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What's Wrong with Engineering Education?

Comparing and combining a teaching-problematization and a culture-problematization

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Abstract

While much has been said about what is wrong with engineering education, the assumptions we make when talking about its problems often remain hidden. One particularly common implicit assumption is that inadequate teaching is the primary antecedent of educational problems. Following such a problematization, efforts to improve engineering education have often centered on developing and spreading better teaching methods. In recent years, however, an alternative assumption has been proposed, locating problems in the culture of engineering education rather than in educational designs. In line with such a problematization, research and reform tasks are significantly broadened.

In this thesis, I interrogate these alternative problematizations and the research that draws on them. I present my own work in two parts, building on case studies and fieldwork. The first part comprises two papers focused on evaluating the pedagogical possibilities of teaching methods positioned as better preparing students for professional practice. The second part comprises three papers focused on how cultural processes facilitate and constrain educational outcomes.

Taken together, the findings illustrate how both teaching methods and cultural processes may serve as barriers to engineering learning, suggesting that researchers and educators alike may do well to combine a focus on teaching with a focus on culture when attending to educational problems. Furthermore, the findings also illustrate that although educational development usually involves making prioritizations between competing educational objectives, value-judgements risk being obscured in talk of educational problems. As such, educators and researchers alike need to develop an aptitude for values-clarification as they take on questions of educational development.

In light of these findings, I argue that there is dual value in adopting a vocabulary of cultural analysis when talking about what is wrong with engineering education. First, such a vocabulary may help to identify leverage points for educational development that otherwise may remain unexplored. Second, such a vocabulary may contribute to talk of educational development becoming more open to critical deliberation.

Keywords: engineering education research, engineering education, teaching methods, engineering culture, educational reform, discourse analysis, ethnography, higher education pedagogy, entrepreneurship education

Appended papers

The thesis is based on the following papers:

Paper 1 Hagvall Svensson, O., Adawi, T., Lundqvist, M., & Williams Middleton, K. (2020). Entrepreneurial engineering pedagogy: models, tradeoffs and discourses. *European Journal of Engineering Education*, *45*(5), 691-710.

I conceived the idea and design together with my co-authors. I carried out the data collection and analysis independently and I wrote the first draft of the paper.

Paper 2 Kohn Rådberg, K., Lundqvist, U., Malmqvist, J., & Hagvall Svensson, O. (2020). From CDIO to challenge-based learning experiences–expanding student learning as well as societal impact?. *European Journal of Engineering Education*, *45*(1), 22-37.

I contributed to theoretical framing and writing up the study.

Paper 3 Hagvall Svensson, O. What lies beneath distinctive difficulties in entrepreneurship education: Cognitive conflicts or cultural clashes?. *Undergoing revisions, to be submitted for second round of review in Academy of Management Learning and Education.*

I was the sole contributor in conceiving, carrying out and writing up the study.

Paper 4 Hagvall Svensson, O., Adawi, T., Johansson, A. Friends and/or professionals? Investigating the discursive formation of teamwork experiences in engineering education. *To be submitted to Journal of Engineering Education*.

I conceived the idea, designed the study together with TA, carried out the data collection independently. Theoretical framing, data analysis, and writing up the findings were done jointly with my co-authors.

Paper 5 Hagvall Svensson, O., Adawi, T., & Johansson, A. (2021). Authenticity work in higher education learning environments: A double-edged sword?. *Higher Education*. Published ahead of print.

I conceived the idea, designed the study, and carried out the data collection independently. Theoretical framing, data analysis, and writing up the findings were done jointly with my co-authors.

Other relevant papers

Hagvall Svensson, O., Lundqvist, M., & Williams Middleton, K. (2017). Transformative, Transactional and Transmissive Modes of Teaching in Action-based Entrepreneurial Education. In *Proceedings of the 5th ECSB Entrepreneurship Education (3E) Conference 2017, Cork, Ireland*. Nominated for best paper.

Hagvall Svensson, O. (2017). Conceptualizing Sustainability Leadership Competences in Higher Education. In *Proceedings of the 8th International Sustainability Transitions (IST) Conference 2017, Göteborg, Sweden.*

Hagvall Svensson, O., Adawi, T., Lundqvist, M., & Williams Middleton, K. (2017). How entrepreneurial are Project-based Courses in Engineering Education? In *Proceedings of the 45th European Society for Engineering Education (SEFI) Conference 2017, Azores, Portugal*

Sterner, E., Hagvall Svensson, O., Toivonen, S., Bill, J., & Adawi, T. (2017). Evaluating the flipped classroom approach in engineering education: Students' attitudes, engagement and performance in an undergraduate sustainability course. In *Proceedings of the 45th European Society for Engineering Education (SEFI) Conference 2017, Azores, Portugal*

Lackéus, M., Hagvall Svensson, O., Henricson Briggs, K., & Faxheden, T. (2017). Hur 'entreprenöriell' är Chalmers grundutbildning? In *Proceedings of the 6th Utvecklingskonferensen för Sveriges Ingenjörsutbildningar 2017, Göteborg, Sweden*

Hagvall Svensson, O., & Adawi, T. (2018). Investigating the Dynamics of Authentic Learning in a Project-based Engineering Course. In *Proceedings of the 46th European Society for Engineering Education (SEFI) Conference 2018, Copenhagen, Denmark*. Awarded best research paper.

Hagvall Svensson, O. (2018). Exploring Students' Transition into Experiential Entrepreneurship Education: Challenges and Learning. In *Proceedings of the 6th ECSB Entrepreneurship Education (3E) Conference 2018, Enschede, the Netherlands*.

Burden, H., Steghöfer, J.P., & Hagvall Svensson, O. (2019). Facilitating Entrepreneurial Experiences through a Software Engineering Project Course. In *Proceedings of the 41st International Conference on Software Engineering 2019, Montréal, Canada*

Hagvall Svensson, O. (2019). Struggling for Authenticity: A Dialectic Framework for Sense-Making Entrepreneurial Experiences. In *Proceedings of the 7th ECSB Entrepreneurship Education (3E) Conference 2019, Göteborg, Sweden*.

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Oskar Hagvall Svensson, Göteborg, 14 November 2021

1. Introduction

This thesis is concerned with engineering education practice and its development. Specifically, what is put in focus is research that directly engages with how engineering education can be improved, that is, research putting forth certain educational problems that needs to be attended to, or proposing certain educational changes believed to be beneficial.

While the development of engineering education is a concern for virtually any and all engineering education research, it is a particularly pronounced interest in certain research programs and certain strands of research. A general example is research on engineering education reform, a continual topic of debate for university leadership and educational scholars alike (Seely 2005, Henderson, Beach, and Finkelstein 2011, Besterfield-Sacre et al. 2014, Edström 2018). There are also several prominent strands of research addressing *specific* educational problems. This includes, for instance, 1) how engineering students may be better prepared for professional practice (Darling and Dannels 2003, Martin et al. 2005, Lucena 2006, Baytiyeh and Naja 2012, Passow 2012, Itani and Srour 2016), and 2) how educators can attend to unequal treatment of students from demographic groups that are underrepresented in engineering education (Tonso 1996, Brown, Morning, and Watkins 2005, Tonso 2006, Beddoes and Pawley 2014, Blair et al. 2017, Beddoes and Panther 2018, Hughes 2018). These issues have proven persistent and difficult to change. Accordingly, they have inspired research and reform initiatives ever since engineering education and engineering education research became institutionalized.

Although much has been said about these issues, the assumptions made in discussions of educational development have rarely been investigated. In this thesis, I focus on a particularly common assumption: When engineering education researchers want to account for educational problems, they usually refer to inadequate teaching methods as a primary antecedent. That is, the role of teaching methods is usually foregrounded when writing about how educational problems come about and are perpetuated. Similarly, developing and spreading new teaching methods is often proposed as an important solution to educational problems (Henderson, Beach, and Finkelstein 2011, Borrego and Henderson 2014). This may be juxtaposed with an alternative assumption that has gained traction in recent years, namely, that problematic cultural patterns and processes within engineering education instead constitute the primary antecedent

to educational problems[1]. In line with this assumption, engineering education researchers have recently started to explore cultural change as an avenue for educational development (Godfrey and Parker 2010).

I discuss these two ways of conceptualizing and approaching educational problems as two "styles of problematization" (Bacchi 2009) that are often drawn upon, implicitly, in engineering education research. In interrogating problematizations, I wish to communicate that there is a need for critical reflection upon the implicit assumptions that we – that is, engineering education researchers – communicate to others when we talk about what is wrong with engineering education. I believe there is a need for such reflection seeing as one style of problematization, focused on teaching methods, has traditionally dominated the research field (Stolk, Somerville, and Chachra 2008, Rodriguez-Mejia et al. 2020, Strubbe et al. 2020). If this dominance is maintained, we risk communicating to others that creating and spreading better teaching methods is the only way to approach educational development, even though this has not proven to be a particularly effective change strategy (Henderson, Beach, and Finkelstein 2011). Furthermore, we risk not providing proper guidance to teachers and educational developers on how they can navigate and interrogate the value-judgement inextricably involved in attending to educational problems, seeing as a teaching methods-oriented vocabulary takes desirable educational outcomes as a given (Biesta 2007).

Throughout the thesis, I aim to characterize, compare, and critically scrutinize these two styles of problematization, including their empirical grounding and their relative strengths and weaknesses. Furthermore, I aim to describe how a focus on teaching methods and a focus on cultural processes may be combined, in order to better inform educational development. Importantly, my aim here is not to prove what the "actual" root causes of problems in engineering education are. Rather, I aim to compare different ways of thinking and talking about engineering education practice, different ways of accounting for its problems, and – specifically – different ways of doing practically relevant engineering education research. While the two styles of problematization I put forth do not cover every way in which educational problems can be conceptualized and

[1] While I will return to the meaning of the term "culture" in this context, it may be briefly noted here that I do not primarily use it in reference to national or ethnic cultures. Rather, I view culture as a rather flexible analytical term, and I use it to discuss patterns of social interaction and ways of thinking that are *shared*, for instance in a certain community of engineers/engineering students, or in a certain engineering education institution/a specific engineering classroom.

approached, their fundamentally different theoretical underpinnings and methodological implications make them fruitful sparring partners for a discussion of how engineering education research has informed – and how it *may* inform – engineering education practice.

I approach the task of comparing these two styles of problematizations by reviewing previous engineering education research and by sharing my own work focused on teaching methods as well as cultural patterns and processes. My discussion is grounded in five appended papers. Because I have adopted diverging theoretical starting points and have focused on somewhat different research questions in my early work and my later work, the aim of the papers and the aim of the thesis do not correspond one-to-one. The aim of my early work was to evaluate teaching methods that have been positioned as better preparing students for professional practice. The aim of my later work has been to investigate how contingent patterns of social interaction and shared ways of thinking – that is, cultural patterns and processes – facilitate and constrain learning. Finally, the aim of the thesis is to reflect on the two styles of problematization that I have drawn on and contributed to in my papers, recognizing that these styles of problematization are common in engineering education research more generally. Here, I use the appended papers in two ways. First, I use them as illustrations. In this regard, I present my early work as examples of research that draws on a teaching methods-oriented style of problematization and my later work as examples of research that draws primarily on a culture-oriented style of problematization. Second, I use findings and theoretical development from the papers to speak to the strengths and limitations of the two styles of problematization.

Because some of my work is underpinned by critical theory, and because I will in some ways engage in criticizing engineering education research, I want to make a brief note on the nature and purpose of critical research before outlining the structure of the thesis. Critical researchers are usually engaged in identifying and interrogating assumptions shared within a certain society or community, assumptions that legitimize certain social activities and orders. Foucault, for instance, argued that social critique "consists in seeing on what type of assumptions, of familiar notions, of established, unexamined ways of thinking the accepted practices are based" (1994, p. 456). The reason for engaging in critique is not primarily to evaluate these assumptions as true or false, not even necessarily to judge them as good or bad. Instead, the intention is to imagine possibilities that could come into fruition if other assumptions were made, and if other social practices were put into place. In my own case, the two social spheres

I will discuss in the thesis are engineering education practice and engineering education research. At a basic level, the assumptions I interrogate concern what we construct as the root cause of educational problems. However, as will become increasingly clear as the thesis unfolds, these assumptions are not normatively neutral, but connect to more general ideas about the nature and purpose of engineering education and of engineering education research. As such, through reimagining the way we think about problems in engineering education, my intention is – simultaneously – to foster broader reflections.

The thesis is structured as follows. In chapter 2, I position the thesis in relation to previous work and outline my theoretical framework. Here, I first briefly describe the field of engineering education research and some proposed educational problems researchers have concerned themselves with. I then introduce "problematizations" and "styles and problematization" as objects of inquiry and describe how they may be interrogated. In chapter 3, I characterize and compare the two styles of problematization with which the thesis is concerned. Having done so, I turn to describe and introduce my empirical work, in order to 1) illustrate how investigations into engineering education practice may be informed by the two styles of problematizations, and 2) provide an opportunity to test some of the assumptions built into the two styles of problematization. To this end, in chapter 4, I describe the methodologies I have drawn on in my empirical work. In chapter 5, I summarize the five appended papers, two focused on teaching methods and three focused on cultural patterns and processes. In chapter 7, I discuss my findings and theoretical developments taken together, drawing out implications for theory and practice. Finally, in chapter 8, I briefly conclude the thesis by reiterating my main points.

