall, the debate on generic skills raises several questions, including for whose sake HE should teach generic skills, what should be taught, and how it should be taught. Finally, whose responsibility is it to realise ambitions regarding generic skills in practice?

Regarding learning skills, an important goal is to promote a greater degree of learning autonomy among students in HE (as compared to previous schooling), for example organising their studying in terms of time and mode as well as maintaining motivation (Coertjens et al., 2017). Therefore, self-regulation and the ability to accurately self-asses one's learning (i.e., make accurate evaluative judgements) are crucial skills to master in HE (Boud & Soler, 2016; McDowell, 2019; Tai et al., 2018). While engineering students' study habits outside the classroom has received relatively little attention by previous research, some studies have shown that metacognitive strategies affect the students' performance in STEM courses (Grohs et al., 2018; Ko & Hayes, 1994; Litzinger et al., 2010; Meyer et al., 2015). Moreover, SRL skills are equally necessary for the students, perhaps especially STEM students, in their professional life, where they will face increasingly complex challenges as a consequence of today's rapidly evolving society (Hadgraft & Kolmos, 2020; McDowell, 2019; Wallin & Adawi, 2018; Zheng et al., 2020). Thus, especially in STEM, 'developing students' evaluative judgement [of their learning] should be a goal of higher education, to enable students to improve their work and to meet their future learning needs' (Tai et al., 2018, p. 468).

Previous research however has shown that students tend to make incorrect judgements about their learning and what effective learning is, for example, which strategies are effective and which are not, i.e., students suffer from metacognitive illusions (Bjork et al., 2013). One example comes from Karpicke et al.'s (2009) study where the findings suggest that students believe that it is more effective to read a text multiple times than to test one's knowledge, which is not true according to research on the effectiveness of different learning strategies (Dunlosky et al., 2013). Metacognitive illusions, such as believing that rereading is more effective than testing, could negatively affect students' development of effective strategies (Metcalfe & Serra, 2009; Tai et al., 2018). Other studies have shown that reading (Carrier, 2003; Gurung, 2005) and highlighting (Dunlosky et al., 2013) are popular among students but not very effective according to previous research (Dunlosky et al., 2013). To what extent students tested their knowledge, a strategy shown to be effective (Dunlosky et al., 2013), has varied across studies (Gurung, 2005; Hartwig & Dunlosky, 2012; Kornell & Bjork, 2007). Possibly, the variation could be caused by differences in study design and context. Another interesting difference across studies is how certain strategies are used. For instance, flashcards have been found to be used to practice testing (Hartwig & Dunlosky, 2012; Kornell & Bjork, 2007) but also just to memorise and because they are easy to use (Wissman et al., 2012). In this thesis, I will not go into more details on what strategies are effective and similar matters—I merely use Paper 1 as an illustration of how ambitions regarding life-long learning skills are realised in practice, and details about the effectiveness of various learning strategies are thus not within my scope. For more details, please see Paper 1 and Dunlosky and colleagues' (2013) comprehensive metareview of the effectiveness of some common learning strategies. For my thesis, the most important take away from this set of previous research is that students seem to suffer from metacognitive illusions regarding how to learn effectively.

In evaluating students' learning—whether they suffer from metacognitive illusions or not—in natural settings, it is important to consider different factors that may affect students learning process and choice of strategies as well as what strategies are actually effective for the particular student in their particular situation. Note that Dunlosky et al.'s (2013) metareview and most of the other studies mentioned above take a cognitive perspective, not accounting other factors such as the context and students' motivation, which is highly relevant in naturalistic settings. While the research in naturalistic settings has increased, there is still a need for more research on HE students' learning and SRL in naturalistic settings and for such research to take not only cognition but also motivation, behaviour, and context (c.f. Pintrich's 2000 model of SRL) into account (Dunlosky & Rawson, 2019; Vermetten et al., 1999; Vermunt, 2005; Winne, 2010). What students actually do, and why, becomes even more difficult to correctly identify and evaluate with this expanded and highly contextual scope, but it provides important knowledge on whether HE actually provides its students with the learning skills that they need to succeed as students and in their future careers. In Paper 1, we addressed this need for research on students' learning and SRL in naturalistic settings that take cognition, motivation/affect, behaviour, and context into account. Specifically, we focused on the STEM context, and thus also addressed the particular importance for STEM students to acquire lifelong learning skills.

2.3 Engagement with society: Science communication

In this section, I will present previous research on science communication, science communication in relation to other dimensions of academic scholarship, and which skills are important for effective science communication. This overview provides a background to Papers 2 and 3—where we explored science communication practices and strategies that senior researchers use in writing science communication—as well as to the overall discussion on the realisation of policy ambitions relating to new tasks and skills in HE.

However, first, I need to give a short description of the term *genre*, which I use frequently in Papers 2 and 3 and also in parts of this thesis. In short, 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 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). An example from Paper 2 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 is socially recognisable by both readers and authors, and they can thus be considered a genre.

Research can be communicated through many different genres. Today, science is disseminated to non-academic audiences at increasing rates, resulting from a shift of perspective about the role of HE in society (Pinheiro et al., 2015; see also Section 3.1.1 on the mission and marketization of HE), on what academic scholarship should include (Boyer, 1990), and political will (Watermeyer, 2015). Papers 2 and 3 are concerned with such *science communication*, which is in itself not a genre but rather an umbrella term for communication of science/research to audiences other than researchers (Vetenskap & Allmänhet, n.d.-b). It comprises many genres, as suggested by previous research (e.g., Bucchi, 1996; Davies, 2021; Kappel & Holmen, 2019; Pérez-Llantada, 2021) and corroborated in Paper 2. 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.

Policies concerning science communication vary across countries (Pinheiro et al., 2015), as does engagement in science communication (Entradas et al., 2020). 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 science communication, sometimes called the 'third mission' (with research and teaching being the first two missions; 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 1990's (Lebeau & Cochrane, 2015). While the first Swedish legislation on science communication 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). 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 organizations, authorities, universities, and companies work 'to promote dialogue and openness between researchers and the public' (Vetenskap & Allmänhet, n.d.-a). Overall, there is a recognition in Sweden that science communication 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 science communication is and should be, with a general expansion from science communication as only dissemination and monologue to science communication as a form of scholarship that also includes dialogue with and participation of various groups outside of academia.

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, 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 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; J. M. Swales, 2004). The existing incentives—for instance some funding bodies nowadays require that the research they fund is communicated to wider audiences (Pérez-Llantada, 2021; Renwick et al., 2020)—seem to be insufficient to realise the political ambitions in practice.

The promotion of science communication therefore needs to acknowledge that engagement in science communication requires a change of priorities within academic scholarship. 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., 2020; 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 do not spend too much time on outreach (Schimanski & Alperin, 2018). They are also less positive to 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 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 2, we therefore mapped science communication at one university. 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 2) 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 in itself may constitute an obstacle to engage (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 2.

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 & 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. These lists (which can be found in Table 5 in chapter 6 Discussion) are important contributions to what science communication training should focus on. However, they illustrate goals and skills rather than strategies that can be applied in practice. In Paper 3, 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 what incentives might be effective to promote science communication in a Swedish STEM context (see chapter 5, section 5.3, where the strategies used by participants are summarised in Table 4).

3. Theoretical framework

This thesis draws on multiple theories to address the overarching aim: to explore how the ambitions of Swedish HE are realised in terms of students' acquisition of learning skills (specifically focusing on self-regulated learning) and researchers' engagement in science communication, and if there seems to be a disharmony between ambitions and practice as well as between individual researchers' multiple roles. To allow for a discussion of disharmonies within individual researchers' multiple roles, I draw on Boyer's (1990) model of *academic scholarship*, with later expansions by Boyer and others (e.g., Barker, 2004; Brew, 2011; Renwick et al., 2020; Trigwell et al., 2000). Specifically, I focus on two parts of an adapted model of Boyer's model: *the scholarship of teaching* and what I have chosen to call *the scholarship of application and engagement*. I will explain the model further in section 3.2. Within the scholarship of teaching, I also use the theory of self-regulated learning (SRL) to discuss students' learning and what role HE teachers' play in students' acquisition of SRL skills. Note that I draw on Boyer's (1990) model of academic scholarship (with my adaptations) in my thesis but have not used it in the individual papers. While in the papers I had a narrower perspective, in this thesis I use the model of academic scholarship to frame my work and broaden the perspective.

3.1 Academic scholarship

Similar to Trowler (2005), Boyer (1990) was concerned about what researchers spend their time on, what they prioritise, what is encouraged by the HE system, what potential disharmonies there may be, and how to resolve such disharmonies. In 1990, Boyer (1990) proposed that *academic scholarship*, a term describing the roles of researchers within higher education, should include four dimensions:

- Discovery: doing research in the traditional sense
- Integration: connecting disciplines and putting the research in a larger context
- Application: scholarly service activities tied to one's own specific field of research, e.g., contributing to shaping policy
- Teaching: teaching to educate and entice students

As a background to how I have adapted and used the model, I will now provide a slightly more detailed description of the different dimensions of scholarship. Boyer (1990) argued that discovery, with its pursuit of knowledge and freedom of inquiry, is crucial to academic scholarship and HE and to an intellectual academic debate. However, he also tried to capture other parts of academics' professional life to better describe academics' multiple roles, and piece these roles together into a model which recognised not only discovery but also other dimensions of scholarship.

The scholarship of integration underscores the importance of making use of the discoveries and putting them into perspective across disciplines. The scholarship of integration overlaps with discovery in the sense that the first step of integration is to do research (i.e., discovery) at the intersection of disciplines and fields. More to the point, what Boyer (1990) called the scholarship of integration is today often referred to as interdisciplinary research (Thompson Klein, 2010).