2. Previous work and theoretical framework

In this chapter, I position the thesis in relation to previous work and outline my theoretical framework. An important aim for this chapter is to distinguish between two levels of abstraction and associated terms that could potentially be used interchangeably in other contexts, namely, "problems" and "problematizations".

This chapter is organized in three main sections. First, I describe engineering education as a research field intimately connected to the development of engineering education practice. Second, I review two proposed educational problems in engineering education, that is, two states of affairs that are often described as problematic: 1) engineering graduates' preparedness for professional practice, and 2) inequality and disadvantageous treatment of students from underrepresented demographic groups. Third, I outline my theoretical framework. Here, I introduce research problematizations and styles of problematization as objects of inquiry and describe how these may be interrogated. Finally, I review how problematizations have been – rarely and selectively – interrogated in engineering education research.

2.1. Engineering education research

The five appended papers in this thesis are aimed towards three specialized fields of educational research: engineering education research (Jesiek, Newswander, and Borrego 2009, Borrego and Bernhard 2011), entrepreneurship education research (Fayolle, Verzat, and Wapshott 2016, Fellnhofer 2019), and – more generally – higher education research (Brennan and Teichler 2008, Daenekindt and Huisman 2020). However, in this comprehensive summary, I specifically foreground engineering education research and position the totality of my work within this field.

Before diving into the field of engineering education research, we may note that the three aforementioned fields of research share multiple characteristics[2]. First, they are all relatively "young" and institutionally unestablished fields of research, when compared to fields such as sociology, psychology, history, and the general field of educational research. Second, and more importantly, research in these fields is intimately connected to specific educational institutions and to

[2] Indeed, my reflections in the thesis are inspired by my reading into literature across the three fields, with emphasis on engineering education research and entrepreneurship education research.

a great many stakeholders who are interested in setting the agenda for educational practice and research. Naturally, a first influential group is the academics and other practitioners that are involved in teaching and educational management, seeing as education is a way to perpetuate the activities and interests of academic and professional communities. A second group of influential stakeholders is national and international policymakers, seeing as higher education is circumscribed by many broader societal and economic interests. Accordingly, research in all these three fields is "driven by policy and practical concerns, often of a rather immediate nature" (Brennan and Teichler 2008, p. 259).

In the case of engineering education research, while there is not a definitive history of how this field emerged, most accounts point to developments in the second half of the 20th century, when a scaling up of higher education and engineering education amplified the need to share experiences as well as to evaluate and innovate educational practices. In the European context, de Graaff (2016) describes how increased enrollment led to the establishment of centers tasked with educational research and development at many European universities in the 1960s and 70s. In the North American context, Jesiek, Newswander, and Borrego (2009) note that in the 1980s, "increasing worries about economic competitiveness and the decline of the Cold War stimulated new discussions about the state of the U.S. engineering education system" (p. 40). The authors go on to describe how the National Science Board in 1986 "called on the academic community to use its 'best scholarship' to strengthen science and engineering education" (ibid., p. 40). These developments were fundamental in securing funding and positions for research that attends specifically to improving the quantity and quality of engineering graduates. In the decades to follow, engineering education research developed from an "emerging" to an established and "globally interconnected" specialized field of education research (Borrego and Bernhard 2011)[3].

As the field of engineering education research has grown considerably in the last decades, the current state of the research field has gradually become more difficult to overview. Still, a number of attempts to characterize the field have been made, for instance in terms of research topics addressed. Wankat (2004)

[3] Some authors still emphasize regional differences between traditions in engineering education research, e.g. noting how the European tradition is more problem-led – emphasizing relevance for practice – and the North American tradition is more method-led – emphasizing rigorous research (Borrego and Bernhard 2011).

analyzed all articles published in Journal of Engineering Education between 1993 and 2002, finding “teaching”, “computers” and “design” to be the most prevalent topics for engineering education researchers to concern themselves with. Somewhat more recently, Jesiek et al. (2011) analyzed 2 173 journal articles and conference papers published between 2005 and 2008 and characterized the field in terms of 38 prevalent topics, the most prominent being “learning”, “assessment”, and “educational technology”. In a large scale effort to create a taxonomy of engineering education research, Finelli, Borrego, and Rasoulifar (2015) developed a list of keywords with which to identify research articles for their topics, practical motivations, and research approaches. Here, topics include for instance “teams”, “diversity” and “professional practice”. Practical motivations include for instance “recruitment and retention” and “[learning] outcomes”. Research approaches include for instance “qualitative analysis” and “quantitative analysis”.

2.2. Proposed problems in engineering education practice

Because engineering education research is usually expected to have at least some bearing on engineering education practice, a major part of the research literature engages directly with questions of how engineering education practice can or should be developed. Usually, this research takes its starting point in a proposed educational problem, motivating specific inquiries into engineering education practice with the aim of contributing new insights as to how the problems may be addressed. Below, I outline two such proposed educational problems, that is, two states of affairs that researchers have often put forth as being problematic: 1) the preparedness of engineering graduates for professional practice, and 2) inequality and disadvantageous treatment of engineering students from underrepresented demographic groups. Together, these two issues have served as starting points for a considerable part of the engineering education research literature (Borrego and Bernhard 2011), as well as for many engineering education reform initiatives (Froyd, Layne, and Watson 2006). Because I am interested in problematizations in engineering education research, I discuss these and similar issues as “proposed” educational problems rather than simply “problems”[4]. While the two styles of problematization that I will discuss in the

[4] In calling them “proposed” problems, rather than simply “problems” I do not mean to say that these states of affairs – in my view – are unproblematic. Rather, I call them “proposed” problems to signal that these states of affairs need to be underpinned by certain arguments – often taken for granted – in order to be viewed as problematic (e.g., that engineering education should prepare students for professional practice or that students should be given equal opportunity to learn).

thesis have been drawn on to account for a wider set of proposed educational problems than this, I will use the two following proposed problems as examples throughout the thesis.

2.2.1. Engineering graduates' preparedness for professional practice

Because engineering is a professional degree and because getting an engineering degree does not guarantee proficiency in the engineering profession, engineering education researchers have paid considerable attention to investigating how prepared engineering graduates are for taking on professional practice and how their preparedness may be improved. This concern has been approached from a number of perspectives and drawing on a number of different research methodologies.

A first set of studies has probed into the perspectives of engineering graduates themselves, asking them about the nature of their work, their own perceptions of how well-prepared they are as well as their experience of transitioning from higher education to work (Darling and Dannels 2003, Martin et al. 2005, Lucena 2006, Baytiyeh and Naja 2012, Passow 2012, Itani and Srour 2016). A second set of studies has asked managers and other industry representatives about how well-prepared newly graduated engineers are (Katz 1993, Lang et al. 1999, Ramadi, Ramadi, and Nasr 2016). A third set of studies has attempted to systematically diagnose engineering practice through observation of practicing engineers (Trevelyan 2007, 2010a, b). A fourth set of studies draws specifically on arguments as to how engineering work has changed, is changing and will change in the near future, drawing conclusion about what this means for how engineering education needs to change in order to keep up (Rugarcia et al. 2000, Bell 2010, Cheville and Bunting 2011, Jamison, Kolmos, and Holgaard 2014, Wankat and Bullard 2016). Finally, a fifth set of studies has reviewed different parts of the literature on graduate competences, preparedness, and employability (Grosemans, Coertjens, and Kyndt 2017, Passow and Passow 2017, Winberg et al. 2020)

While it is understandably difficult to paint a time-, context- and perspective-independent picture of how well-prepared or unprepared engineering graduates are for taking on their chosen profession, three conclusions may be drawn from surveying this work. First, there are many reports of graduates being inadequately prepared for professional practice, with studies usually finding at least some area in which engineering graduates struggle. Second, these reports often specifically center on engineering graduates' lack of collaborative and communicative competences (Katz 1993, Trevelyan 2007, 2010a, b, Ramadi, Ramadi, and Nasr 2016, Darling and Dannels 2003, Itani and Srour 2016),

including the ability to work with people from other disciplines (Martin et al. 2005, Van den Beemt et al. 2020). Third, professional preparedness has been and remains a central concern for engineering education researchers.

2.2.2. Inequality and disadvantageous treatment of underrepresented groups in engineering education

Inequality and disadvantageous treatment of students from underrepresented groups in engineering education is another proposed problem to which engineering educators and researchers have paid considerable attention. In terms of research, this concern has been approached from a number of perspectives and drawing on a number of research methodologies.

This research can be characterized for instance by the specific demographic groups with which it is concerned, including women (Tonso 1996, 2006, Beddoes and Pawley 2014, Blair et al. 2017, Beddoes and Panther 2018), ethnic minorities (Brown, Morning, and Watkins 2005, Samuelson and Litzler 2016, Revelo and Baber 2018), socio-economically disadvantaged students (Foor, Walden, and Trytten 2007, Bowen, Johnson, and Powell 2020), and LGBTQ students (Hughes 2017, Cech and Rothwell 2018, Hughes 2018). Among other things, this research has: 1) investigated graduation rates and persistence for students from specific demographic groups (Brown, Morning, and Watkins 2005, Hughes 2018), 2) investigated students' experiences and perceptions through large-scale surveys (Cech and Rothwell 2018), in-depth interviews (Foor, Walden, and Trytten 2007, Samuelson and Litzler 2016, Revelo and Baber 2018, Hughes 2017) and longitudinal observation (Tonso 1996, 2006), and 3) investigated how educators reason around inclusion and diversity in engineering and in their teaching (Beddoes 2011b, Beddoes and Panther 2018, Blair et al. 2017).

While it is, again, understandably difficult to paint a time-, context- and perspective-independent picture of inequality and disadvantageous treatment in engineering education, a few more clear-cut conclusions can be drawn from surveying this work. First, underrepresentation is still an issue after decades of efforts to recruit and retain a more diverse group of students (London, Lee, and Hawkins Ash 2021). In summarizing the situation with regard to gender representation, Mills, Ayre, and Gill (2011) write:

> Although the numbers of female students commencing undergraduate engineering studies have increased in most western countries during the past 25 years, they remain low. In addition, the indications are that these numbers have now reached a plateau or are actually in decline in countries such as Australia, Canada, the US and the UK (p. 4)

Second, students from underrepresented groups often meet prejudice from peers and teachers about their (in)ability to do engineering (Secules et al. 2018, Bloodhart et al. 2020), and disproportionally report having negative experiences of studying engineering (Cech and Rothwell 2018).

2.3. Problematizations as objects of inquiry

Most often, engineering education research is positioned as simply *addressing* educational problems such as the ones reviewed above, treating them as objects of inquiry existing externally to research endeavors and independently of value-judgements about what engineering education should be. Here, research that interrogates "problematizations" takes a different approach, geared towards locating what is taken for granted in discussions of educational problems and what the consequences of these assumptions are (Bacchi 2009).

2.3.1 Interrogating problematizations

Specifically, the focus of this thesis is to interrogate two "styles of problematization" (Bacchi 2009) often drawn on in engineering education research. In order to approach a definition of the term "problematization" in the way I use it, as a noun, we first need to pin down the verb "problematize". In line with Bacchi (2015), I view researchers as perpetually engaged in problematizing, that is, perpetually engaged in framing and shaping problems to be investigated and solved. Alternatively put, before any research can be pursued, the researcher needs to problematize a certain territory or issue, by employing a particular set of terms and theories and by constructing a particular set of relationships between different variables or dimensions. In engineering education research, the territory that is usually problematized is different aspects of engineering education practice[5]. I use the term "problematization" to refer to the outcomes of this problematizing, an object of inquiry that may be identified for instance in research articles. While "problematization" in this sense may be used to analyze the way in which a particular issue is conceptualized and approached in a particular research article, I use the term "styles of problematization", in line with Bacchi (2009), to refer to especially *pervasive* ways of problematizing engineering education practice[6]. As such, a "style of problematization" describes a pattern in how educational problems are thought about across research

[5] There are, of course, also engineering education researchers that engage in problematizing engineering education *research* rather than engineering education practice, just as I am doing in this comprehensive summary.

[6] Although I mostly use "problematization" with inspiration from Bacchi (2009, 2015), her usage of the term is – in turn – heavily inspired by Foucault, who used and developed the term in a number of different texts (see e.g. Foucault 1986).

investigations, referring for instance to terms, theories, and metaphors that are often drawn on and cause-effect relationships that are often constructed.

Interrogating problematizations and styles of problematization is a common activity in research that aims to facilitate reflection on 1) what states of affairs, people, institutions, practices and so on are considered problematic in a certain field of research or in a certain social setting, 2) how these states of affairs, people, institutions, or practices are constructed as being problematic, and 3) what solutions are implicitly implied or explicitly proposed through problematizing an issue in a particular way. In arguing for the value of interrogating problematizations, Bacchi (2009) emphasizes that "[r]ather than accepting the designation of some issue as a 'problem' or a 'social problem', we need to interrogate the kinds of 'problems' that are presumed to exist and how these are thought about" (p. xiii)[7].