The scholarship of application is closely connected to service to society: how research can be applied to contribute to society in one way or another and how research can be designed based upon what would be useful for society to do research on. Boyer (1990) carefully points out that the scholarship of application is as serious and rigorous work as that of discovery or integration and is, as for the other scholarships, tied to the researchers' field (or fields) of expertise.

Finally, the scholarship of teaching emphasises that teaching is a scholarly enterprise which requires expertise in the field being taught as well as pedagogical knowledge. Instead of seeing teaching as an act of transferring knowledge to students, Boyer (1990) described it as a process including also transforming and extending knowledge. For example, he described that researchers can be pushed in new creative directions by classroom discussions with students or by comments and questions.

Note how the different dimensions of scholarship include various types of dialogue, where researchers both communicate what they do to, and are inspired by, other researchers; researchers in other disciplines; interdisciplinary, applied, problems; larger societal problems; and students. Moreover, the different dimensions of scholarship overlap and are not always easily distinguishable from each other, as exemplified by the overlap between the scholarship of integration and the scholarship of discovery.

Boyer's (1990) work is tightly linked to a US context, meaning that some aspects of the model might make less sense in a European or Swedish context. This contextualisation does not provide major difficulties for using Boyer's model of academic scholarship in other contexts, but it affects some dimensions of scholarship more than others; the scholarship of application is for example built on a US model for service to society. In addition, the model is fairly old, and it goes without saying that a lot has happened since the beginning of the 1990's in society and HE. How to prioritise between different tasks, or different parts of scholarship, is however still an issue for academics across the globe today (Chalmers, 2011; Llorente et al., 2019; Pérez-Llantada, 2021; Schimanski & Alperin, 2018; Tomlinson, 2018; Trowler et al., 2005), and thus Boyer's (1990) work is still used and useful in the debate about what academic scholarship entails and should entail.

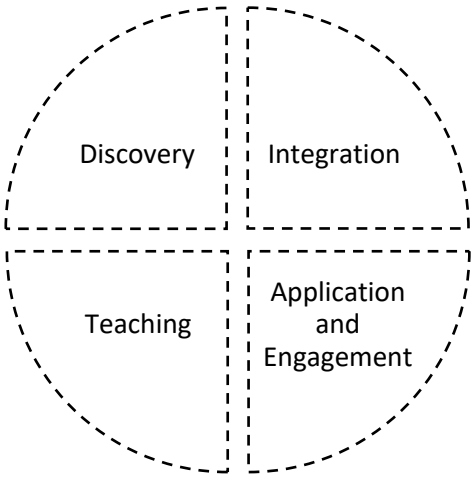
Since Boyer (1990) first proposed his model, Boyer himself and other scholars have elaborated and expanded on it (e.g., Barker, 2004; Brew, 2011; Renwick et al., 2020; Trigwell et al., 2000). Boyer (1990) expanded on the model by adding a fifth part of scholarship, the scholarship of engagement, shortly after proposing the original model. This fifth part of scholarship focuses on how higher education in a democratic spirit collaborates with society to address various societal problems, from wars to the citizens' health. However, Boyer's model—especially this later addition of engagement—is not without its detractors. For instance, in an overview of the literature, Barker (2004) concluded that scholarship of engagement and similar terms are now used in various, sometimes seemingly conflicting ways to describe a scholarship that challenges the mainstream academic scholarship and consists of:

> '(1) research, teaching, integration, and application scholarship that (2) incorporate reciprocal practices of civic engagement into the production of knowledge.' (Barker, 2004, p. 124)

In this thesis, I have chosen to not use Barker's (2004) exact definition, since it is unclear what qualifies as reciprocal practices of civil engagement into the production of knowledge; it could be interpreted as only referring to actively involving citizens in doing science. This definition does not include disseminating science by monologue, having a dialogue with policy makers, or communicating relevant research findings to industry. In this thesis, I am interested in all these aspects of engagement with society, all of which broadly can be categorised as scholarship of engagement and/or scholarship of application. To better illustrate my broader focus on a scholarship of various forms of engagement with society (i.e., science communication), I have adapted Boyer's (1990) model so that the fourth part of scholarship is a scholarship of both application and engagement. The adapted model is shown in Figure 2. In section 3.3 in the theoretical framework chapter, I will elaborate further on how engagement with society can be seen as a continuum ranging from dissemination to the active inclusion of

citizens in doing science that goes under Barker's (2004) definition of scholarship of engagement. I have not made any further adaptations to the model for the other part of scholarship—i.e., discovery, integration, and teaching—but will elaborate on what scholarship of teaching entails in section 3.2.

Figure 2.
Visualisation of my adapted version of the four dimensions of academic scholarship described by Boyer (1990, 1996)*. Note that the figure is somewhat simplified and that the different dimensions of academic scholarship overlap.*



As mentioned, I focus on the *scholarship of teaching* and the *scholarship of application and engagement* and will elaborate further on these dimensions of scholarship in the following sections. The thesis will touch also upon the scholarship of discovery and the scholarship of integration in discussing researchers' prioritizations and researcher's and HE's role in society. The scholarships of discovery and integration are however not the main focus, and I will thus not elaborate further on them in this chapter.

3.2 Learning in HE: *The scholarship of teaching* and self-regulated learning

In this section, I will elaborate on the scholarship of teaching, which I use in this thesis, and how this relates to self-regulated learning (SRL), a theory used in Paper 1 to analyse engineering students' learning and in Paper 3 to analyse senior researchers' science communication writing process. I will also describe SRL and which SRL models I have used.

Several models exist that are closely related to what Boyer (1990) referred to as the scholarship of teaching, for example expanding on the scholarship of teaching in different ways or linking it to already existing theories and concepts. Before providing my rationale for using Boyer's model, I will therefore give a brief overview of other models. Interestingly, Boyer's initial description of scholarship of teaching is somewhat limited, focusing on the knowledge of the teacher and the resulting quality of teaching content knowledge. Shulman (1993) developed the theory of pedagogical content knowledge—a way of conceptualising how teachers need pedagogical knowledge that is specific for their content, in addition to general pedagogical knowledge and content knowledge (Loughran et al., 2012; Shulman, 1993). Others, such as Andresen (2000) and Schön (1995), have been influenced by Dewey (1910) and his notion of inquiry. For instance, Schön (1995) concluded that 'if teaching is to be seen as a form of scholarship, then the practice of teaching must be seen as giving rise to new knowledge' (p. 31), which is also the key component of another related model called scholarship of teaching

and learning (SoTL). Scholarship of teaching, pedagogical content knowledge, SoTL and similar models and theories take slightly different perspectives, but they all tend to shift the focus of what constitutes good teaching or a good teacher in HE from only content expertise to also including (to a varying degree) knowledge about teaching and learning and the ability to implement this knowledge in teaching. Knowledge about teaching and learning could for example mean knowledge about effective learning strategies and how to scaffold students' learning strategies and SRL in teaching.

The term scholarship of teaching has proven very useful in my thinking in this thesis. Many of the related models overlap and are not easily distinguishable from each other (e.g., Potter & Kustra, 2011). I have chosen to use the scholarship of teaching since Boyer's model is useful in discussing the different dimensions of scholarship in relation to each other in academic professional life and policy ambitions. In particular, I find Trigwell and colleagues' (2000) model of scholarship of teaching useful in illuminating the multiple dimensions of teaching in HE, how it can be scholarly, and how the scholarship of teaching connects to the students. Trigwell and colleagues' (2000) model comprises four dimensions of the scholarship of teaching:

- Informed dimension: the extent to which a teacher engages with literature on teaching and learning on a general and discipline specific level, from using informal theories to themselves engage in research on teaching and learning
- Reflection dimension: what teachers focus on in their reflections on teaching and learning within their discipline, if it is goal-oriented (i.e., they identify what knowledge they need and how to get it) or not.
- Communication dimension: The extent to and quality with which teachers communicate about teaching and learning with their colleagues, ranging from coffee break discussions to publishing on the topic in scholarly journals
- Conception dimension: How teachers conceptualise teaching and learning, if they focus on the teacher and the teaching or on the students and thus on both the teaching and students' learning.

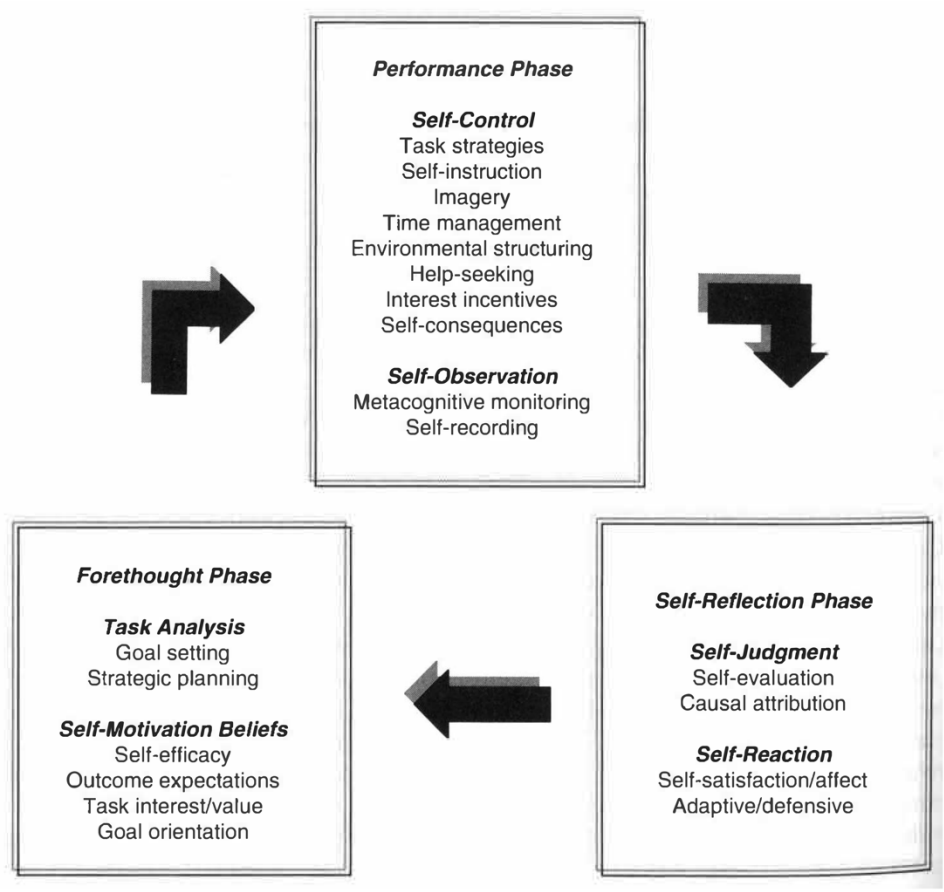
The reflection and conception dimensions—i.e., how HE teacher reflect upon and conceptualise their own teaching and learning as well as students' learning—are particularly interesting in my licentiate thesis and in relation to Paper 1, where we investigated engineering students learning strategies and SRL.