Another common argument in studies of problematization is that the manner in which things are constructed as "problems" in turn creates problems in a more literal sense. A key reason why problematizations may have undesirable consequences is that of inadvertent complexity reduction (Gough 2013) and oversimplification: "by positing an issue as a particular sort of issue, a range of factors must be simplified. Only part of a story is being told" (Bacchi 2009, p. xii). While complexity reduction is arguably a necessity in research – seeing as no single research endeavor can take everything into consideration – undesirable consequences can arise when certain perspectives are *systematically* privileged, and others are systematically omitted. As an example, in this thesis I interrogate whether the treatment of proposed educational problems in engineering education research may, in turn, be problematic. While I will later discuss other potential negative consequences, the styles of problematizations discussed here have particularly direct implications for engineering education reform efforts. Specifically, seeing as "how we frame the problem matters for the solutions we imagine" (Beddoes 2011a, p. 1118), the dominance of a teaching methods-oriented problematization may lead reformers to focus on developing teaching methods even in situations where it would be more impactful to foster cultural

[7] While Bacchi (2009) primarily uses the term problematization to discuss how problems are represented and approached in government policy, she also notes that "We can also use [it] […] to analyse academic theories and academic texts. The argument here is that, since all theories posit forms of explanation, they necessarily contain implicit problem representations that demand scrutiny" (p. xviii).

change, or even to go down completely different "remediation avenues" (Secules et al. 2018, p. 60).

In this context, Bacchi (2009) outlines a number of analytical tasks that are important for researchers who want to interrogate problematizations. Some of these are particularly relevant for the thesis, namely, those that focus on identifying: 1) what (educational) "problems" are put forth in a theory or in a research investigation, 2) what assumptions underlie the problematizations that are constructed, 3) what is left unproblematized, and 4) what the consequences are of the use of certain problematizations.

2.3.2. Interrogating problematizations in engineering education research

Before turning to characterize the two styles of problematization with which this thesis is concerned, it may finally be noted that there is a very limited set of studies that have explicitly interrogated problematizations in engineering education research. While there is indeed research on engineering education research (see e.g., Borrego et al. 2008, Jesiek, Newswander, and Borrego 2009), research that adopts an explicitly *critical* perspective on engineering education research – with a sensitivity towards implicit assumptions, including whose interests are privileged in and through research endeavors – is a relatively recent phenomena (Riley 2017, Mejia et al. 2018, Slaton and Pawley 2018). That is, while researchers are increasingly adopting critical perspectives on engineering education practice[8], there is a particular need for further exploring engineering education *research* from a critical perspective.

In a rare study of problematization in engineering education research, Beddoes (2011a) analyzes how one of the proposed educational problems outlined above, underrepresentation of women in engineering, is problematized in engineering education journals and conference papers between 1995 and 2008, paying particular attention to arguments made as to why underrepresentation is problematic. Through the analysis, Beddoes (2011a) finds four common arguments, constructing increased participation of women in engineering as important for 1) achieving national economic competitiveness, 2) increasing the quality of professional service through representativeness, 3) improving engineering through bringing in women's (presumed) unique and beneficial attributes, and 4) social justice and equality, that is, doing right by women in the education and labor market. Regarding styles of problematization, Beddoes (2011a) furthermore shows how the arguments have very different status, noting

[8] Some of this research will be reviewed in Section 3.2.

that arguments regarding economic competitiveness have been particularly popular and are able to stand for themselves, and that – in contrast – arguments concerning social justice and equality are not ascribed equal legitimacy, being always accompanied by one or several other arguments.

In the thesis, I am interested in continuing the interrogation of problematizations in engineering education research. However, instead of focusing exclusively on how the specific problem of underrepresentation has been approached – which has been the focus of much scholarly work in engineering and science education research (see e.g., Henwood 1996, Blickenstaff 2005, Watson and Froyd 2007, Lykkegard and Ulriksen 2019) – I am interested in two styles of problematization that have been drawn on to discuss a broader range of issues. Furthermore, rather than focusing solely on arguments made in engineering education research as to why we should *care* about specific issues, I focus primarily on assumptions about what *causes* these issues and, accordingly, what we can do about them.

3. Characterizing two styles of problematization

In this chapter, I characterize two styles of problematization that engineering education researchers have frequently drawn on to account for educational problems, namely, a teaching methods-oriented style of problematization and a culture-oriented style of problematization. This characterization is based on my assessment of the engineering education research literature concerned with educational problem and educational development, as well as argumentation and literature reviews presented by others (Stolk, Somerville, and Chachra 2008, Godfrey and Parker 2010, Henderson, Beach, and Finkelstein 2011, Rodriguez-Mejia et al. 2020, Strubbe et al. 2020).

3.1. A teaching methods-oriented style of problematization

Usually, when educational problems and educational development are discussed, the teaching methods used in engineering education are put into focus. Specifically, research that draws on a teaching methods-oriented style of problematization starts from two primary assumptions: 1) the teaching methods used in engineering education determine the outcomes of engineering education, and 2) the teaching methods used in engineering education are insufficiently effective in bringing about desirable educational outcomes. The term "teaching method" here is an analytical construct used to study different ways of designing and implementing engineering instruction. Depending on what proposed educational problems are discussed, desirable educational outcomes here may include, for instance, learning of engineering concepts, competence development, student participation, retention, or well-being. See Figure 1 for a stylized model of this approach.

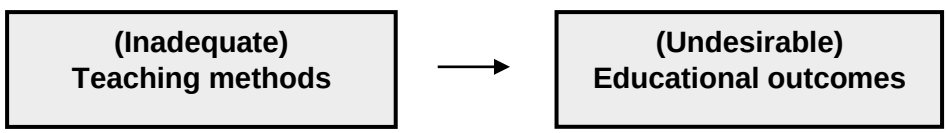

Figure 1: A stylized conceptual model constructed in and through teaching methods-oriented engineering education research. Here, inadequate teaching methods are constructed as the most important antecedent of educational problems.

A main precursor to and vehicle for the first assumption – that teaching methods determine educational outcomes – is research aspiring to evaluate the relative effectiveness of different teaching methods. In this research, specific engineering courses, activities, or interventions are treated as instances of certain teaching methods, that is, as representatives of certain ways of organizing engineering

instruction. These courses, activities, or interventions can be either designed and implemented by researchers or sought out as examples of ordinary practice in engineering education institutions. By evaluating these courses, activities, or interventions, researchers infer certain conclusions about the teaching methods that the activities are taken as representatives for.

Through such research, particularly through work that systematically compares different courses, activities, or interventions varying only a small number of variables, researchers have indeed been able to connect certain patterns of variation in the character of learning activities with certain systematic patterns of variation in learning experiences and learning outcomes (see e.g., Prince 2004, Crouch et al. 2004, Freeman et al. 2014, Deslauriers et al. 2019). That is, such research has shown that courses, activities, and interventions with certain characteristics are more effective than others when it comes to bringing about for instance conceptual understanding, student motivation, or self-efficacy (although there are also cases of discrepant results). Starting from such findings, engineering education researchers have argued that improving teaching methods is an important way of developing engineering education. Such arguments are particularly salient in discussions of the use of "evidence-based" and "high-impact" teaching methods in engineering education (Borrego and Henderson 2014, Wankat and Bullard 2016, Bubou, Offor, and Bappa 2017, Zilvinskis 2019).

Coming to the second assumption, engineering education researchers have frequently suggested that the teaching methods used in engineering education are poorly aligned with effective teaching methods. For instance, engineering education researchers have proposed that educators rely too much on lectures, that the problems engineering students are trained to solve are too structured, and that learning activities in engineering education correspond poorly with professional practice (Mills and Treagust 2003, Jonassen, Strobel, and Lee 2006, Prince and Felder 2006). A common argument here is that engineering education is too "traditional" and has not kept up with the times. Lang et al. (1999), for instance, write that "[i]n an era of unprecedented technological advancement, engineering practice continues to evolve but engineering education has not changed appreciably since the 1950s" (p. 43). This assumed state of affairs is seen as detrimental to learning, and this is positioned as leading to problems such

as not sufficiently motivating students and/or not helping them transfer knowledge learned in academia to "real world" engineering contexts[9].

Prominent examples of engineering education research that draws on a teaching methods-oriented style of problematization include studies of "active learning" (Prince 2004, Freeman et al. 2014), "problem-based learning" (De Graaf and Kolmos 2003, Hmelo-Silver 2004), and "project-based learning" (Adderley 1975, Blumenfeld et al. 1991). That is, in engineering education research, it is commonplace to view certain courses, activities, or interventions as instances of active learning, problem-based learning, and project-based learning and to investigate these activities in order to infer certain conclusions about the supposed nature of the teaching methods[10]. For instance, in a large scale meta-study, Freeman et al. (2014) analyze findings from 225 papers measuring the effectiveness of active learning vis-à-vis lecturing, finding how "students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning" (p. 8410). Such teaching methods have often acted as vehicles for educational reform, and they are frequently put forth as solutions to issues in engineering education practice[11]. As outlined by Edström and Kolmos (2014), problem-based learning and the Conceive-Design-Implement-Operate (CDIO) framework have been especially prominent in this regard. De Graaf and Kolmos (2003) describe problem-based learning as a "successful and innovative method for engineering education" (p. 657), where problems – rather than content – are used as starting points for learning

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[9] I call this an "assumed" state of affairs simply because statements regarding engineering education typically being "traditional" and misaligned with effective instruction and professional practice are very seldom corroborated with empirical evidence as to what teaching methods are used in engineering education.

[10] I write "supposed" nature here, rather than simply "nature", to again signal that for me, teaching methods are primarily analytical and communicative concepts that does not necessarily correspond directly with "real" objects in the world (although they are often treated as very real in teaching methods-oriented research).

[11] Apart from the aforementioned three, engineering education researchers have written, for instance, about the benefits of adopting "practice-based learning" (Goller et al. 2020, Mann et al. 2021), "authentic learning" (Palmer 2004, Strobel et al. 2013), "service learning" (Dukhan, Schumack, and Daniels 2008, Huff, Zoltowski, and Oakes 2016), "undergraduate research experiences" (Zydney et al. 2002, Wallin, Adawi, and Gold 2017), learning through "knowledge creation" (Ellis et al. 2011, Salmisto and Nokelainen 2015), "challenge-based learning" (López-Fernández et al. 2020), "collaborative learning" (Terenzini et al. 2001, Shooter and McNeill 2002), "design-based learning" (Gómez Puente, van Eijck, and Jochems 2011, Gómez Puente, van Eijck, and Jochems 2015), and "experiential learning" (Medini 2018, Li, Öchsner, and Hall 2019).

processes. Mills and Treagust (2003), in turn, ask whether problem-based learning or project-based learning is the answer to how we should prepare engineering students for contemporary working life.

3.2. A culture-oriented style of problematization

More recently, an alternative style of problematization has gained traction, namely, a culture-oriented problematization. Here, problems in engineering education are treated as stemming from problematic cultural patterns and processes pervading engineering education institutions, rather than as stemming from teaching methods or educational designs. The term "culture" in this context is an analytical construct used to study patterns of social interaction and shared ways of thinking that are salient in a certain setting or community[12]. Tonso (1996) was one of the first contemporary engineering education researchers to give voice to a culture-oriented view of engineering education, arguing that "[e]ngineering education, as one facet of engineering culture, is not simply training in a prescribed set of appropriate, academic courses, but is enculturation into a well-established system of practices, meanings, and beliefs" (p. 218).

In short, research that draws from a culture-oriented style of problematization starts from two primary assumptions: 1) cultural patters and processes in engineering and engineering education determine educational outcomes, and 2) there are problematic cultural patterns in engineering education that serve as barriers for the attainment of desirable educational outcomes. See Figure 2 for a stylized model of this approach. Again, what desirable educational outcome – or lack thereof – that is highlighted depends on what proposed educational problem that is put in focus.

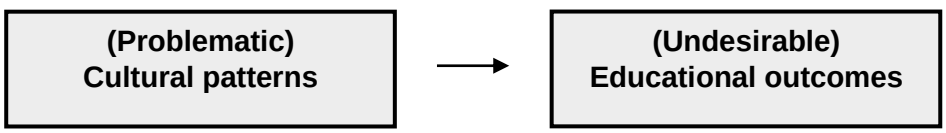

Figure 2: A stylized conceptual model constructed in and through culture-oriented engineering education research. Here, problematic patterns of social interaction are constructed as the most important antecedent of educational problems.

[12] Note here that the term culture, in this context, is used to talk about a much wider set of patterns of social interaction and shared ways of thinking than those that are implied when culture is (only) used to discuss particularities of certain national and ethnic contexts.

A main precursor and vehicle for a culture-oriented problematization of engineering education practice is research studying engineering up close with an eye to understanding the contingent nature of engineering education, that is, the ways in which engineering education is affected by the particularities of the (social) context in which it is undertaken. Through such work, researchers have indeed found contingent patterns of social interaction that they deem beneficial to learning experiences and educational outcomes and others that they deem problematic (Tonso 1996, 2006, Krishnan, Gabb, and Vale 2011, Samuelson and Litzler 2016, Cech and Rothwell 2018, Jensen and Cross 2021). These patterns of social interaction are sometimes analyzed as germane to engineering or engineering education in general, that is, as belonging to "the" engineering culture or "the" engineering education culture (Godfrey and Parker 2010). Alternatively, cultural patterns and processes can be treated as pertaining to specific engineering disciplines, institutions, programs, or – indeed – specific groups of students and teachers (Handford et al. 2019).