In Papers 1 and 3, we draw on the theory of SRL. As described in the introduction (chapter 1) and the conceptual background and previous research (chapter 2), one role of HE is to make sure students acquire skills, such as the ability to regulate their own learning to be able to continue learning after graduation. 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, whereof I have used two in the research presented in this thesis: one by Zimmerman (2000) and one by Pintrich (2000). Zimmerman's (2000) cyclical model (shown in Figure 3) 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 3.
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.



Similar to Zimmerman and Moylan's (2009) model, Pintrich's (2000) model describes SRL as a process with several phases, though Pintrich describes four phases: (1) forethought, planning and activation, (2) monitoring, (3) control and (4) reaction and reflection. The first and final phases are very similar in the two models, while phase 2 and 3 in Pintrich's model corresponds fairly well to phase 2 in Zimmerman's model. In Paper 1, we chose to describe phases with Zimmerman's model since there was no need to separate between monitoring and control in the studies I have conducted. In addition, Pintrich divides SRL into four areas: (1) cognition, (2) motivation/affect, (3) behaviour, and (4) context. While the phases are similar in the two models, the areas are exclusive for Pintrich's model and are the reason why we used this model in Paper 1. In evaluating students' learning and their ability to regulate their learning, researchers often use a purely cognitive perspective in assessing what works. I believe this focus to be too narrow to paint a fair picture of students' learning skills, since the realities of students and teachers are multi-faceted and do not only contain cognitive factors (Winne, 2010; see also Paper 1). Pintrich's (2000) model acknowledges and underscores that learning and SRL in a real-world context is about more than just pure cognition. This makes the model

particularly useful when investigating self-regulation (SR) of generic skills that are used, or are to be used, in complex real-world contexts outside of classrooms.

In Paper 3, 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 SR of many different processes (see e.g., Schunk & Greene, 2018) including 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 3, we were interested in the process and how researchers go from planning to evaluating their science communication; i.e., what the writing process 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 3, we also examined at 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 3). 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.

3.3 Science communication and the scholarship of application and engagement

In this section, I will elaborate on the scholarship of application and engagement and the closely related term science communication, which connect to Papers 2 and 3 where we investigated science communication practices and writing processes. I will both describe what science communication and *the scholarship of application and engagement* are and how the terms are related, as well as specify my conceptualisation of them in this thesis.

As for scholarship of engagement (see section 3.1), 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 other audiences than the research community (Vetenskap och Allmänhet, n.d.). 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 HE's functions in society as well as how HE is managed, as suggested by the six roles of science communication described by Davies (2021):

- Contribute to the **accountability** of HE 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 in shaping that culture
- Fulfil **economic purposes/values** for society, including recruiting more people into science and increase 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 of science communication literature, Kappel and Holmen (2019) suggested a similar set of aims of science communication, again relating to HE's functions in society:

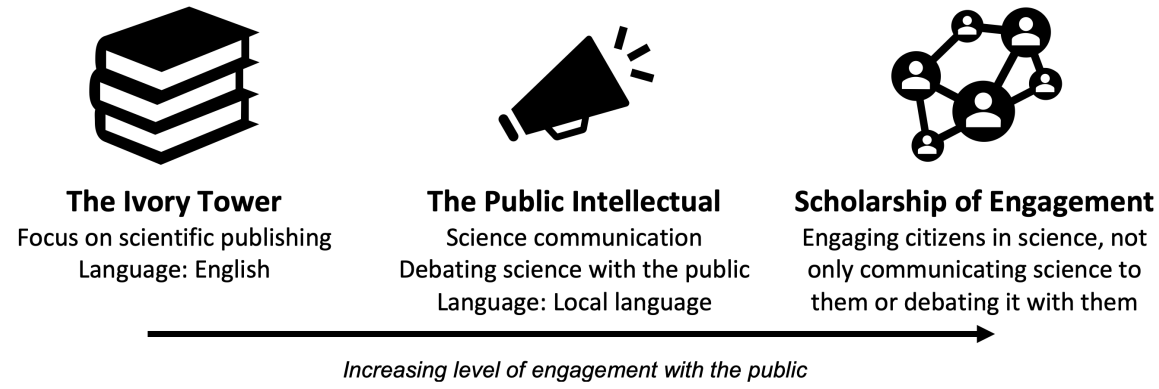
- Improving populations beliefs about science
- Generating social acceptance
- Generating public epistemic and moral trust
- Collect citizens input about acceptable/worthwhile research aims and applications of science
- Generating political support for science
- Collect and make use of local knowledge
- 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 the second dialogue or even more extensive participation from people outside of academia (Kappel & Holmen, 2019). Overall, what the many conceptualisations agree upon is that science communication may have many purposes and audiences and that these tend to overlap. Note that the purpose of science communication is, as mentioned, in many ways tied to the purpose of HE overall and HE's functions in society, which I will return to later in this thesis in my discussion of potential disharmonies in HE.

In this thesis (and in the ideas underlying Papers 2 and 3), I conceptualise science communication and engagement with society in academic scholarship as a continuum, ranging from the ivory tower via the public intellectual to scholarship of engagement (see Figure 4). By the ivory tower, I mean a scholarship that does not include engagement with society, and where the researcher never engages with the public but focuses on scientific publication. At this end of the continuum, there is no *scholarship of application and engagement*. Instead, the focus is on the other dimensions of scholarship, and perhaps in particular on the *scholarship of*

discovery. By the public intellectual (Said, 1994), I mean a scholarship that includes engagement with society in the form of monologue or dialogue, but where the focus is on dissemination and transmission of knowledge to society rather than a mutual exchange that both parties—for example the public and the researcher—benefit from. By scholarship of engagement, I mean a scholarship that does entail a mutual exchange of some sort (similar to Barker, 2004). This could for example be to engage citizens in doing science or in deciding what research to do. Both scholarship of engagement and to some extent the public intellectual role entail a dialogue, which is important to provide ideas, stimuli, and new interpretations from actors outside academia, moving science and its applications forward (Bucchi, 1996). Note that my model is a continuum rather than a scale with discreet steps and is mainly intended to enable discussion (in contrast to classify science communication into well-defined categories).

Figure 4.
Visualisation of engagement with society as a continuum, relating science communication to theories of scholarship.



This conceptualisation resembles Gaffikin and Morrisey's (2008) description of university engagement models, with several steps ranging from the ivory tower model to the engaged model. Although I agree with Barker (2004) that engagement, in the strict sense, requires some level of service or collaboration with various actors in society, my perspective underscores that engagement with society may occur in different ways, for example in debates, collaborations, reports of various kinds etc. Examples of what engagement with society can look like in practice can be found in Papers 2 and 3, as well as in Negretti et al. (2022) from the same project. As Renwick et al. (2020) pointed out, the key element of scholarship of engagement lies perhaps in its purpose, rather than its form. In my conceptualisation, *the scholarship of application and engagement* entails 'broadening and deepening connections with community outside the academic domain' (Renwick et al., 2020, p. 2), whatever form this may take.

4 Methodology

The aim of this chapter is to explain the methodological decisions made in this thesis. In the investigations of how the ambitions of Swedish HE regarding life-long learning and science communication are realised in practice, I have used several methodological approaches. All three papers included in this thesis are co-authored, and my role varied in regards to the methodological design, collection and analysis of data in the three studies. Paper 1 builds on data collected for my master's thesis, and presents an extension of the analysis of this data with a stronger theoretical underpinning as well as an updated contextualisation. In this paper, I collaboratively designed the intervention with my supervisors, and took the main role in the analysis and interpretation of the findings. I also wrote the paper as main author. Papers 2 and 3 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 amanuens (a form of research assistant), and then as main and co-author in two studies (Papers 2 and 3 in my thesis). In Paper 2, we collaboratively designed the intervention, and I took the main role in data collection and analysis, in addition to authoring the paper. In Paper 3, I was involved in the initial phase of the design, that overlapped with the analysis in Paper 2, but not in the continuation of the design or in the data collection. I contributed to the analysis and interpretation of the data.

Before diving into the details of the methods, 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 be considered mixed methods research and motivate why I have combined so many different methods.