To illustrate how cultural patterns and processes have been referred to as explanations for educational problems, I review some examples here. Tonso (1996), in accounting for women's negative experiences of studying engineering, ethnographically investigated "the ways that a 'masculine discipline' is created or maintained in the everyday, face-to-face interactions and activities of undergraduate engineering education" (p. 217). Describing and analyzing situated interactions between students as well as students and faculty, Tonso summarized:

> In this engineering classroom, men engineering student's and faculty's talk set the tone of the design class. Men used mild profanity, humor based on semi-sexual, double entendres, and metaphors encouraging symbolic violence, but women did not. In student and faculty teamwork discussions, more often than not discourse reinforced established practices, to the detriment of women faculty and at least one student" (p. 224)

Discussing the development of socially conscientious engineering, Cech (2014) analyzed survey data from four American universities of technology, showing how students' interest in public welfare concerns may well decline rather than increase over the course of their studies. Cech accounts for this dynamic in terms of engineering education institutions perpetuating a "culture of disengagement" from societal concerns among engineering students. Lönngren (2021), in turn, in a study of how ethics is constructed in an introductory engineering course finds five discursive processes through which such a culture of disengagement is accomplished and maintained, constructing:

(1) Ethics as "something other" than the core subject area, (2) Ethics as irrelevant for the profession, (3) Ethics as common sense, (4) Writing about ethical reflection as inferior to scientific writing, and (5) Ethics and ethical reflection as "anything goes." (p. 61)

3.3. Comparing the two styles of problematization

As I have previously indicated, these two styles of problematization are not equally established. There is a long-standing tradition of treating proposed educational problems in engineering education as stemming from inadequate teaching methods. In contrast, Godfrey and Parker (2010) argue that while "the concepts of 'culture' and 'culture change' are common within the wider educational community" (p. 5), engineering education researchers did not use these terms to any large extent before the 2000s in their discussion of educational development. There have indeed been some developments since then. A larger number of engineering education researchers have adopted socio-cultural perspectives on education and learning (Johri and Olds 2011, Johri, Olds, and O'Connor 2014), different perspectives on how to conceptualize the term "culture" have been discussed (Handford et al. 2019), and different ways to perform cultural analysis of learning and educational problems have been put forth (Secules et al. 2018, Philip et al. 2018). However, a teaching methods-oriented style of problematization still remains dominant (Stolk, Somerville, and Chachra 2008, Rodriguez-Mejia et al. 2020, Strubbe et al. 2020). To get a rough sense of relative proportion, we can look at the research articles published in European Journal of Engineering Education. Out of the 299 papers that were published in the journal the last five years (between 2017 and 2021), 81 mention either "problem-based learning", "project-based learning" or "active learning" in their title, abstract or keywords[13]. That is, only counting three specific – albeit highly prominent – teaching methods, almost 30 % of the research published in this journal in this time period acknowledge teaching methods as important objects of inquiry or as communicating something significant about their empirical settings. In comparison, among the same 299 papers, only 28 highlight or inquire into the role of "culture", "discourse" or "ideology"[14].

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[13] I searched Scopus for papers with "problem-based learning" OR "project-based learning" OR "active learning" in their title, abstract or keywords. I limited the search to papers published the last five years (2017-2021) in European Journal of Engineering Education. The search was undertaken 2021-09-07 and yielded 81 results. At the same time, I manually counted the number of papers published in EJEE to 299.

[14] I searched Scopus for papers with cultur* OR discours* OR discurs* OR ideolog* in their title, abstract or keywords. I limited the search to papers published the last five years

Second, the two styles of problematization have been used for somewhat different things. A teaching methods-oriented style of problematization is particularly prominent in discussions of students' professional preparedness (Felder et al. 2000, Shuman, Besterfield-Sacre, and McGourty 2005, Jonassen, Strobel, and Lee 2006). A culture-oriented style of problematization, on the other hand, have often been used in discussions of diversity, inequality, and inclusion (Tonso 1996, 2006) and, to some extent, engineering ethics (Cech 2014, Lönngren 2021). Each style of problematization is, however, not exclusively linked to a particular proposed educational problem. Adopting new teaching methods has also been proposed as a solution to issues such as student retention and underrepresentation (Haak et al. 2011, Beneroso and Erans 2020, Stentiford and Koutsouris 2020). Conversely, working to change cultural patterns and processes has also been proposed in discussions of graduates' preparedness for professional practice (Gilbuena et al. 2015, Briody et al. 2019).

Finally, we may note that the assumptions perpetuated in and through a teaching-problematization vis-à-vis a culture-problematization have diverging consequences for engineering education research and development. First, regarding practical consequences: Constructing inadequate teaching methods as the primary antecedent of educational problems implies, at the level of individual classrooms, that educators should focus primarily on improving their educational designs if they want to reach better educational outcomes. At a broader level of educational change, a teaching-oriented problematization implies that universities should focus their reform efforts on spreading better teaching methods or, more generally, create conditions for better teaching. In contrast, constructing problematic cultural patterns and processes as the primary antecedent of educational problems implies, at the level of individual classrooms, that educators need to intervene in social dynamics inside and outside the classroom if they want to reach better educational outcomes. At a broader level of educational change, a culture-oriented problematization implies that universities should focus their reform efforts on attending to problematic patterns of social interaction, fostering cultural change for instance through sensitizing students and teachers to habits and hierarchies that they might not be aware of.

In terms of direct consequences for research, while the two styles of problematization are distinguished primarily by the object of inquiry they focus

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(2017-2021) in European Journal of Engineering Education. The search was undertaken 2021-09-07 and yielded 28 results.

on, it needs to be noted that constructing either teaching methods or cultural processes as the main factor in bringing about educational outcomes – and educational problems – also have consequences for what research approaches appear reasonable. Looking to the dominant teaching methods-oriented style of problematization, the ambition to evaluate and develop transferrable, relatively context-independent, teaching methods implies that engineering education research should ideally be done across different contexts, with large population of students. Furthermore, regardless of the scale of investigation, a teaching-oriented problematization implies that when we investigate engineering education practice, we should pay close attention to how courses and programs are designed, interpreting the educational outcomes we observe – or lack thereof – as a consequence of educational design. Furthermore, to supply tools for educational improvement we should investigate factors that contribute to successful adoption of more effective teaching methods.

Instead foregrounding the role of cultural patterns and processes in producing educational problems, this opens up for an alternative set of research tasks. Here, a culture-oriented style of problematization – recognizing the role of learning context in determining educational outcomes – implies that researchers need to really interrogate the particularities of the socio-cultural setting in which education happens, including how these contingencies shape educational outcomes. As such, in-depth investigations are preferred. Moreover, a culture-oriented style of problematization implies that we should investigate initiatives for socio-cultural change and develop tools and recommendations for how to go about it.

3.4. Research at the intersection of the two problematizations

Bacchi (2009) notes that much research writing draws on more than one style of problematization, combining them in different ways. Some combinations are more common than others and within a single study, one problematization may be foregrounded, while another is positioned as secondary. For instance, different problematizations may be bolstered by varying degrees of theoretical deliberation.

Similarly, in the engineering education context, there is indeed research that recognizes the role of *both* teaching methods *and* cultural patterns and processes in shaping educational outcomes and bringing about educational problems, giving both factors at least some empirical attention. Two specific research topics in which a focus on teaching methods is combined with a focus on cultural patterns and processes are reviewed below, seeing as they are particularly

relevant for this thesis[15]. In reviewing this research, I exemplify how the two styles of problematization have been combined in previous work, including a brief commentary on some of the limitations of these combinations.

3.4.1. Students' talk within the context of teaching methods

First, there is a line of work investigating how engineering students talk to each other when engaging in learning activities that are characterizable as instances of prominent teaching methods (Purzer 2011, Selcen Guzey and Aranda 2017, Wendell, Wright, and Paugh 2017, Menekse and Chi 2019). An important precursor for this research is discrepant findings as to the effectiveness of teaching methods in bringing about certain educational outcomes. Here, students' social interaction is seen as a confounding variable that can explain why researchers arrive at inconsistent conclusions. As an example, Menekse and Chi (2019), using an experimental study design, investigated students' learning of engineering concepts taking into consideration both educational design decisions – in terms of whether students worked individually or in groups – and patterns of social interaction – in terms of the frequency of certain discursive moves in student dialogue. They found that on the whole, working collaboratively positively impacted learning of engineering concepts. Furthermore, the quality of students' verbal interactions contributed significantly to individual learning gains. In other words, Menekse and Chi (2019) showed that while collaborative learning is, in general, more effective in helping students to learn engineering concepts, contingent patterns of social interaction moderate the effect. These findings suggest that when attending to engineering graduates' potential lack of certain knowledges and skills, engineering education researchers need to take both teaching methods and social interaction into account.

However, while this line of work focuses directly on social interaction, it is positioned only as a mediating or moderating variable. Furthermore, the analysis thereof is often not underpinned by cultural theory and analysis. That is, the patterns of social interaction and ways of thinking that authors identify here are not interpreted and analyzed as being shared in a *specific* context or a *specific* community with a shared history. As such, this work does little to explain how certain patterns of social interaction are culturally interlinked or co-produced,

[15] Specifically, these two topics are particularly relevant because they align with the topics I have explored in my two papers that combine a focus on teaching methods with a focus on cultural patterns and processes (Paper 4 and 5).

giving limited insight into why certain patterns of social interaction are observed in a particular setting and what may be done about it.

3.4.2. Teachers' talk about teaching methods

Second, engineering education research has also ascribed considerable importance to the way *teachers* talk, specifically focusing on how they talk *about* the teaching methods they employ[16]. That is, there is an increasing interest in how engineering educators describe and explain their teaching methods to their students. Talking about teaching methods in specific ways has been highlighted as being of particular importance when implementing teaching methods that students are unaccustomed to. Here, a strategic framing is seen as a way to bolster students' participation in engineering activities and, as a result, improving their engineering learning (Petraglia 1998, Herrington, Oliver, and Reeves 2003, Woolf and Quinn 2009, Tharayil et al. 2018). However, to find actual investigations of how teachers describe and explain learning activities and teaching methods to their students – as well as analysis of the consequences of this talk – we need to look (mostly) beyond engineering education research.

In the field of the learning sciences, Engle (2006) and Engle, Nguyen, and Mendelson (2011) investigated the relationship between how teachers frame learning activities and what students learn. They found that teacher talk has direct – rather than only moderating – consequences for educational outcomes, showing that teachers' framing of learning activities impacts both students' ability to transfer knowledge to other settings and their ability to critically reflect on what has been taught in class. However, their treatment of educators' talk is, again, not underpinned by a cultural perspective. That is, teacher talk is portrayed here as wholly strategic and intentional rather than locally ingrained and socially accomplished.

In contrast, in the field of science education, Hsu and Roth (2009) used a culturally informed mode of discourse analysis to investigate how a high school science teacher introduced science internships to her students. Specifically, the authors identified the culturally shared "interpretative repertoires" – that is, the "register[s] of terms and metaphors drawn upon to characterize and evaluate actions and events" (Potter and Wetherell 1987, p. 138) – that the teacher used in encouraging students to participate. Hsu and Roth (2009) note that the students they studied, when accounting for their own reasons for participating in learning

[16] As opposed to the question of how educators talk *in general* within engineering classrooms.

activities, “reproduced words and genres of the teacher’s discourse” (p. 570), meaning that they took up the teacher’s way of talking about the activities and the implicit messages about science embedded therein (see also Chua and Cagle 2017).

Drawing out implications for engineering education research and development, these findings suggest that when teacher talk or other sorts of communicative efforts are positioned as solutions to educational problems (e.g., as means of strengthening participation), this communication needs to be recognized as a cultural phenomenon and evaluated as such (see also Berge, Silfver, and Danielsson 2019).

In order to further illustrate how these styles of problematization can inform empirical investigations, I now turn to introduce my empirical investigations of problems and possibilities in engineering education practice. Apart from illustrating what kinds of empirical results such work can arrive upon, this also provides an opportunity to test some of the assumptions built into the two styles of problematization.

4. Methodology and methods

In this chapter of the thesis, I describe the methodologies and methods I have drawn on in my empirical work. A brief reminder is called for here regarding the relationships between the thesis and the appended papers: As previously indicated, the aims of the thesis and of the appended papers do not correspond one-to-one. That is, while the aim of the thesis is to interrogate two styles of problematization, the aim of the individual studies has been to investigate some proposed educational problems in engineering education practice. In other words, the object of inquiry in my appended papers is engineering education practice rather than research problematizations. However, seeing as I have drawn on a teaching methods-oriented style of problematization in my early work and a culture-oriented style of problematization in my later work, the methodologies and methods presented here can be seen as examples of procedures that is used in research focused on teaching methods vis-à-vis research focused on cultural patterns and processes.

Having made this clarification, I discuss methodologies and methods in four sections below. First, I briefly reflect on methodologies and methods in engineering education research in general. Second and third, I describe my research on teaching methods as well as my research on cultural patterns and processes. Because this division between teaching methods-oriented research and culture-oriented research in my case reflects a shift that happened somewhere in the middle of my thesis work, I describe this research as having been undertaken in two "phases". Fourth, I reflect on some ethical considerations in conducting my research.

4.1. Methodology and methods in engineering education research

Appropriate methodology is a long-standing topic of discussion in engineering education research. As outlined by Beddoes (2014), these discussions initially emphasized the need for more scientific rigor in engineering education research (see e.g., Streveler and Smith 2006). Specifically, pursuing increased rigor was the most prominent methodological idea up until – roughly – the 2010s. Here, rigor was often discussed in line with natural science ideals, privileging quantitative methods and controlled classroom experiments (Koro-Ljungberg and Douglas 2008, Borrego, Douglas, and Amelink 2009). Many writers trace these research norms to the fact that most engineering education researchers have their research background in engineering rather than in pedagogy or other social sciences/humanities (Osorio 2005, Koro-Ljungberg and Douglas 2008,

Lönngren 2017). Adding another perspective, Beddoes (2014) notes that emphasizing scientific rigor was a way for engineering education researchers to gain legitimacy and communicate that they were contributing to a distinct and valuable field of research.

However, from 2010 and onwards – again, roughly – the emphasis has gradually shifted towards instead recognizing and encouraging methodological diversity (Beddoes 2014). Here, there have been repeated calls for drawing on a wider set of methodological frameworks, methodologies that are already well-established in other fields of research (Case and Light 2011, Beddoes 2013). These include specific calls for interpretive and critical approaches to engineering education research (Jawitz and Case 2009, Johri, Olds, and O'Connor 2014), which is where I position most of my work. In general, the field has indeed seen a recent surge in the use of qualitative research approaches (Walther, Sochacka, and Kellam 2013, Malmi et al. 2018). Moreover, recent scathing critiques of research ideals in engineering education research (Riley 2017, Slaton and Pawley 2018) further highlight that the field is becoming less consensual and more readily characterized as containing multiple competing research paradigms.

4.2. Phase 1: Studying teaching methods through case studies

In my early work, represented in the thesis by Paper 1 and Paper 2, I drew on a teaching methods-oriented style of problematization. Specifically, I took my starting point in arguments concerning the need for new competences among engineering graduates, including entrepreneurial competences and ability to solve increasingly complex problems (Creed, Suuberg, and Crawford 2002, Jamison, Kolmos, and Holgaard 2014, Mäkimurto-Koivumaa and Belt 2016, Lönngren 2017, Rae and Melton 2017). That is, I positioned this work as addressing the educational problem of engineering graduates not being sufficiently prepared for (future) professional practice. Furthermore, I positioned reform of teaching methods as an important strategy in working towards fulfilling these competence needs, and I constructed description, evaluation, and development of teaching methods as an important research task to be undertaken to support teaching method reform.

Against this background, the aim of my early work – broadly stated – was to evaluate the pedagogical possibilities of teaching methods that have been put forth as (better) suited for preparing students for professional practice. As such, with my early work, I wanted to contribute to improved understanding of the relationship between the teaching methods used in engineering education and its educational outcomes. Here, I primarily drew inspiration from research on project-based learning (Adderley 1975, Blumenfeld et al. 1991), entrepreneurial

learning (Mäkimurto-Koivumaa and Belt 2016, Lackéus 2016), authentic learning (Barab, Squire, and Dueber 2000, Herrington, Reeves, and Oliver 2014), and situated learning (Johri and Olds 2011, Barab and Duffy 2012).

In this early work, I drew on case study methodology (Merriam 2009). Case studies are often motivated by an ambition to investigate certain phenomena in their real-life context, as opposed to in controlled environments (Crowe et al. 2011). This is usually done in order to study issues in their full complexity. In the engineering education context, Case and Light (2011) noted that case study is particularly appropriate "to address research questions concerned with the specific application of initiatives or innovations to improve or enhance learning and teaching" (p. 191). In studying specific settings, specific organizations, or – in my case – specific courses as cases of something, emphasis is often put on strategically sampling these settings/organizations/courses on the grounds of research questions and aims (Flyvbjerg 2006). In terms of research methods, data collection, and data analysis, case study methodology is very flexible, with researchers often using a variety of data sources and not seldom a combination of qualitative and quantitative measures and analytical techniques.

Here, I investigated a number of engineering courses as cases of innovative teaching methods in action. Specifically, Paper 1 reports on a multiple case study investigating pedagogical possibilities through teacher interviews. Paper 2, in turn, reports on a longitudinal single case study investigating student-reported learning experiences and outcomes in a specific learning environment. These studies and papers are described in greater detail in the next chapter of the thesis.

4.3. Phase 2: Studying cultural processes through ethnography and discourse analysis

After having gotten some overview of the workings and pedagogical possibilities of the teaching methods I initially set out to investigate, I moved on to studying learning processes up close by following students and teachers over time. To that end, I investigated teaching and learning activities in two empirical settings: 1) in an undergraduate level project course on software development, and 2) in the context of a similar course, focused on entrepreneurship and business design, where I was involved as a teacher. Although my initial intention was to study how innovative teaching methods unfolded in practice, while undertaking my fieldwork my attention was instead drawn to the nature and consequence of

cultural patterns and processes in these settings[17]. As such, the unit of analysis in my early work and my later work is different. In my early work, I saw educational outcomes as consequences of teaching methods and interpreted what I observed (e.g., teacher-reported pedagogical possibilities or student-reported learning outcomes) as effects of the supposed nature of teaching methods. In my later papers, I instead describe educational outcomes as fundamentally contingent on the learning context and – primarily – on locally salient patterns of social interaction and shared ways of thinking[18]. That is, in my later work, I draw on a culture-oriented style of problematization, seeing the educational problems I discuss as stemming primarily from problematic cultural patterns and processes.

Accordingly, the aim of my later work – broadly stated – has been to investigate how cultural patterns and processes shape learning experiences, and, specifically, how they can serve to *constrain* educational outcomes. My general approach here has been ethnographic and, in later stages, discourse analytical.

Because the methodological frameworks I have adopted in my later work are more clearly associated with specific epistemological commitments[19], I first want to make a brief note on these matters. With my later work, I have aimed to contribute to the more recently established interpretative and critical research paradigms in engineering education research (Walther, Sochacka, and Kellam 2013, Slaton and Pawley 2018). Researchers in these traditions share a skepticism about the tendency of some social sciences to model their inquiries on the methods of natural science, and usually reject the ambition to formulate law-like regularities from which increasingly precise predictions about the social world can be made (Salmon 1992). Instead, interpretative and critical researchers usually emphasize the importance of studying the context, intentions, and historicity of human affairs. Here, interpretivism usually emphasizes the importance of *understanding* – rather than predicting – human practices (Ewert 1991). A key issue in doing so is getting close to people to make sense of the way they, in turn, make sense of the world. Critical theorists additionally

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[17] I will elaborate on what inspired this shift when summarizing the results of my appended papers, in the next chapter of the thesis.

[18] A comparison between Paper 1 and Paper 4 can illuminate this difference. In Paper 1, I argue that all courses following a certain entrepreneurial course design in themselves offer a set of pedagogical possibilities. In Paper 4, I studied a course that could indeed be characterized as following such a course design. However, in Paper 4, I instead point towards local social practices in the particular empirical setting in explaining how educational outcomes were facilitated and constrained.

[19] That is, in comparison to case study methodology.

emphasize that both social organization and scientific endeavors are infused with power and politics that potentially impinge on human freedom. As such, critical research often consists of empirically studying how different interests come to dominate in certain settings, with an eye to foster reflection on established social practices so that they may be changed (Horkheimer 1972, Giroux 1986, Ewert 1991).

To this end, I have drawn on a range of methods and methodological frameworks that have been developed within interpretative and critical research traditions. First, in line with my ambition to understand cultural patterns and processes in engineering classrooms, I have drawn on both ethnography and discourse analysis. Ethnography is a methodological framework with roots in anthropology (Geertz 1973, Agar 1986, Eisenhart 1988). The basic premise of ethnography is that the researcher should observe and interact with people in a certain social setting over an extended period of time in order to understand what is "going on" in this setting (Delamont 2012). Through such an engagement, ethnographers are ideally able to unveil and thickly describe the social practices of a certain community, practices of which actors inside and outside the community are potentially unaware.

Second, I have combined my ethnographic approach with different forms of discourse analysis (Potter and Wetherell 1987, Fairclough 1992, Gee 2014). In relation to my ethnographic approach, discourse analysis provided analytical vocabularies and procedures with which to analyze social practices and, specifically, to identify their consequences for learning and educational outcomes. The term "discourse" here – generally stated – is an analytical construct used in many fields of social science to study different ways of "talking about and understanding the world (or an aspect of the world)" (Jørgensen and Phillips 2002, p. 1). In the context of engineering education, Case and Light (2011) emphasize that:

> it is important to note that discourse not only comprises written text; it also includes mathematical equations, graphs, figures, verbal exchanges, and so on. […] In short, discourse comprises everything that describes the academic and professional activities which characterize engineering practice (p. 201).

A key goal in discourse analysis is to analyze functions of salient discursive patterns, making it a promising methodological framework to adopt when being interested in the consequences of cultural patterns and processes for educational outcomes. Here, discourse analysts adopt a constructionist view of language and social interaction. That is, text and talk do not simply reflect or communicate

information about the world. Rather, social interactions and experiences of the world are *constructed* through language.

Although researchers who adopt a discursive lens share this basic premise, there are multiple ways of doing discourse analysis (Jørgensen and Phillips 2002). Among these different traditions, I have drawn specifically on discursive psychology (Potter and Wetherell 1987) and critical discourse analysis (Fairclough 1992, Gee 2014). Jørgensen and Phillips (2002) highlight how researchers of discursive psychology are especially interested in everyday discourse rather than in analyzing abstract discourses that circulate in society, and therefore focus on "people's active and creative use of discourse as a resource for accomplishing social actions in specific contexts of interaction" (p. 21). In demarcating critical discourse analysis, Gee (2014) distinguishes it from what he calls "descriptive" forms of discourse analysis that aims to (only) describe language patterns in a certain social setting. In contrast, the goal for critical discourse analysts "is not just to describe how language works […] They also want to speak to and, perhaps, intervene in, institutional, social, or political issues, problems, and controversies in the world" (p. 9). In my research, drawing on critical discourse analysis is thus particularly relevant because it speaks directly to overarching problems in engineering education practice and points towards ways in which these problems may be resolved. In distinguishing discursive psychology and critical discourse analysis from one another, Jørgensen and Phillips (2002) note that while they share basic epistemological commitments, critical discourse analysis – taking its grounding in linguistics – often involves detailed linguistic analysis whereas discursive psychology – taking its grounding in social psychology – focus mostly on analyzing rhetoric.

In terms of data collection, the studies I have undertaken in the second phase all combine different forms of classroom observation and/or audio recordings – to access engineering education as it happens – with interviews – to access students' and teachers' own reflections and their way of talking about engineering education. Here, I have stayed close to "real" educational practices, undertaking extensive data collection in the context of two courses as they unfolded.

In terms of data analysis, I have mostly followed an "abductive" or – alternatively labelled – "retroductive" logic (Locke, Golden-Biddle, and Feldman 2008, Timmermans and Tavory 2012, Glynos and Howarth 2019). That is, rather than letting theory "emerge" gradually from the processing of rich data without working explicitly with theory – as in inductive analysis (Braun and Clarke 2006) – or forcing the data into pre-established theoretical codes – as in deduct-

ive analysis (Braun and Clarke 2006) – my analysis procedures have been both data- and theory-driven. Rather than coming to the field knowing exactly what theoretical terms I would use to make sense of the materials I collected and in relation to what theories I would position my study, I entered the field with hunches, ideas, alternative hypotheses, and sensitizing concepts (Bowen 2006) which were gradually transformed, replaced, and refined as the fieldwork progressed. A first key activity in this process was trying to get a grip of what was "in" the collected material and to try out different ways of categorizing it. This was usually facilitated by multiple listenings to recordings and readings of transcripts, and – in some cases – open coding. A second key activity was to continuously read more and increasingly specific literature on topics related to my studies, putting my observations in relation to previous work. The aim here has been to gradually arrive at theoretical conclusions that are properly "grounded" in the empirical material (Glaser and Strauss 1967) while at the same time being properly informed by and relevant to previous research.

4.4. Ethical considerations

More than employing methodologies and methods that are appropriate in light of what questions are to be investigated, all researchers need to take research ethics into account when designing their studies. I put forth my own main ethical considerations here, basing my discussion on guidelines from the Swedish Research Council (2002, 2017).

A first thing to reflect upon is the risk of causing harm to research participants. In conducting engineering education research, as a branch of social science, it is primarily social and psychological harm that needs to be considered, as opposed to the physical harm that needs to be considered in fields such as medicine. My assessment has been that in my research, there has been little risk of causing my respondents, for instance, psychological stress or loss of social standing. Although one can never be sure of what issues and situations arise when doing fieldwork or what experiences respondents may share in interviews, my data collection has not been focused on particularly sensitive subjects. In interviews, especially when talking to teachers, the focus has remained on a rather analytical level, asking about how their courses are designed and how they think about their teaching.

When interviewing students and asking about their learning experiences, conversations may, however, sometimes border on topics that can be somewhat more sensitive. For instance, students may have had negative learning experiences that they do not wish to talk about. In my own case, I have tried to be responsive to what students seem prepared to talk about and I have not drilled

into subjects they seem uncomfortable with. As an example, in one of my studies I conducted focus group interviews with students who had done a project together. In one of the interviews, it was apparent that the topic at hand (group dynamics in the project group) was sensitive for one of the students who had struggled with the dynamic of the group. Although the student brought up having had a somewhat negative experience, the student seemed uncomfortable to talk more about it. Here, I tried to repair the situation, moved on to the next point on the agenda and followed up with the student individually afterwards.