4.1 Research philosophy

As an engineer, my focus is on solving problems: identifying a problem and trying to figure out possible ways to solve it. Though 'solving' a problem is often not as straightforward in 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, 2017; 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 (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 (Given, 2012). 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; Given, 2012). Broadly, pragmatism can be considered mainly an ontological construct (Given, 2012), 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 (Given, 2012). 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) (Given, 2012; 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 (Given, 2012), 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, make these rationales particularly important.

Based on the above description and my readings about different research paradigms, I believe that pragmatism has much to offer in its orientation towards real-world problems and informing practice (c.f. 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, it is often associated with pragmatism as both pragmatism and mixed methods emphasise choosing methods (and theories) that works for a particular research problem (Creswell & Plano Clark, 2011; Morgan, 2017).

I will elaborate on how I have mixed methods 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 (Greenbank, 2003). This influence is recognised, even central, within pragmatism (Given, 2012; Robson & McCartan, 2016) I am therefore transparent about the fact that a pragmatist approach chimes well with my engineering, problem solving-focused background, and I recognise that my background has undoubtedly affected my methodological choices.

4.2 Mixed methods research

There are various definitions of mixed methods research. As summarised by Creswell and Plano Clark (2011), some definitions focus on methods and quantitative/qualitative research while other 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 three studies, Papers 1 and 2, the research problem warranted the directed use of use of several methods and/or collection of several types of data. 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 the six characteristics described by Creswell and Plano Clark (2011). I will briefly describe the design of studies 1 and 2 below to justify this statement.

Paper 1 used the questionnaire variant of convergent design (Creswell & Plano Clark, 2018) where quantitative and qualitative data was collected simultaneously through a questionnaire with open and closed questions. In a convergent design, quantitative and qualitative data is

collected during the same time period and not sequentially one after the other (Creswell & Plano Clark, 2018). This design was chosen based on the method used in a previous study (Karpicke et al., 2009) that served as inspiration for study 1 and for the following reasons: the need for a relatively high number of participants to enable statistical comparison between different groups; the need for a deeper understanding than could be provided by a purely quantitative method; and what was possible with the available resources.

Similar to Paper 1, Paper 2 used a convergent design. Quantitative and qualitative data were obtained from a database on publications and additional qualitative data in the form of full texts of articles was then added from other sources. The convergent design in study 2 was 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 meta-data file, and finding and downloading the full texts. In both studies, the data was analysed both quantitatively, after inductive coding of the 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 2, 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 studies 1 and 2 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 contrast, Study 3 was a qualitative narrative inquiry study. It does not fulfil the six core characteristics since we used only one qualitative method: interviews (not fulfilling characteristic number 1). Note however that studies 2 and 3 were part of a larger research project. This larger study overall fulfils the criteria of mixed methods (see characteristic number 4) and follows an explanatory design. An explanatory design typically entails a first quantitative phase followed by a qualitative phase aiming to explain the findings from the quantitative phase (Creswell & Plano Clark, 2011). In my research, study 2 served a mapping purpose and study 3 elaborated on the findings from study 2 and aimed to provide an understanding of what lay behind them through episodic/narrative interviews.

4.3 Methods

My methodological choices have been guided by the research problem at hand, as explained in the previous sections of chapter 4. These choices resulted not only in a mixed methods approach, but also in the use of different methods in the different papers, as summarised in Table 2 (see next page), where I provide an overview of the three articles from a methodological perspective.

In the following sub-sections, I will present the methods used in the three papers and why we found them suitable to address the research problems.

4.3.1 Paper 1: Questionnaire

In Paper 1, we collected data through a questionnaire. Paper 1 was a replication and expansion of a study by Karpicke et al. (2009) that also used a questionnaire, and the methodological choices were closely tied to this study to achieve comparability. As mentioned in the mixed methods section (section 4.2), we needed a relatively high number of participants to enable

Table 2.
An overview of the methodology of the three papers included in this thesis

Paper	1. Metacognitive illusion or self-regulated learning	2. Science communication	3. Self-regulation and science communication
Purpose of approach	Assess how students study outside of class and why to see if they base their choices on metacognitive illusions or effective self-regulation and if they need further scaffolding	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
Methods	Questionnaire • 2 open questions • 1 closed question • Opportunity to comment	• Analysis of metadata for publications • Content analysis • Aspects of genre analysis • Network analysis	• Narrative/episodic interviews • Sampling based on findings from Paper 2
Objects of enquiry	416 engineering students, from two different programs (bioengineer and civil engineering) and two different types of courses (calculation courses and conceptual courses)	506 publications • Meta data • Full texts	7 researchers experienced in writing science communication genres
Data source	Questionnaire handed out to 418 students in person	• Metadata from a publication repository • Full texts available online	One interview with each participant, specific questions targeting MSK and SR

statistical comparison between different groups, but needed a deeper understanding of the reasons behind students' choice of strategies than could be provided by a purely quantitative method. Thus, we decided to design a new questionnaire inspired by Karpicke and colleagues (2009) and include both closed and open questions.

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. In Paper 1, we minimised this time by using a pre-existing questionnaire by Karpicke and colleagues (2009) and adapting it to the context, as advised by (Iwaniec, 2019), adding to the reliability of our study. However, one part of Karpicke and colleagues' (2009) questionnaire generated ambiguous answers, which we tried to avoid in study 1 by testing our questionnaire with a focus group, a test which also ensured reliability and validity of the questionnaire. To then ensure an acceptable response rate (Iwaniec, 2019), we conducted the survey with pen and paper on occasions (lectures or laboratory sessions) where most of the students were present. This approach rendered a very high response rate (64.4 percent of the students registered in the included courses; see Paper 1 for more details).

Another challenge in using questionnaires is that self-report data cannot be seen as entirely objective, 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 1, we tried to limit the effects of these issues by conducting the study in close connection to the participants' courses. Moreover, we were trying to capture students' perspectives on learning strategies and their own motivations for using their strategies, both of which are not objective in themselves (c.f. Iwaniec, 2019). Details about the specific questions in our questionnaire can be found in Paper 1.

Responses to closed 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 1, the responses to the closed question were analysed with descriptive statistics while the responses to the open-ended questions were analysed both qualitatively and quantitatively, after having been coded using inductive thematic analysis (see section 4.3). After being coded, the students' learning strategies and motivations were analysed using descriptive statistics. The strategies were also compared across programs and types of courses. Based on the type of data, we used a chi-square test (Devore, 2011) to analyse whether there were any significant differences between programs and types of courses and Cramér's V as a measure of the strength of the association (McHugh, 2018).

4.3.2 Paper 2: Qualitative content analysis and genre analysis

In Paper 2, 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 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.

Qualitative content analysis (Cho & Lee, 2014; Schreier, 2012) aims to describe the meaning of the material in a systematic—rather than identifying relationships between materials or build theory, as in grounded theory—and was therefore used to identify the main topics in the publications in Paper 2. Similar to in study 1 (see section 4.3.1 and 4.3.4), I used an inductive approach where the topics were derived progressively from the data 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.

Similar to qualitative content analysis, genre analysis is an inductive process. Following Miller (1984), in Paper 2, I took three requisites of genre into account in the analysis of the texts, considering their: 1) systematic similarities in content and form, 2) fulfilling of socially recognised purposes and situations, and 3) function as social action rather than as created to fulfil requirements stated in policy.

In Paper 2, we also used network analysis to explore the co-authoring patterns in our data set. This analysis was mainly conducted by one of my co-authors, which is why I will not go into details about it here. In short it is a method from bibliometrics used to study authoring patterns

in research fields (Schreier, 2012). This method can for example reveal who the key authors in a field are, which different groups there are (and what they are writing about), if there are authors who link different groups together, etc. See Paper 2 for further details.

4.3.3 Paper 3: Interviews

In Paper 3, we used interviews to capture researchers' metacognitive strategy knowledge (MSK) and self-regulation (SR) in relation to writing science communication. It was thus not a mixed methods study, in contrast to the other papers.

The interviews used in Paper 3 are best described as episodic narrative interviews, meaning interviews that focus on the narratives of episodes and involves some prompting in relation to the episode (Flick, 2000; Mueller, 2019). In our case, the interviews also involved some prompting in relation to the theoretical concepts. 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 2 and 3. 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 2. (Note that some of the participants in Paper 3 were also included in the dataset in Paper 2.) 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 were carefully 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).

4.3.4. Data analysis for Papers 1 and 3: Thematic analysis

Thematic analysis can be described as 'a method for identifying, analysing, and reporting patterns (themes) within data' (Braun & Clarke, 2006, p. 79). 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 1, we used inductive thematic analysis to find patterns within our data. Thereafter, the themes were analysed using the respective theoretical framework of the study. In Paper 3 on the other hand, we used both an inductive and deductive approach.

In Paper 1, the qualitative responses were coded using inductive thematic analysis. Starting from the students' responses, we successively created codes for the themes we found for each of the open-ended questions, following the six steps described by Braun and Clarke (2006). In addition, intercoder reliability (Lombard et al., 2017) between myself and the other author who participated in the coding process was calculated to ensure consistency. The results were then compared to the theoretical framework of self-regulated learning (Pintrich, 2000; Zimmerman, 2002).

In Paper 3, 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). While Paper 1 and 2 used an inductive approach, the approach in Paper 3 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 for inductive thematic analysis (Braun & Clarke, 2006), similar to some parts of the analyses in Papers 1 and 2. Note that in Papers 1 and 2, we quantified the data as a part of the analysis, while we in Paper 3 were interested only in the qualitative aspects of our data and what that could tell us in relation to our research questions.

4.4 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 (The Swedish Research Council, 2021): reliability in terms of quality; honesty in all parts of the research process; respect for participants, society, colleagues, etc; and accountability throughout the research process and for consequences relating to the project.