When conducting my classroom observations, I have tried not to disturb learning activities and not to take the focus away from learning. This means that I have positioned myself physically at the back or side of classrooms in order to not steal focus during whole class activities. Furthermore, when I have approached students during group activities, I have again tried to be responsive to whether or not they seem comfortable with being observed. While I have asked questions to teachers and students during my observations, I have mostly done so in breaks.

When starting up my data collection and when inviting respondents to participate in interviews, I have informed them about my research aims, process, and output, as well as the conditions of their participation, so that they would be able to give informed consent to participating. Furthermore, I have anonymized all data and used pseudonyms in all publications in order to protect the confidentiality of my respondents. In my papers and in this comprehensive summary, I have furthermore chosen not to disclose certain information about the courses I have studied (e.g., locations, course names, exact topics), because otherwise respondents – especially teachers – would have been too easily identifiable.

When it comes to conducting research in the context of a course that I was involved in teaching, I have taken some additional measures to ensure that students felt comfortable with participating and with speaking frankly. First, I have taken care to clarify the relationship between information collected in the course for grading purposes – through assignments – and the extra data collection I conducted for research purposes. Furthermore, when I have interviewed students, I have done so after grading had been finished, so that they did not have to worry that what they said in the interviews would affect their assessment. Finally, when I was teaching – that is, in literature seminars and occasional lectures – I usually did not conduct any data collection, in order to show that teaching was my first priority.

While I believe that my research helped improve both my own teaching and the overall course quality by providing new perspectives on what happened in class,

I cannot completely rule out that my research also impacted some students' learning experiences negatively. At the very least, I have not had any explicit indications that my ongoing fieldwork has interfered with the quality of the teaching. That is, I have never gotten any comments, neither openly nor in the anonymous course surveys, that would suggest that the data collection was too intrusive. Similarly, while I have informed students that they may retract their participation at any time, no one has done so.

5. Summary of appended papers

Having outlined the methodological frameworks on which I base my research, I now turn to summarize the five appended papers. Rather than only share the results of my papers, I summarize them in terms of background, methods, results, and implications, seeing as I have not yet explicitly framed the more specific topics with which the individual papers are concerned. The chapter is organized in two parts. In part one, I summarize my early research aimed at evaluating the pedagogical possibilities of innovative teaching methods in engineering education. I first summarize the two papers that comprise this research (Papers 1 and 2) and then reflect on their findings taken together. In part two, I summarize my later work aimed at investigating how cultural patterns and processes facilitate and constrain learning in engineering education. Here, again, I first summarize the three papers that comprise this research (Paper 3, 4, and 5) and then reflect on their findings taken together. In the next chapter of the thesis, I discuss the totality of my work and draw out implications for engineering education research and practice.

5.1. Part 1: Summarizing my teaching methods-oriented research

In this section I summarize my early work, aimed at evaluating the pedagogical possibilities of innovative teaching methods in engineering education. This comprises two case studies and two papers resulting from these case studies.

5.1.1. Paper 1: Entrepreneurial engineering pedagogy: models, tradeoffs and discourses

The first paper departs from a specific item on the reform agenda for engineering education, namely an entrepreneurship-focused reform (Creed, Suuberg, and Crawford 2002, Byers et al. 2013, Mäkimurto-Koivumaa and Belt 2016, Rae and Melton 2017). Compared to other competences deemed important for engineering graduates, talk of an entrepreneurial deficit in engineering education is a relatively recent phenomenon. In recent years, the field has seen repeated calls for strengthening entrepreneurial capabilities among engineering graduates. Infusing entrepreneurship into the engineering curriculum has thus increasingly been considered a matter of importance.

Accordingly, the proposed educational problem with which this research is concerned is that engineers do not have sufficient entrepreneurial competences when they graduate from engineering education. When it comes to solutions, I and my co-authors – in line with previous research – argue that this proposed problem may be redressed if engineering is taught in a different manner.

Specifically, some proponents of an entrepreneurial reform argue that engineering students need to learn *about* entrepreneurship and consequently should be given entrepreneurship courses. Others argue that it is more important that engineering is taught in an *entrepreneurial manner*, drawing on specific teaching methods that are especially effective in developing entrepreneurial competences[20]. The study latches on to the latter kind of solution, aiming to identify different forms of entrepreneurial project-based learning in engineering education and to evaluate the kind of learning experiences students can have in the context of these different versions of entrepreneurial project-based learning.

Operationalizing this research interest, I and my co-authors investigated entrepreneurial project-based learning as a "pedagogical framework" (Nunes and McPherson 2003, Goodyear 2005) that engineering educators can use to infuse entrepreneurial experiences in their project-based courses. The term "pedagogical framework" – akin to the term "teaching method" – is an analytical construct used to study and prescribe different ways of organizing teaching and learning (Nunes and McPherson 2003, Goodyear 2005). In conceptualizing educational design, Goodyear (2005) notes that "the tendency has been for leading writers in this field to position the problem of educational design at the levels of either broad pedagogy and philosophy […] or specific pedagogical techniques" (p. 85). He proposes that pedagogical frameworks occupy a "middle ground", including considerations regarding both high level educational philosophy – e.g. in relation to the nature of knowledge and learning – and regarding day-to-day practicalities of the classroom. Nunes and McPherson (2003) highlight the value in empirically studying as well as raising educators' awareness of pedagogical frameworks by asserting that "[o]ne of the crucial success factors of an educational environment is that any assumptions made about the learner and the learning process, are incorporated into the design process in an explicit and consistent manner" (p. 496).

In the paper, we were guided by the following research questions, where the first is focused on identifying different types of entrepreneurial project-based learning and the second is focused on their pedagogical possibilities:

> *RQ1: What pedagogical models and methods do engineering educators use to infuse entrepreneurial experiences into project-based courses?*

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[20] I was initially employed to follow a reform project at Chalmers university of technology (the ENG-project) focused on developing and supporting the adoption of such a teaching method.

RQ2: How do the educators motivate their instructional design choices in terms of the quality of the students' learning experiences, taking into account potential tradeoffs between competing aims?

In order to address these research questions, I and my co-authors conducted a multiple case study. A particular strength of multiple case studies in this context is that they may help to identify variation in a specific phenomenon, in our case, variation in entrepreneurial project-based learning. The first phase of this project was to identify courses – out of all courses at a specific European university of technology – that were aligned with how pedagogy is described in previous research on entrepreneurial engineering (Creed, Suuberg, and Crawford 2002, Mäkimurto-Koivumaa and Belt 2016, Wheadon and Duval-Couetil 2017). Through surveying course documentation, 17 courses were identified and 14 of the educators responsible for these courses agreed to be interviewed. Interviews were chosen as a primary mode of data collection here in order to get access to a broad set of information about educational design and associated pedagogical possibilities. Furthermore, interviews were chosen over, for instance, an open-ended survey, in order to establish a first contact with teachers involved in entrepreneurial project courses, with an eye to facilitate subsequent access to further data collection in these courses. In the interviews, I asked about the design of their courses and what pedagogical possibilities they believed that the courses offered students. The 7 courses in the final sample were all project-courses where students engaged in creating new artefacts, services, or knowledge in collaboration with peers, teachers, and external stakeholders[21].

Variation among these courses – including different ways to design entrepreneurial project-based learning as well as associated pedagogical possibilities – was analyzed using an inductive thematic analysis (Braun and Clarke 2006). That is, rather than prescribing certain theoretically informed codes with which we made sense of the material, the analysis process was facilitated by iteratively coding small data units and by iteratively comparing across the different courses. Through this process, we constructed a set of categories that captured the major aspects of variation among the different courses, in terms of three different pedagogical models (Goodyear 1999, Nunes and McPherson 2003) and two different design dimension.

[21] The other 7 courses were upon interviewing found to not be aligned with the kind of educational design that is espoused in literature on entrepreneurial engineering.

We identified three types of entrepreneurial project-based courses: 1) *student-framed and user-oriented projects*, 2) *client-framed and student-driven projects*, and 3) *co-creation platforms*. These three types of projects were primarily distinguished by whether students, teachers, or external stakeholders frame the projects or whether project framing is done dialogically. We characterize the three types of projects as follows (here I cite directly from Paper 1, p. 695-697):

- *Learning through student-framed and user-oriented projects*. Students work in small teams and choose a project topic of their own interest, with the goal of conceiving a new solution or product in relation to a user or customer need, and to seek out actual users for input on the solution/product. Students are supervised regarding use of disciplinary methods, such as ideation, interviews, and modelling tools. In the sample cases, students' project results are presented to the class or invited guests, who provide feedback, and a project report serves as the main basis for assessment.
- *Learning through client-framed and student-driven projects*. Students work in medium-sized teams on client-framed projects that are arranged by instructors beforehand, with the goal of conceiving new solutions to problems relevant for clients' ongoing practice. Students are supervised regarding use of disciplinary design methods, such as computer modelling and programming, as well as project management methods, such as agile methodology. The clients provide feedback on the students' solutions during and at the end of the projects, and students incorporate this feedback into their solutions. A project report serves as the main basis for assessment.
- *Learning through co-creation platform projects*. Students seek out a learning environment aligned with their personal interests. They conceive a project idea, and connect external stakeholders, who are either sought out as problem owners or as resource providers, with interest in students' project results. Educators help students in finding and contacting these external stakeholders. Students are supervised in using disciplinary methods and more tangible resources, such as research labs, design workshops, and disciplinary networks. Results are showcased to other project teams and external stakeholders.

Further, we identify that the specific educational design choice of whether students, teachers, and/or industry representatives frame the project has implications for how *personal* (in the sense of connecting to students own interests and motivations) vis-à-vis *professional* (in the sense of connecting to engineering practice beyond academia) learning experiences in the context of these entrepreneurial project-based courses could become. Finally, we observed how the educators made *trade-offs* between these two aims in designing their courses. While these trade-offs seemed to be reconciled in the co-creation

platform projects, this may be partially accounted for in terms of contextual variables (rather than educational design) seeing as these courses enjoyed certain additional resources (e.g., time and space) and other beneficial characteristics (being elective).

In sum, through our investigation, we found that educators can and do draw on a variety of different pedagogical models in order to facilitate entrepreneurial learning experiences in engineering education. Furthermore, we found two design heuristics for engineering educators to keep in mind if they want to work towards making engineering education, on the whole, more entrepreneurial: making learning activities more personal and more professional. Here, finding ways to reconcile tradeoffs between these two design dimensions is an important task for educators in planning their courses. Specifically, we identify framing of course projects as a particularly consequential design choice in this context.

In terms of implications for research, the findings point towards a need for evaluating the educational consequences of who frames course projects, both through comparative research using pre- and post-tests of learning outcomes, and through studying learning processes up close as they unfold using in-depth fieldwork. Furthermore, the findings indicate that researchers investigating entrepreneurial teaching methods need to consider how the educational designs they encourage overlap or clash with other ideas about engineering education design, for instance those that are encouraged in frameworks such as problem-based learning and authentic learning.

5.1.2. Paper 2: From CDIO to challenge-based learning experiences – expanding student learning as well as societal impact?

The second paper departs from another item on the engineering education reform agenda, namely preparing engineering graduates to engage with "grand challenges" (Olson 2016), that is, global challenges for progress and human well-being (e.g. sustainability issues). The proposed educational problem here is that while engineering graduates will increasingly need to engage with such issues, contemporary engineering education does not sufficiently prepare them to do so (see also Lönngren 2017). Again, in line with previous literature on the matter, my co-authors and I propose that this problem may be redressed by adopting new teaching methods.

Against this background, the aim of the paper was to evaluate student learning in the context of challenge-based learning (Malmqvist, Rådberg, and Lundqvist 2015, Gallagher and Savage 2020), a teaching method put forth as apt at preparing students for working with grand challenges. Specifically, we asked

whether the multiple ambitions educators ascribe to this teaching method – that is, simultaneous academic learning, additional competence development relevant for working with grand challenges, as well as value creation for society – are compatible with or at odds with each other[22].

We situated our study in a learning environment that centered on engaging students with sustainability challenges, the Chalmers Challenge Lab. In this learning environment, students – predominantly from an engineering background – undertook their master thesis projects, while being introduced to a set of tools and theories aimed at working with sustainability challenges (for a detailed description of this learning environment, see Larsson and Holmberg 2018). This learning environment was chosen because its design aligned with the premises of challenge-based learning and because some of the authors had (mostly peripheral) roles in organizing the course, which facilitated access and a preliminary understanding of the setting.

Our research objectives were (here I cite from Paper 2, p. 24)

- *to assess whether the students' self-perceived learning fulfils the required learning outcomes for MSc theses at Chalmers in general, i.e. the required academic learning outcomes for their education;*
- *to identify some potential additional learning outcomes that the students perceive that they have achieved, which are not developed to the same extent in traditional MSc theses;*
- *to assess how much the MSc thesis projects at Challenge Lab have achieved in the pathway from problem to implementation, in line with the CDIO cycle, and to discuss this in relation to the ambition to create transformative and integrative values for society.*

To fulfil these research objectives, a longitudinal case study methodology (Eisenhardt 1989) was applied, studying self-assessed student learning in three course iterations, with data collection undertaken between 2014 and 2016. A particular strength of the longitudinal case study methodology in this context is that the evaluation of student learning becomes less impacted by yearly

[22] Facilitating a more diverse set of learning objectives is a common argument also for many other alternative teaching methods, where adopting a teaching method is seen as a way to reach *both* better learning of academic content *and* better preparedness for professional practice. The specific ambition that students should create value for society while they are engaging in their education, and that this value creation is a mechanism for improving student learning, has also been proposed in relation to other teaching methods (see e.g. Chen and Hong 2016 and Lackéus 2016).

variations pertaining to small differences in, for instance, educational design or student group composition.