In terms of quality, the three studies presented in the three papers are all carefully designed to answer their research questions or as in paper 2, which has no explicit research questions, fulfil their aim. The studies were designed to address the questions 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 study 1 and 3, the questionnaires and the interview protocol 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 three studies have been presented at various conferences, and Paper 1 is published in a high-ranking journal, meaning that the studies have been scrutinised by peer reviewers.

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. 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 three studies. In study 1, data that could identify participants were never collected. In study 2 and 3, the participants' identities were known to us during the studies, but anonymised in the papers. Importantly, I had no prior connection involving power relations (for example through teaching) to the participants in the studies. In all three 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 Paper 2 and 3 are a part of was also funded by a specific initiative at Chalmers University of Technology and therefore had to report back to the organisation of this initiative, adding to the accountability of study 2 and 3. Regarding accountability for wider impacts of the research, one goal of the research presented in this thesis is indeed to have wider impacts. 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.

5 Summary of appended papers

In this chapter, I summarise the three papers appended to this thesis, focusing on the results of each paper (section 5.1-5.3). Thereafter, I in section 5.4 provide a short summary of the contribution and take away of the three papers relation to the overarching aim of my thesis.

5.1 Paper 1

Metacognitive illusion or self-regulated learning? Assessing engineering students' learning strategies against the backdrop of recent advances in cognitive science

In this paper, we investigated how university students, and specifically engineering students, manage their own learning. It was inspired by a previous study by Karpicke et al. (2009), where students were found to not be aware of the effectiveness of some learning strategies. However, the previous study focused on only two strategies—testing and rereading—and was conducted in a laboratory setting. We replicated Karpicke et al.'s (2009) study in an authentic HE setting, in connection to students' real courses, and expanded it to include seven strategies for which the effectiveness from a cognitive perspective is comparatively well studied (Dunlosky et al., 2013).

Our study addressed the following research questions:

- What learning strategies do engineering students report for studying outside the classroom?
- How do the learning strategies that students apply outside the classroom differ between engineering programs and types of courses?
- How aware are students of the effectiveness of their learning strategies?
- Why do students use their specific learning strategies?

In the analysis, we found that our participants took both cognitive effectiveness and other factors into account when deciding how to study in their courses. Therefore, we used Pintrich's (2000) model of self-regulated learning (SRL) as our theoretical lens. This model allowed us to paint a picture of students' attempts to self-regulate cognition, motivation/affect, behaviour, and context.

Data was collected through a questionnaire designed specifically for this study, where students were asked: 1) which strategies they used in a specific course; 2) why they used these strategies; and 3) how effectiveness they thought some of the strategies they used in a specific course were. The 416 participants were students from four courses of two types and mainly two different engineering programs (see Table 3) at a technological university in Sweden. The two types of courses were: conceptual courses, where students learn facts and reason based upon those; and calculation courses, where the focus is on doing calculations rather than learning facts.

Table 3.
Overview of the courses and programs included in Paper 1

Program	Bioengineering	Civil engineering
Conceptual course	Molecular biology course (second year students)	Environmental course (second year students)
Calculation course	Mathematical course (first year students)	Mathematical course (first year students)

The findings revealed that students use a wide range of learning strategies, though to *study old exams*, *read course materials/notes*, *do practice problems*, and *summarise* were by far the most used strategies. Which strategies students used did not differ across programs but differed

significantly across courses, where it was, for example, more common to do practice problems in the mathematical courses and to summarise in the conceptual courses. Interestingly, the findings also showed that students use strategies for many different reasons, relating to all areas of Pintrich's (2000) model of SRL. From a purely cognitive perspective, students did use seemingly ineffective strategies. However, we could conclude that when taking all four areas into account, the students were in general aware of the effectiveness of their strategies. This was also confirmed in the findings from the third question in the questionnaire, where student evaluation of strategies had clear resemblances to the evaluation in Dunlosky et al.'s (2013) metareview. The use of seemingly ineffective strategies could often be explained by the fact that students attempted to regulate not only their cognition but also their motivation, behaviour, and context, in their authentic learning context. Thus, the findings confirmed that while students seem to be more aware than Karpicke et al.'s (2009) findings suggest, there is indeed a need for explicit guidance to promote student SRL skills.

Paper 1 adds to the understanding of students' abilities to reflect upon and regulate their own learning, in an authentic setting. Such understanding can be used to design interventions and policy to promote students' development of SRL skills, and in the long run increase students' preparedness for facing the complex challenges of today's everchanging society.

5.2 Paper 2

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

In Paper 2, 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 2.3 in the previous research chapter, science communication has, received increasing recognition as an important role of the HE 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 4, 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 higher number of publications in our dataset.

However, this overrepresentation could largely be explained by 15 researchers who had written comparatively many texts each. Notably, 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 they want to optimise their chances of tenure and promotion (e.g., Bohlin & Bergman, 2019; Schimanski & Alperin, 2018), and was 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 2 provides one piece of the puzzle of how science communication fits into the role of HE 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 for our research, what science communication is happening at their department, and in the 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 the support. Both practice and research need a concrete starting point, a map of where we are to know what to do next. In Paper 2, we contributed to this starting point.

5.3 Paper 3

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

In Paper 3, 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 about 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 3 addressed the following research questions:

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

In our analysis, we used we used MSK (Karlen, 2016) and SR (Zimmerman & Moylan, 2009) as our theoretical lenses (see chapter 3 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 (c.f. Zimmerman & Moylan, 2009).

The data in this paper came from an ethnographic interview study on science communication, and the data presented in Paper 3 is a cross-section of narrative interview data (Barkhuizen, 2015), as described in chapter 4. 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, which is originally from Paper 3.

Table 4.
MSK in science communication writing according to SR phases

SR Phase	Strategies (themes) from out data
Forethought	Task analysis (conceptualization) • Think about the argument and the story your 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 Planning and goal setting • Convey scientific knowledge and a clear message • Set content-related and rhetorically related goals • Planning: Deciding on the message (discussion w 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 Self-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

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 to think about the readers' expectations, calibrating stylistic and linguistic choices to audience, and consider 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).

With Paper 3, 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 to develop 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).

5.4 Key take aways from the three studies in relation to HE's ambitions and practice

As a reminder, the overarching aim of my thesis is to explore how the ambitions of Swedish HE are realised in terms of students' acquisition of learning skills (specifically focusing on self-regulated learning) and researchers' engagement in science communication, and if there seems to be a disharmony between ambitions and practice as well as between individual researchers' multiple roles. I will here briefly summarise important take aways from the three papers and how they relate to the aim of my thesis.

- Students' SRL and choice of learning strategies are not only based on cognitive effectiveness of certain strategies but also on other factors relating to motivation/affect, behaviour, and context, as shown in Paper 1. This is important to acknowledge in both research evaluating students learning and in scaffolding learning skills.
- While the students in Paper 1 seemed to be relatively aware of the effectiveness of different learning strategies and attempt to self-regulate their learning, there was still room for improvement, as illustrated by this quote from one of our participants:

  > 'I would like to get suggestions on learning strategies from the teachers, for every course.'

  This suggests that more scaffolding is needed to realise ambitions regarding learning skills.
- A few researchers engage comparatively to a large extent in science communication while a majority do not, as found in Paper 2. Most of those who engage are senior and tenured. In other words, only some researchers realise policy ambitions regarding science communication.
- Even researchers who engage comparatively to a large extent in science communication often lack formal training—as found in Paper 3—and base their writing strategies on experience, knowledge of the task, and individual preferences. Presumably, this suggests that more scaffolding is needed to encourage more researchers to realise ambitions regarding science communication.
- Metacognitive strategy knowledge and self-regulation are important in science communication writing, as suggested in Paper 3. Metacognitive strategy training could potentially be beneficial to develop expertise in this type of writing—and consequently in promoting the realisation of ambition regarding science communication.
- Mixing methods—like we did in Paper 2 and in the project from which Papers 2 and 3 stem—is one way of better capturing the complexity of science communication practices and thereby clarify to what extent ambitions regarding science communication are realised in practice.

The three papers can also provide starting points to discuss the scaffolding of SRL and science communication respectively as well as whose responsibility it is to make sure that ambitions regarding these tasks/skills are realised in practice.

In the following chapter, I will further discuss the above take aways and what my three papers taken together with previous research suggest about disharmonies in HE and academic scholarship in relation to integration of life-long learning skills and science communication.

6. Discussion

In this chapter, I will bring together the different parts of my licentiate, contextualise these within the research field, and thereby demonstrate my contribution to knowledge. First, I will shortly reiterate the background and aim of my thesis: HE today is a complex system of goals and expectations that has many functions in society, which can cause disharmony between those functions (Trowler et al., 2005). It is however not entirely clear what HE's functions should entail and how they should be played out (Tomlinson, 2018). Similarly, institutions, departments, and individual researchers' role, or roles, are multifaceted and ever-evolving, and researchers are frequently expected to take on new tasks and acquire new skills as a consequence of ambitions in policy.

In this thesis, I explore how the ambitions of Swedish HE are realised in terms of students' acquisition of learning skills (specifically focusing on self-regulated learning) and researchers' engagement in science communication, and if there seems to be a disharmony between ambitions and practice as well as between individual researchers' multiple roles. My aim translates into the following research questions:

1. How are the ambitions of Swedish HE realised in terms of students' acquisition of learning skills (specifically self-regulated learning)?
2. How are the ambitions of Swedish HE realised in terms of researchers' engagement in science communication?
3. In relation to both questions 1 and 2, is there a disharmony between the ambitions of Swedish HE and the multiple roles researchers take on in their everyday practice?

In this chapter, I will discuss each of the above research questions and then discuss limitations and directions for future research.

6.1 Life-long learning skills

First, let me provide a brief recap of previous research on life-long learning skills. Both previous research and Swedish policy point out that HE students should acquire the ability to keep on learning independently after graduation (Bjork et al., 2013; Hadgraft & Kolmos, 2020; SFS 1977:218; SFS 2021:317). Furthermore, the acquisition of adequate learning skills is especially important for STEM students, since the challenges they face in their professional life will inevitably evolve alongside the rapid societal and technological development (Hadgraft & Kolmos, 2020; McDowell, 2019; Wallin & Adawi, 2018; Zheng et al., 2020). To keep on learning after graduation, students need to learn to self-regulate their own learning, which includes planning, monitoring, and evaluating their learning (Zimmerman, 2002) and choosing appropriate and effective learning strategies (Dunlosky et al., 2013) based on cognitive factors as well as their motivation, behaviour and context (Pintrich, 2000). While research in naturalistic settings has increased, there is still a need for more research on HE students' learning and self-regulation of learning (SRL) in naturalistic settings—especially in STEM—and for such research to take not only cognition but also motivation, behaviour, and context into account (Dunlosky & Rawson, 2019; Vermetten et al., 1999; Vermunt, 2005; Winne, 2010).

Paper 1 provides an increased understanding of students' choice of learning strategies and self-regulation of their learning. Importantly, we considered not only cognition, but also motivation/affect, behaviour, and context (c.f. Pintrich's 2000 model of SRL), to account for factors that can influence students' choices and SRL in a naturalistic setting. Our findings suggest that students may be more aware of the effectiveness of different learning strategies and better at regulating their learning than suggested by previous research with a cognitive focus (Bjork et al., 2013; Dunlosky et al., 2013; Karpicke et al., 2009). For example, some students explained how they sometimes lost focus and started chatting about other things when

they studied in a group, but at least they were studying some of the time, which they might not have done on their own. These students had seemingly evaluated the overall effectiveness and decided that while possibly less cognitively effective (in terms of material they could learn per time unit), study in a group was so much more effective in terms of motivation and behaviour that it was an overall more effective option than studying alone. Another example speaking in favour of students' awareness is that we found a significant difference in what strategies students used across the two types of courses, which shows that students adapted their learning to the specific context of the course they were taking. Overall, these findings underscore the importance of conducting research on learning strategies and SRL in naturalistic settings and trying to account for HE students' complex context and factors that might affect their study choices (Dunlosky & Rawson, 2019; Vermetten et al., 1999; Vermunt, 2005; Winne, 2010). Research with a purely cognitive focus risks underestimating students SRL and concludes that they suffer from metacognitive illusions about effectiveness of learning strategies, while they are in fact just taking their whole reality, not just cognitive factors, into account in their study choices.

Paper 1 also provides insights into the specific context of engineering education, where students' study habits outside the classroom have received relatively little attention in previous research. Possibly, some of the differences compared to findings in previous research might be explained by the difference in context. While I cannot conclude if this is the case, it further highlights the importance of research in naturalistic settings. An understanding of students' study choices is perhaps especially important in STEM, given the increasingly complex challenges they will face in their professional life (Hadgraft & Kolmos, 2020; McDowell, 2019; Wallin & Adawi, 2018; Zheng et al., 2020). With Paper 1, we contribute with one piece of this puzzle.

Regarding to what extent ambitions are realised in practice, Paper 1 suggests that in this particular context—at a large Swedish STEM university—ambitions are partially realised, and students do to some extent acquire learning skills needed for life-long learning. However, our findings also suggest that students sometimes do suffer from metacognitive illusions of what constitutes effective learning. To give one example, some students deemed repetition and rereading to be very effective, which is not the case according to previous research (Dunlosky et al., 2013; Karpicke et al., 2009). Our findings suggest that to further realise ambitions regarding the integration of life-long skills into HE, students need scaffolding (c.f. Bjork et al., 2013), preferably scaffolding that takes the students' specific context—such as which type of course they are taking—into account, since this was an important factor in our participants learning choices (c.f. Winne, 2010).

6.1.1 Implications for practice

Although Paper 1 provided an overview of previous research on SRL, an additional overview of previous research on SRL training and the teachers' perspective was needed in order to derive a fully fledged implications section regarding training of SRL an. For this thesis, I therefore conducted a relatively extensive overview of literature—a scoping study (Arksey & O'Malley, 2005)—about training of SRL and why such training is not more common. I will here discuss a selection of important findings from this literature review, starting from the effectiveness of interventions before moving on to barriers to implement SRL in practice. With this additional overview of literature on training, I attempt to look beyond the common conclusion that scaffolding is needed and contribute to an understanding of what is needed to implement scaffolding in practice. Thereafter, I will discuss scaffolding of SRL in relation to the scholarship of teaching.

Generally, SRL interventions for HE students have a positive effect on students' performance and SRL skills—regardless of the exact design—(Jansen et al., 2019) in for example online learning (Edisherashvili et al., 2022), courses using a flipped classroom design (Pérez-Sanagustín et al., 2021; Zarouk et al., 2020), programming (Marquès Puig et al., 2022), other STEM courses (e.g.,Grohs et al., 2018; Ko & Hayes, 1994; Litzinger et al., 2010; Meyer et al., 2015), teacher education (Keller-Schneider, 2014; Kramarski & Kohen, 2017; Paz et al., 2011; Sáiz-Manzanares et al., 2022), and academic writing (Akhmedjanova & Moeyaert, 2022; Graham et al., 2018; Inan-Karagul & Seker, 2021; Teng & Zhang, 2020). Possibly, the positive effect is mediated by an increased use and/or improvement of SRL activities, use of more effective learning strategies, increased time on task, and increased task motivation (Jansen et al., 2019). It might seem encouraging that doing any SRL intervention seems to have a positive effect compared to no intervention, as concluded in a metareview by Jansen and colleagues (2019). However, the advice *do anything, it most often works!* provides very little guidance and no real pointers for HE teachers who would like to promote students' SRL but do not know how. This lack of practical guidelines is also one of the main issues with SRL research so far: while researchers agree that SRL interventions generally are needed and effective, considerably more attention is paid to the effectiveness of the interventions for students than to how the interventions can be implemented, especially on a larger scale, in a way that is both doable and practically sustainable for the teachers.

Indeed, there are several barriers to applying the research on SRL, and academics struggle to translate the pointers (and lack of pointers) from research into practice (MacMahon et al., 2022; Vrieling et al., 2018). According to MacMahon et al. (2022, p.4), six main barriers are:

- Lack of access to literature
- Ontological differences between educational researchers and teachers
- Lack of time to engage with the literature and to try out new practices
- Low self-efficacy, meaning teachers do not feel confident to translate the research into their practice
- Perceived relevance of the evidence for the teacher's own practice and a reluctancy to "buy-in" to the evidence
- Differences in the context between the research and the teacher's practice, leading to a perceived lack of relevance

In addition, HE teachers often lack training: they typically have a strong background within their discipline but limited pedagogical training. Thus, pushes towards integration of SRL skills need to be accompanied by incentives making sure teachers have adequate competence. It may for instance be difficult for teachers to find a balance between providing opportunities and scaffolding for SRL and on the other hand their instructional planning and the course content (Vrieling et al., 2018). In this balance act, HE teachers tend to prioritise the course content and provide limited to no SRL scaffolding (Moos & Ringdal, 2012). This disharmony within individual academics' teaching, within their scholarship of teaching, needs to be addressed in HE teachers' pedagogical training and in designing courses and programs for students.

To overcome the barriers described above, previous research has pointed to the importance of collaborations with knowledge brokers or with peers in a community of practice, to support understanding of the evidence and its implementation in practice (MacMahon et al., 2022). (Interestingly, this is similar to how students in Paper 1 sought the support of peers in their learning.) Such approaches to overcome barriers to the implementation of SRL require that it is supported by at least the local culture within a group or department, but preferably by institutions, to increase its legitimacy. Another approach is to identify what teachers need to implement SRL scaffolding in their teaching, as suggested by Vrieling and colleagues (2018).

Importantly, teachers first need to see the value of SRL and be willing to integrate it into their teaching, but also have the skills and knowledge to do so, as mentioned earlier. Second, students too need to see the value of SRL skills, for example being prepared to change their ideas of what effective learning is and be motivated to invest time and energy into improving their SRL skills. Third, the learning task needs to be designed to allow for and promote SRL and the context—in terms of culture, group size, evaluation systems, resources available—needs to be beneficial rather than impede the integration. Drawing on the findings in Paper 1, perhaps one approach to making scaffolding relevant for students is to properly address that SRL is not only about cognition, but also about motivation/affect, behaviour, and context, thus acknowledging that students' learning happens in a real-world context where many factors might affect their learning. Overall, training of those who should scaffold SRL skills is important to integrate SRL into HE, but the integration of SRL also has to be valued by teachers, students, and, importantly, by HE institutions.

To summarise: Paper 1 suggests, in line with previous research, that there is disharmony between ambitions and practice regarding life-long learning skills, and the overview of literature on SRL training suggest that this disharmony is mediated by a lack of training for HE teachers. In the following paragraphs, I will discuss how these conclusions relate to the scholarship of teaching.

In this thesis, I apply an adapted version of Boyer's (1990) model of academic scholarship to widen the perspective and discuss disharmonies between functions in HE and within individual academics' role. By applying this lens to the discussion about the realisation of ambitions regarding life-long learning, I contextualise the need for more scaffolding for students and more training on how to scaffold it for teachers. As I will explain below, such contextualisation is crucial to actually implement scaffolding of life-long learning skills, such as SRL, in practice.