In comparison to Paper 1, the data collection here focused on pedagogical possibilities as perceived by *students* rather than by teachers. Data was collected through 37 student interviews, focused on understanding students' experiences and what they learned from engaging in challenge-based learning. The interviews were also complemented with a student self-assessment survey in which students rated their perceived competence development in relation to 12 intended learning outcomes that all master thesis projects at Chalmers should strive for. These self-assessments were compared to similar self-assessments done by 479 students at Chalmers in 2016 after having undertaken their master thesis projects. Here, the interviews facilitated a broad picture of student learning experiences and perceived competence development, while the self-assessment of intended learning outcomes facilitated a data point that could be compared with master thesis projects undertaken in other learning environments. While using self-assessment as an indicator for how much students have learned has certain limitations in terms of reliability (see e.g. Deslauriers et al. 2019), it also has a number of strengths that are difficult to attain with knowledge tests. In this case, the aim was to measure student learning against learning outcomes that were multi-facetted. Constructing a reliable knowledge test for such a broad set of learning outcomes was simply not feasible. Moreover, such a procedure would not have facilitated a comparison with all other master thesis project at Chalmers. We may also note that using student-assessed learning outcomes is an established practice in evaluating teaching methods in engineering education research (see e.g. Terenzini et al 2001, Beagon, Niall, and Ní Fhloinn 2019, Huerta et al. 2021). Finally, impact on society was studied in terms of how far student projects progressed towards actual implementation and evaluation of proposed solutions in practice.

In terms of student learning in relation to the traditional intended learning outcomes for master thesis projects, it was found that (here I cite directly from Paper 2):

> The mean values in the self-assessment for all 3 years for all ILOs [intended learning outcomes] are at least 3.3 on a 1–5 scale, which is in line with the results from a questionnaire in 2016 sent to all students at Chalmers who performed their MSc thesis in that academic year (p. 31)

Furthermore, in terms of additional competence development, "the results from the interviews show that the students perceived that they had developed

additional skills that are not offered or usually developed in traditional MSc theses, such as working across disciplines and with stakeholders" (p. 32). Finally, in terms of creating value for society, there was considerable variation among different projects, seeing as:

> 41% of the students reached the second phase by generating an idea or model, 32% reached the third phase to develop a concept and 23% reached the fourth phase to test/evaluate their project within an academic setting. One thesis project (5%) reached the last phase, of being tested/evaluated by external stakeholders (p. 33)

As such, it was found that the additional learning objectives ascribed to challenge-based learning do not necessarily conflict with students perceiving they have also reached more traditional academic learning outcomes.

In terms of practical implications, these findings suggest that challenge-based learning is a promising teaching method when it comes to preparing engineering students for working with grand challenges, seeing as it may combine traditional academic learning with additional competence development. These findings should compel engineering educators to increase the complexity of the problems and projects taken on in engineering courses, for instance by bringing in external stakeholders to frame problems and develop solutions in dialogue with students. A cautionary note, however, is that among the challenge-based projects studied here, few reached a stage where the solutions proposed were implemented and evaluated in practice. The challenge-based approach, thus, may not be able to replace more practice-based learning activities, where students get to experience ongoing and established engineering operations, e.g. in the context of a practicum. The appropriateness of challenge-based learning in preparing students for the practicalities of engineering is a topic that may be investigated further in future work.

5.1.3. Reflecting on my inquiry into innovative teaching methods

The first two papers both draw on and contribute to a teaching methods-oriented style of problematization, starting from two different proposed educational problems, accounting for these in terms of teaching methods needing to change, and – finally – working to identify design choices that may make teaching more effective in bringing about educational outcomes that are constructed as desirable (entrepreneurial competences and ability to work with grand challenges). In Paper 1, we draw on such a problematization through positioning educational design as an important object of inquiry in view of the ambition to make engineering education more entrepreneurial. Through our study and analysis – tapping into the experiences of engineering educators – I and my co-

authors identified a relationship between design of project-based courses on the one hand and variation in possible learning experiences on the other. This provides additional support for the hypothesis that teaching methods shape learning experiences and outcomes, indicating that conscious (re)design of engineering courses is indeed an important activity to engage in if we want to strengthen students' entrepreneurial competences. Furthermore, in Paper 2, my co-authors and I suggest that educational design does not have to be a zero-sum game, and that redesigning engineering courses in order to better prepare students to work with complex problems does not necessarily come at the expense of other intended learning outcomes. This, again, indicates that deliberate educational design is an important activity for engineering educators to engage in, and evaluation of teaching methods is an important activity for engineering education researchers.

However, from these studies, I also took away a feeling of the data having "kicked back" (Alvesson and Kärreman 2011) at some of my initial assumptions, as well as some of the assumptions embedded in a teaching methods-oriented style of problematization. First, we arrived at discrepant findings in Paper 1 and 2 as to whether engineering educators need to make trade-offs between different learning objectives when designing their courses. While we suggest in the papers that conscious educational design can lead to not having to make priorities, the fact that certain learning environments in our sample seemed to reconcile a wider variety of learning objectives could alternatively be ascribed to local contextual circumstances. Indeed, findings from Paper 1 indicates that teachers *usually* need to make tradeoffs. As such, while research drawing on a teaching methods-oriented style of problematization usually emphasize that different teaching methods bring about different *amounts* of educational outcomes (e.g., that their effectiveness in bringing about conceptual understanding varies), my findings suggest that teaching methods crucially need to be distinguished in terms of what *kind* of learning experiences and educational outcomes they bring about. This means that any reformer of teaching methods should be mindful of what learning experiences are foregone through educational redesign, not only what outcomes are better achieved[23]. Similarly, when new teaching methods are positioned as solutions to proposed educational problems, we need to remember that there are no silver bullets when it comes to engineering education. As long as we want engineering students to have a broad set of learning experiences and as long as

[23] See e.g. Edström (2018) for an extended discussion of inherent and persistent tensions between different valued learning objectives in engineering education.

we want them to graduate with a diverse set of competences, we will need to draw on a variety of teaching methods.

Second, while we have implicitly constructed entrepreneurial project-based learning and challenge-based learning as new and alternative teaching methods in the papers, my interviews with teachers across campus revealed that there is already a wide range of teaching methods in use in engineering education. Entrepreneurial project-based courses were found at both undergraduate level and master level, and across a number of different programs and disciplines. In this sense, Paper 1 kicked back at my initial assumption, as well as the recurring argument in engineering education research, that engineering education is usually "traditional" and misaligned with what is positioned as effective instruction in research on teaching methods. Instead, the findings align with Rae and Melton's (2017) assertion that "[e]ngineering programs often exhibit practical and experiential approaches and project-based and team learning consistent with best practices in other disciplines" (p. 6). Constructing the general mode of teaching in engineering education in this way shines a new light on proposed problems and proposed solutions in engineering education: if we assume for a second that Rae and Melton's assessment generally reflects the state of affairs in engineering education, then we need alternative explanations for why engineering graduates lack certain competences, other than engineering education not being "experiential" or "practical" enough.

5.2. Part 2: Summarizing my culture-oriented research

In this section I summarize my more recent work, focused on how cultural patterns and processes shape learning experiences and educational outcomes, including how proposed problems in engineering education may be accounted for in these terms. This comprises two fieldwork studies and three papers resulting from these two studies. The three papers are outlined below, in terms of background, methods, results, and implications.

5.2.1. Paper 3: What lies beneath distinctive difficulties in entrepreneurship education: Cognitive conflicts or cultural clashes?

Having found in Paper 1 that there are certain barriers to learning in courses that can be characterized as drawing on experiential and practical teaching methods, I turned my attention to investigate how such courses unfold, including where and when opportunities for learning are at stake, are realized, and/or are lost[24].

[24] This particular paper is positioned completely in the field of entrepreneurship education research and so in summarizing the paper, the focus on engineering education is briefly bracketed.

Theoretically, this paper is motivated by previous research into experiential education, an alternative teaching method focused on learning through "real" (entrepreneurship) experiences, the preferred mode of instruction in entrepreneurship education (Nabi et al. 2017). Specifically, the paper departs from similar observations that experiential education does not always lead to positive and impactful learning experiences. On the contrary, engaging in courses aligned with such a teaching method can be frustrating and confusing for students (Lackéus 2014, Täks et al. 2014, Rose et al. 2018), and may lead to students being overwhelmed, opting out of learning activities, or feeling excluded (Kirschner, Sweller, and Clark 2006, Dean and Jolly 2012, Waitoller and Kozleski 2013). The proposed problem here is that students often exit entrepreneurship education without having learned as much as they could have. The proposed solution is that teachers give adequate support to students.

In the paper, I thus construct *distinctive difficulties* as an important mediating variable that critically determines the success of entrepreneurship education, and – accordingly – as an important object of inquiry for entrepreneurship educators and entrepreneurship education researchers alike[25]. Specifically, a multi-facetted understanding of difficulties in experiential learning is needed to design continuous support for students that target actual rather than assumed barriers to learning. Against this background, I aimed to investigate the cognitive and socio-cultural difficulties that students face in entrepreneurship education. Furthermore, I aimed to investigate under what circumstances the difficulties that students faced where mostly cognitive or mostly socio-cultural.

This was the start of an extensive data collection that I undertook in my own teaching, that is, in the context of an undergraduate level project course focused on entrepreneurship in the construction sector (7.5 ECTS). Both Paper 3 and Paper 4 is a result of this fieldwork. In the course, the students – working in teams – were to generate business models within their industry sector, repeatedly contacting external stakeholders to get information and feedback to use in moving their projects forward. The course catered to approximately 30 students each year and was mandatory to most of the participants, who were in the third year of a technical bachelor's program.

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[25] In labelling my object of inquiry "distinctive difficulties", I here consciously forego other attempts at a similar labelling – e.g. "threshold concepts" (Meyer and Land 2003) or "threshold practices" (Gourlay 2009) – seeing as these come with a certain metaphorical and theoretical baggage which runs counter to my attempt to compare and reflect on different theoretical groundings.

The fieldwork was undertaken over four course iterations. The data collection included individual interviews, group interviews, classroom observations, reflective student writing, audio recordings, and surveys. The data collection was most intense in the first iteration of the course – conducting a first set of student interviews – and the final iteration of the course – recording student conversations and conducting focus group interviews (see Paper 4). The extent of the empirical material is shown in Table 1, which is copied directly from Paper 3.

Table 1: Summary of empirical material collected in my first fieldwork study

Course iteration	**Classroom observation** (hours)	**Team discussion** (hours)	**Reflective writing** (pages)	**Inter-views** (number)	**Evaluation survey** (respondents)	**Evaluation meetings** (number)
1	18	-	175	8	14	2
2	11	-	190	-	24	2
3	14	-	230	-	11	2
4	12	13	102	4	21	2
Total	**55**	**13**	**697**	**12**	**70**	**8**

In analyzing this material for Paper 3, focused on distinctive difficulties, I drew on an alternate templates strategy (Langley 1999), which is an analytical framework aimed at comparing and evaluating competing theories that may be used to account for the same set of observations. The theories, in my case, were cognitive conflict theory (Posner et al. 1982, Driver and Erickson 1983, Eaton, Anderson, and Smith 1984) and cultural clash theory (Kolikant and Ben-Ari 2008, Akkerman and Bakker 2011), which have both been used in educational research to account for the difficulties students face in a variety of educational settings. Here, cognitive conflict theory emphasizes difficulties as caused by students' individual cognitive misrepresentations of disciplinary activities, while cultural clash theory emphasizes difficulties as caused by local socio-cultural practices that students participate in. To identify what course activities were particularly challenging for students, I conducted an inductive thematic analysis (Braun and Clarke 2006), looking for similarities between student cohorts and the struggles they reported having. To analyze what cognitive and socio-cultural mechanisms made these activities challenging, I conducted two theoretical thematic analyses (Braun and Clarke 2006), coding students' talk about these

challenging activities with concepts from cognitive conflict theory and cultural clash theory respectively.

Through my analysis I first found a number of cognitive conflicts that students may encounter in entrepreneurship education: 1) a conflict between viewing entrepreneurship as a process of actualizing ideas or as a process of developing ideas, and 2) a conflict between viewing entrepreneurship as an isolated activity or as a collaborative activity. Second, I also found a number of cultural clashes that students may encounter in entrepreneurship education: 1) a clash between being professionals and doing entrepreneurship, 2) a clash between being friends and doing entrepreneurship, and 3) a clash between doing school and doing entrepreneurship. Finally, starting from my findings, I argue that the salience of cognitive vis-à-vis socio-cultural mechanisms is contingent upon the social consequences at stake in learning activities. Specifically, cognitive conflicts are more salient when the primary consequence at stake in learning activities is entrepreneurial learning and cultural clashes are more salient when the primary consequences at stake in learning activities are social.