Overall, there seems to be a gap between what research suggests should happen—SRL skills should be integrated into HE—and what is promoted and encouraged by the system as well as by the training and support provided to academics. As for other parts of HE teaching, implementation of SRL faces systemic barriers related to policy and management of HE, such as research being valued over teaching and a lack of incentives to improve teaching (MacMahon et al., 2022), as also described in sections 2.2 and 3.2. It is however unclear how the teaching of generic skills such as SRL is valued in HE. As briefly mentioned in section 2.2, generic skills are difficult to evaluate, and what cannot be easily measured is difficult to promote in a system based on managerialism and performativity (c.f. Deem & Brehony, 2005; Tomlinson, 2018). Thus, in addition to a disharmony within individuals' scholarship of teaching, there also seems to be a disharmony between ambitions regarding life-long learning skills and what is promoted in practice.

To minimise these disharmonies, scaffolding of SRL skills has to be seen as an important and legitimate part of teaching and be included in the scholarship of teaching. Tying back to Trigwell and colleagues' (2000) model of the scholarship of teaching, inclusion in the scholarship of teaching could mean that teachers engage with literature on SRL and related topics such as learning strategy use (the informed dimension in Trigwell et al.'s model); reflect upon teaching and learning in their discipline or specifically in their classroom in relation to SRL (the reflection dimension); include SRL in discussions among peers, for example in discussions about teaching in a program or department (the communication dimension); and finally that teachers conceptualise teaching in a way that includes their teaching and learning as well as the students' learning of both content and other skills such as SRL skills (the conception dimension).

Study 1 provides one possible way of enhancing reflection: to let students fill in the questionnaire designed for study 1 and use this as a basis for discussion. This could make the students reflect upon their learning, as we found in the pilot for the questionnaire, and make students learning process and skills more visible for the teacher—i.e., help teachers in conceptualising students learning in relation to their own teaching.

6.2 Science communication

First, let me provide a brief recap of previous research on science communication. Both previous research and Swedish policy point out that it is important to communicate research beyond academia and that researchers engage with society, i.e., engage in *science communication* (Bucchi, 1996; Davies, 2021; Entradas et al., 2020; Hetland et al., 2020; Kappel & Holmen, 2019; Renwick et al., 2020; SFS 1992:1434). Previous research has underscored that while policies may be well intended, there is a lack of incentives for academic scholars to engage in science communication in practice—both internationally (Pérez-Llantada, 2021; Schimanski & Alperin, 2018) and in Sweden (Bohlin & Bergman, 2019; Dryler et al., 2022)—and researchers thus tend to prioritise other tasks over science communication. In addition, researchers often lack training in science communication and perceive this as a barrier to engagement (Baram-Tsabari & Lewenstein, 2017; Bohlin & Bergman, 2019; Fähnrich et al., 2021).

Paper 2 contributes to the knowledge about researchers' science communication practices, providing insights regarding the extent to which researchers engage in science communication—i.e., to what extent the ambition that researchers should engage is realised. Overall, our results show a complex picture of what science communication is, including genres, purposes, and practices, in line with previous research (Davies, 2021; Kappel & Holmen, 2019). The publications belonged to many different genres, whereof some genres where 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 data set. 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 tradition of publishing in trade magazines within architecture, 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).

We also found that a few senior and tenured researchers had authored a majority of the registered science communication publications at the university. 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 (see section 3.3 in the theoretical framework; Said, 1994).

Indeed, the most active researchers in our dataset in Paper 2 could mainly be placed somewhere around the public intellectual in my continuum of engagement with society (Figure 5, which is identical to Figure 4 in section 3.3). This was further corroborated in study 3, 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. 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 2 and 3 should be placed further towards the scholarship of engagement of the continuum.

Figure 5.
Visualisation of engagement with society as a continuum, relating science communication to theories of scholarship. This figure is identical to Figure 4 in section 3.3.

Paper 2 provides an important indication of what type of science communication is being conducted and to which extent, which is interesting since science communication is difficult to measure and there is limited data available (Pinheiro et al., 2015; Schultz et al., 2020; Thelwall, 2021). 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 do engage in science communication—i.e., should it be part of every researcher's academic scholarship? Is science communication a mission for HE institutions overall, or is it a role of each individual researchers—or perhaps both?

While answering these questions should be the objective of future research, institutions, and policy makers, I will discuss barriers for engagement in science communication and how to overcome such barriers. As suggested in Papers 2 and 3—as well as in previous research—there is room for improvement in the support of researchers who wish to engage, including training (Baram-Tsabari & Lewenstein, 2017; Besley & Tanner, 2011; Bohlin & Bergman, 2019; Fähnrich et al., 2021), and providing sufficient incentives for researchers (Alperin et al., 2019; Bohlin & Bergman, 2019; Dryler et al., 2022; Llorente et al., 2019; Pérez-Llantada, 2021; Schimanski & Alperin, 2018), which I discuss below.

6.2.1 Implications for practice

In Paper 3, we investigated what characterises expert science communication writers' writing process, thereby providing input to training as well as what incentives might be effective to promote science communication. We compiled our findings into a list of strategies, 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., compared the communication within their scholarship of application and engagement with that within their scholarship of discovery. Overall, study 3 underscore the importance of metacognitive strategy knowledge (MSK) and SR in science communication writing. Consequently, study 3 suggests that metacognitive strategy training could potentially be beneficial to develop expertise in this 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).

The question is then how to train researchers 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 3, we added to the limited evidence about training effectiveness by taking a slightly different perspective than previous studies in identifying what expert science communication writing entails. In section 2.3 (previous research on engagement with society and science communication), 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. These lists are shown together with the list of strategies from Paper 3 in Table 5.

As can be seen in Table 5, 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 3 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 3 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 (c.f. Tardy et al., 2020). Similarly, Mercer-Mapstone and Kuchel's (2017) list of skills includes several aspects of adaption to audience and genre that implicitly points to using genre awareness in SR of science

Table 5:
The list of strategies in science communication writing from Paper 3 alongside Baram-Tsabari and Lewenstein's (2017) *list of learning goals for science communication and Mercer-Mapstone and Kuchel's* (2017) *list of key skills in effective science communication.*

Paper 3	**Baram-Tsabari and Lewenstein** (adapted from Baram-Tsabari & Lewenstein, 2017, p. 288)	**Mercer-Mapstone and Kuchel** (adapted from Mercer-Mapstone & Kuchel, 2017, p. 191)
Strategies in science communication writing according to SR phases	Learning goals for science communication training	Key skills in effective science communication
Forethought <u>Task analysis (conceptualization)</u> • Think about the argument and the story your 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 w 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 Self-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	• Affective goal: Experience excitement, interest, and motivation about science communication activities and develop attitudes supportive of effective science communication • Content goal: Generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science communication • Methods goal: Use science communication methods, including written, oral, and visual communication skills and tools, for fostering fruitful dialogues with diverse audiences • Reflective goal: Be able to reflect on science and science communication's role within society; on processes, concepts, and institutions of science communication; and on their own process of learning about and doing science communication • Participatory goal: Participate in scientific communication activities in authentic settings, create written, oral and visual science messages suitable for various non-technical audiences and engage in fruitful dialogues with those audiences • Identity goal: Think about her- or himself as a science communicator and develop an identity as someone who is able to contribute to science communication	• Audience: Identify and understand a suitable target audience • Language: Use language that is appropriate for your target audience • Purpose: Identify the purpose and intended outcome of the communication • Prior knowledge: Consider the levels of prior knowledge in the target audience • Content: Separate essential from non-essential factual content in a context that is relevant to the target audience • Mode: Use a suitable mode and platform to communicate with the target audience • Context: Consider the social, political, and cultural context of the scientific information • Style: Use/consider style elements appropriate for the mode of communication (such as humour, anecdotes, analogy, metaphors, rhetoric, images, body language, eye contact, and diagrams) • Theory: Understand the underlying theories leading to the development of science communication and why it is important • Engagement: Promote audience engagement with the science • Narrative: Use the tools of storytelling and narrative • Dialogue: Encourage a two-way dialogue with the audience

communication. Finally, in Paper 3, it was clear that analysing the task and its purpose is very important in science communication, which is also specifically highlighted in Mercer and Mapstone's list of skills. Overall, study 3 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.

In Paper 3, our participants seemed to have built their science communication confidence and expertise over time, and since they were senior researchers, they can be assumed to have the scientific authority that follows with 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/SRL (c.f. Pintrich, 2000)—despite a lack of incentives to do so (Bohlin & Bergman, 2019). In Paper 3, 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 intrinsically found it important. In section 6.2, 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 3 suggest that one way of promoting science communication and a scholarship of application and engagement 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.

Regarding disharmonies, my research taken together with previous research suggests that there is disharmony between policy and the existing incentives for researchers to include a scholarship of application and engagement. This disharmony within the system also creates a disharmony within individual researchers' scholarship—which might be what we see the result of in Paper 2 in terms of which researchers engage in science communication. Possibly, the disharmony partly lies in a conflict between HE's role in educating, informing, and engaging with society for a kind of greater good and the system's development towards managerialism and performativity (Deem & Brehony, 2005; Tomlinson, 2018), where activities that do not result in a clear outcome are not easily encouraged. The lack of training adds yet another dimension of disharmony for individual academics. In the following section, I will discuss possible ways of overcoming the disharmonies connected to science communication as well as to life-long learning.

6.3 Disharmony in HE

In this thesis, I aimed to explore how the ambitions of Swedish HE are realised in terms of students' acquisition of learning skills (specifically focusing on self-regulated learning) and researchers' engagement in science communication, and if there seems to be a disharmony between ambitions and practice as well as between individual researchers' multiple roles. To address these questions, I have included both my research and overviews of previous research relating to HE's mission and management; generic skills and self-regulated learning (SRL); and science communication. Overall, this research suggests that there is indeed disharmony, on multiple levels: within single dimensions of scholarship—such as in the scholarship of teaching; between the different dimensions of individual academics' scholarship—such as between the scholarship of discovery and the scholarship of application and engagement; and on a higher level between ambitions in policy and actual incentives and training.

To effectively integrate teaching of learning skills and engagement in science communication into HE, these functions have to be properly valued by the system, in incentives connected to

external motivating factors—such as in recruitment, promotion and tenure processes. The individual researcher may of course choose to prioritise these functions despite a lack of incentives, but it is, as described in previous chapters of this thesis, unrealistic to believe that researchers in general will do so. In today's HE system, with its managerialism and performativity (Deem & Brehony, 2005; Tomlinson, 2018), the integration needs to be evaluated properly, preferably quantitatively due to the quantitative preference of performativity, to be valued in practice. This suggests that policy should be accompanied by an evaluation system, where universities have to report how the integration is going on a somewhat regular basis. However, adding more evaluation to HE would further complicate the system and potentially add to what Trowler (2005) referred to as the different games institutions have to play and thus to the disharmony.

Another approach to properly value learning skills and science communication is to consider HE's functions in our society, and the value of HE today and in the future (Tomlinson, 2018). Do we value HE for future personal economic return, for example for students; for other personal/institutional advantages, perhaps in comparison to others; for societal benefits; or for some sort of mutual exchange and benefits, for example between institutions and society? In the marketized HE system, there is a tendency in policy to focus on values in terms of economic return and institutional accountability (i.e., getting value for the money) rather than societal, or even personal, benefits on a longer scale (Tomlinson, 2018). Note that both learning skills and science communication fall under the latter category. While marketisation, managerialism and performativity addressed challenges of yesterday's HE, they do not seem entirely compatible with some of the functions of today's HE—such as preparing students for solving large complex interdisciplinary problems and increasing interactions between researchers and the surrounding society.

Perhaps an additional cause of disharmony is that it seems unclear who has the responsibility to make sure ambitions regarding the integration of learning skills and science communication into HE are realised in practice. Is it the role of policymakers, institutions, or individual researchers? And who is responsible for the training that is required? Here I echo Jacobson's (2004) point that a focus on how individual researchers prioritise and on guidelines for promotion and tenure risk making the realisation of these ambitions 'into a matter of individual-level motivation rather than organizational-level commitment' (p. 248). Following this line of argumentation, I suggest that commitment must start with policy and decisions by HE managements that are not only anchored in ambitions regarding functions of HE but also in the realities of the researchers whose professional lives and scholarships are affected by the policies and decisions. Note that while this thesis underscores the importance of incentives from policy and from decisions made by HE managers, individual researchers can still choose to prioritise integration of SRL in their teaching and/or science communication in their scholarship—as our participants in Paper 3.

Institutions may commit to this cause and promote the teaching of learning skills and engagement in science communication in various ways. In Sweden, institutions can for example choose how and to what extent they value such things in recruitment processes (Dryler et al., 2022). Given that collaborations, encouragement from peers, and the local culture are important for both the implementation of SRL scaffolding (MacMahon et al., 2022; Vrieling et al., 2018; Winne, 2010) and science communication engagement (Benneworth et al., 2015; Entradas et al., 2020), institutions can contribute for example by creating opportunities for researchers to share and discuss experiences, collaborate in teaching or science communication, and create ways of lifting or awarding good examples. While HE is an international job market, and individual institutions thus have limited possibilities to affect what is valued in HE overall, initiatives at an institutional level have the advantage of being able to adapt the support and

incentives to the local context—whether it is the local context at a large Swedish university of technology or some other university.

Institutions could also provide training opportunities for researchers, since a lack of training is a barrier to both scaffolding SRL skills (MacMahon et al., 2022) and engaging in science communication (Bohlin & Bergman, 2019). Such training could include providing researchers with tools that might make these tasks easier for them. One tool to aid in SRL scaffolding could be the questionnaire used in Paper 1—or a further developed version of it. This could make researchers aware of what is effective learning and how students approach their learning, providing a good basis for scaffolding which could be further supported by additional material with brief information regarding effective learning and discussion questions. One tool to aid in science communication engagement could be the list of strategies in Paper 3, which could serve as inspiration for the writing process and as a starting point for discussion. Training should also acknowledge that the extent to which researcher's scaffold students learning skills and engage in science communication does not necessarily depend upon their motivation, but also to the extent they can afford to prioritise it in their academic scholarship.

6.4 Limitations and future research

There are of course limitations to this thesis. First, I want to underscore that the questions discussed in this thesis are broad, multi-faceted, and multi-disciplinary and that my examples only provide some pieces of a large and complex picture. I provide insights to the Swedish context and contextualise my research in relation to Swedish policy and other situated factors, specifically for learning skills and science communication. I also compare my findings with previous findings from Sweden and other countries and analyse them using well-established theories to provide a larger, though not complete, picture that is relevant also outside the Swedish STEM context. My findings together with previous research suggest that the disharmonies highlighted in this thesis—within single dimensions of academic scholarship, among dimensions of academic scholarship, between policy and incentives, and finally between ambitions and reality—are present across HE contexts. How the issues manifest themselves might vary, but regardless of the exact manifestation they need to be addressed to ensure that ambitions to integrate learning skills and science communication into HE are realised in practice. Future research could investigate the realisation of ambitions regarding life-long learning skills and science communication in other HE contexts. Currently, HE policy research is dominated by Anglo-Saxon perspectives, and it would be interesting and valuable with more research from other countries to see how for example different policies, incentives and local variations in academic culture might influence the realisation of policy.

To provide a larger picture, I have engaged in extensive reading of previous research—some of which is included in thesis and some of which did not make it to the final version of the thesis. My findings to a great extent agree with conclusions in previous research, and fit well into this picture, which strengthens my argumentation and conclusions. My reading of previous research was preceded by extensive literature searches, similar to scoping studies (Arksey & O'Malley, 2005). The searches regarding training of self-regulated learning and science communication were particularly extensive and fairly systematic. However, an even more systematic approach and an account of the method behind the literature reviews could have further strengthened my conclusions (c.f. Sutton et al., 2019).

In the three papers and in this thesis, I have focused on the emic perspective of students and researchers. To further address questions such as where the disharmonies lie, to which extent different stakeholders see them as disharmonies, and how to overcome disharmonies, future research could expand to other stakeholders such as HE managers and policymakers, as well as to more in depth examinations of policy documents. For example, how do policymakers

envision the realisation of policy on life-long learning skills and science communication, and what do university managements' do to realise policies?

Future research closer to practice could also conduct and evaluate the training interventions on life-long learning skills and science communication suggested in section 6.3. In addition, future research could attempt to design measurements for evaluation of science communication, learning skills, and other generic skills to make it easier to evaluate and promote these in today's HE.

Finally, a direction of research that I find particularly interesting is to explore researchers' communication of research to non-academic audiences in instances where the non-academic audience is a direct stakeholder, such as in collaborations with industry. Such studies could provide an interesting complement to Paper 3, where science communication was often driven by a wish to communicate rather than a requirement to do so. It could also provide important insights into research communication in industry, a context where for example many PhD students in STEM end up after earning their PhD (Boman et al., 2017), and how communication skills can be transferred across contexts—similar to how the participants in Paper 3 transferred writing strategies between science communication and scientific communication.

7. Conclusion and reflection

Trowler and colleagues (2005), who authored the quote in the introduction, pointed out how HE today is a complex system of goals and expectations, and that the different goals and expectations result in disharmony. Overall, my licentiate thesis paints a vivid picture of the complexity of HE in Sweden today in relation to the integration of new tasks and skills into teaching and into academic scholarship. In the research presented in this thesis, I have specifically explored the integration of learning skills and engagement in science communication in a Swedish HE STEM context. Disharmonies seems to be built in to both the system and individual researchers' academic scholarship. This thesis has also provided some concrete suggestions about how to take some steps towards less disharmony. However, decreasing the disharmony and promoting the integration of new tasks and skills—i.e., harmonising, or perhaps reharmonising, the academy—requires further rethinking and modernising of the HE system.

I started this licentiate thesis by briefly describing my background and why I do this research. My research interests originated in my experiences as an engineering student—where I saw a mismatch between students need to develop learning and communication skills and what I perceived as insufficient scaffolding of these skills—and a wish to improve engineering education in terms of support for students in learning to learn and communicate effectively. Over time, I realised that there are similar mismatches, or disharmonies, for other people in HE, for example for researchers as shown in my thesis. To resolve the mismatches for students, this thesis suggests that we first must address disharmonies for their teachers, i.e., researchers/academic scholars.

A lack of incentives and a lack of training recur as issues throughout the thesis. Looking ahead, I—as a problem-solving oriented engineer—wish to contribute to solving these issues. I have tried to identify where I could contribute the most, drawing on the realisations from my first three papers and this licentiate thesis as well as my interdisciplinary background. Consequently, my ongoing research addresses the lack of training of science communication by further investigating how researchers communicate scientific knowledge to audiences outside of academia, and identifying what should be included in training. As mentioned in the preface, I have chosen to focus on industrial PhD students. They have a unique position with one foot in academia and one foot in industry and have to learn to communicate to both researchers and people in industry. My preliminary findings suggest that there are challenges in balancing between academia and industry, but also that these PhD students can provide valuable insights into how communication of research differs between their two contexts, how communication skills can be transferred across these contexts, and what role self-regulation plays in this transfer. Hopefully, this knowledge can be used in training of future researchers and thereby contribute to reharmonising the academy.

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