The findings suggest that in trying to make sense of why students are struggling in entrepreneurship education, it is useful for teachers and researchers alike to investigate both students' individual conceptions of disciplinary – e.g., entrepreneurial – activities and locally shared and interactively achieved ways of thinking and doing. Furthermore, the findings point towards the need for reflexivity in both teaching and research (Alvesson and Sköldberg 2009, Malaurent and Avison 2017, Gabriel 2018). That is, teachers and researchers alike need to reflect upon their own beliefs as well as culturally shared conceptions of entrepreneurship and – indeed – of learning and education when designing courses and when shaping research designs. Explicitly drawing on cognitive, socio-cultural, *and* socio-political learning theory is deemed a promising strategy to achieve such reflexivity.

5.2.2. Paper 4: Friends and/or professionals? Investigating the discursive formation of teamwork experiences in engineering education

This paper departs from the proposed problem that engineering graduates are not sufficiently prepared to work in teams as a part of their professional practice (Katz 1993, Trevelyan 2007, 2010a, b, Ramadi, Ramadi, and Nasr 2016, Darling and Dannels 2003, Itani and Srour 2016). While much work has gone into measuring the effect of different teaching methods and interventions on collaborative skills (Seat, Parsons, and Poppen 2001, Terenzini et al. 2001, Warnock and Mohammadi-Aragh 2016, Baytiyeh and Naja 2017, Beagon, Niall, and Ní Fhloinn 2019, Huerta et al. 2021), the discrepant findings from these

studies have sparked interest among engineering education researchers as to how students' social dynamics while working in teams shape their learning experiences and outcomes (Tonso 2006, Richter and Paretti 2009, Menekse and Chi 2019). Against this background, I and my co-authors investigate how social norms are established linguistically in and through student group discussions. Furthermore, we analyze the consequences of these discursively established norms for what kinds of teamwork experiences are made (im)possible in the context of team projects in engineering education.

This study was undertaken in the same context as Paper 3, focusing specifically on the cultural patterns and processes that serve as barriers to learning in this particular setting. However, in Paper 4, we zoom in on a team development intervention (Lacerenza et al. 2018) that I developed and implemented in the final course iteration, aiming to attend to some of the difficulties that students faced. Specifically, we investigate how the teamwork and the team development intervention unfolded as a consequence of how students communally interpret their teamwork and the intervention as they participate in it.

Operationalizing a cultural analysis, we draw on discursive psychology, inspired by Potter and Wetherell (1987), and analyzed the nature and consequence of the "interpretative repertoires" that the students drew on in making sense of and negotiating their teamwork. An interpretative repertoire is a "register of terms and metaphors drawn upon to characterize and evaluate actions and events" (Potter and Wetherell 1987, p. 138) in a certain social setting. That is, we view interpretation as a cultural rather than individual process. Furthermore, we recognize that certain ways of interpreting actions and events carry certain normative consequences in terms of encouraging some future actions and discouraging others. In our analysis, we pay particular attention to how the use and the status of these interpretative repertoires make certain learning experiences possible within the groups, and conversely, what kinds of learning experiences are foregone.

The study was guided by the following research questions:

RQ1: What interpretative repertoires do the students draw on to make sense of their teamwork in the course project?

RQ2: How are the team development activities interpreted in student group discussions as the intervention unfolds?

RQ3: How does the status of these repertoires and interpretations shape the teamwork experiences the students are able to have in the context of the course?

Wanting to analyze aspects of students' social interaction, our data collection centered on recording team discussions as the teamwork and team development intervention unfolded. The empirical material overlaps to some extent with the empirical material for Paper 3, with the main empirical material for Paper 4 being the 13 hours of recorded team discussion and 4 interviews reported for the fourth course iteration in Table 1. The team discussions were recorded in the beginning, middle, and end of the team development intervention, and the interviews were undertaken after the course had ended. See Figure 3 for a description and illustration of the teamwork development and associated data collection.

At first glance, the methodological procedures for this paper are similar to the procedures outlined for Paper 3, working with the same kind of empirical material, collected over time as students' learning processes unfolded. There is, however, a major difference in how students' talk is understood and analyzed. In Paper 3, respondents' talk was taken more or less at face value. When students talked about the problems and possibilities they face in this course, this was approached as descriptions of cognitive and cultural processes. In Paper 4, however, we adopt a discourse analytical starting point, and – as previously outlined – a constructionist view of language. This has far-reaching implications for the analysis of talk and text, the central media of qualitative research. Here, the functional character of students' talk and the effect language has in constructing the (social) world, are recognized. An important point of departure here is that respondent's talk is not necessarily "their own". The terms they use and the way they combine them are shaped by social language practices. In such a view, the talk and text collected in qualitative research does not *reflect* the social world, it is part of the social processes through which the social world is *constructed*.

Accordingly, in our analysis, we looked for both interpretative variation and function in the team discussions. First, we extracted utterances focused on the teamwork and the team development intervention. Second, through analyzing variation in students' talk, we identified interpretative repertoires drawn on to characterize the teamwork and interpretations drawn on to characterize the team development intervention. Third, to analyze function, we investigated how these interpretative resources were generally taken up or rejected when presented in team discussions and whether or not they prevailed or were left by the wayside as the dialogues unfolded. Finally, we analyzed these dynamics in relation to general developments in the teams.

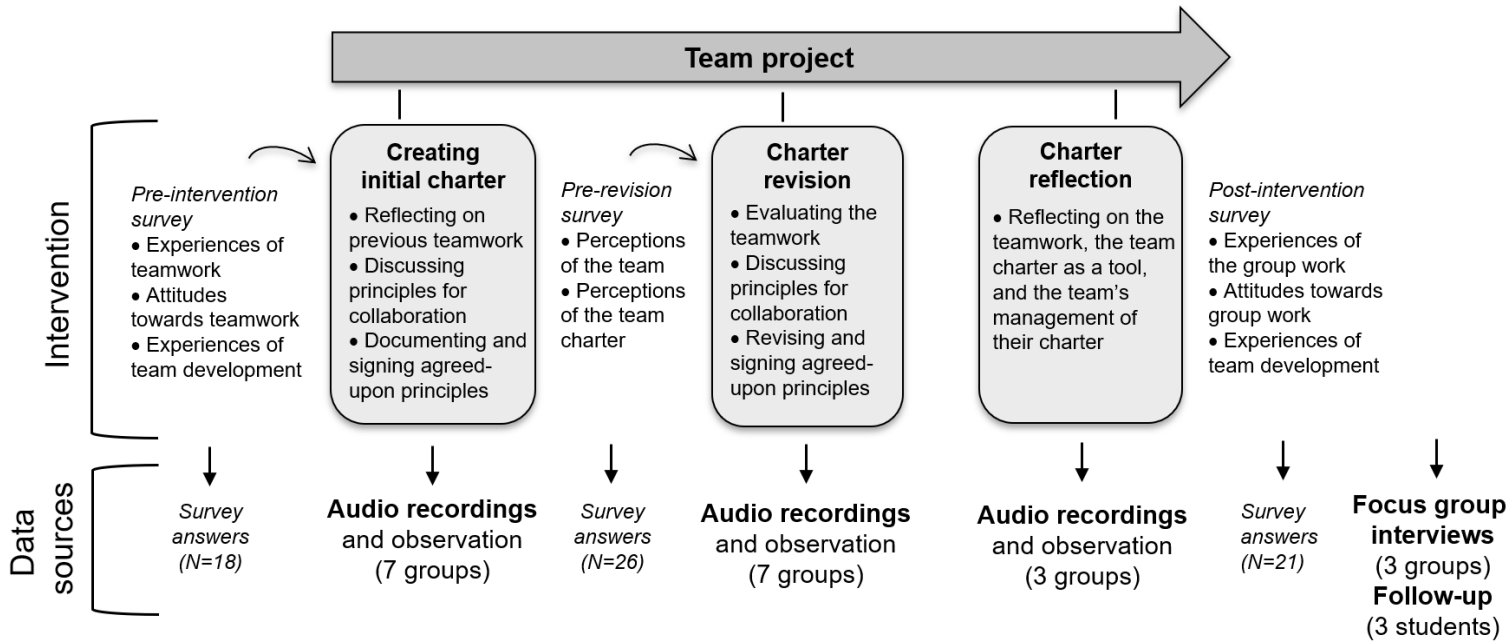

Figure 3: The team development intervention, including data sources for the study. The three main activities in the intervention as well as the most important data sources are marked in bold letters.

Through our analysis of team discussion and group interviews, we identified two overarching interpretative repertoires with which students generally interpreted their teamwork. Using these repertoires, the students constructed each other alternately as “friends” or “professionals”, and simultaneously worked towards establishing either informal or formal norms and relationships. Additionally, we found four more specific interpretations with which students made sense of the team development intervention, constructing it alternatively as: a meaningless assignment, a team-building exercise, a contract-writing process, and, finally, a process of continuous improvement. Through our analysis of function, we found how the friendship repertoire and the team building interpretation gradually gained more status as the authoritative ways to interpret and approach the teamwork and the team development activities. This meant that students who wanted to take on the teamwork and team development in a more formal manner had a hard time getting their opinions across, and that a more formal mode of teamwork was left by the wayside. A troublesome finding is that it was possible for the students to construct their talk about teamwork in a way that neutralized the potential of the team development activities to challenge the established social norms.

In terms of practical implications, our findings suggest that if engineering educators want to prepare students for professional teamwork, it is not enough to organize team projects and team development activities with inspiration from decontextualized design frameworks. Educators also need to consider the cultural construction of teamwork experiences, seeing as contingent group dynamics and social norms critically influence what kinds of teamwork can be realized. Specifically, we found that engineering teamwork experiences can become increasingly one-dimensional in settings where interpretative repertoires and their associated social norms have been settled to the point where they are taken for granted, serving as a barrier to experience new forms of teamwork. Here, a proper understanding of local cultural patterns and processes may inform better design choices in fashioning team development interventions. In the specific case of team development activities, educators should supply students with explicit help so that they themselves may articulate and scrutinize pre-established social norms. Furthermore, a cultural understanding may inform more comprehensive interventions aimed at changing the classroom culture in order to facilitate new kinds of teamwork experiences.

In terms of research implications, future work should further theorize the relationship between cultural patterns in engineering education and collaborative skills as a valued educational outcome. Specifically, our findings suggest that it

is important for discourse analytical work studying how students talk within and about engineering education to adopt culturally sensitive modes of discourse analysis, to give further insights into how different patterns of talk are interlinked, co-dependent, and mutually reinforced. Furthermore, an important task for engineering education researchers is to develop tools – realistically implementable for individual educators – for performing cultural analysis as well as for evaluating pedagogical (im)possibilities.

5.2.3. Paper 5: Authenticity work in higher education learning environments: A double-edged sword?

In Paper 5, I and my co-authors take our starting point in the proposed problem that students often fail to transfer what they have learned in engineering education to their professional practice. Two interconnected and often-proposed solutions to this are 1) that learning activities should be designed so that they *correspond* with engineering activities beyond academia, that is, that learning activities should be designed to be "authentic" (Newmann, Marks, and Gamoran 1996, Herrington and Oliver 2000, Strobel et al. 2013), and 2) that teachers should simultaneously encourage students to view learning activities as authentic and pedagogically appropriate (Petraglia 1998, Herrington, Oliver, and Reeves 2003, Woolf and Quinn 2009). While much work has focused on how to design for authenticity, we instead focus on teachers' *authenticity work*[26], that is, "the rhetorical work teachers engage in to establish their learning environments as authentic and pedagogically appropriate" (Paper 5, p. 3).

We investigate how such talk plays out in a project-based software engineering course, studying the nature and consequence of two teachers' – Jonas and Frank's – authenticity work. In the paper, we investigate the following research questions:

> *(1) What discursive strategies do the two teachers draw on to establish their learning environment as authentic and pedagogically appropriate?*
> *(2) What are the ideological consequences of their authenticity work?*

With "discursive strategies" here, we mean linguistic patterns serving to (re)construct the legitimacy or illegitimacy of certain engineering practices and pedagogical practices (Vaara, Tienari, and Laurila 2006). In looking for ideological consequences, we recognize that when certain practices are established as

[26] A term that we borrow from Peterson (2005), reinterpreted here for use in educational research.

legitimate and others as illegitimate, this has associated consequences for what social norms become established within engineering and engineering education.

In investigating our research questions, we combine ethnography with critical discourse analysis (Krzyżanowski 2011). In terms of data collection, I conducted 23 h of classroom observation, 5 interviews and meetings with Jonas and Frank, as well as 10 interviews with students. In our analysis, we analyzed discursive strategies through looking for recurring patterns in Jonas and Frank's talk about the nature and purpose of engineering, about the course and the events that transpired therein, as well as about the students and their actions[27]. Here, we paid particular attention to their attempts to shape the way in which their students talked about engineering and about the learning environment. Furthermore, to analyze the function of Jonas and Frank's authenticity work, we analyzed 1) what happened when certain discursive strategies were drawn on in student–teacher interactions, and 2) if and how students took up and/or rejected elements of Jonas and Frank's authenticity work.

Through our analysis, we discerned three discursive strategies involved in Jonas and Frank's authenticity work: *deficitization* of students and of academia, *naturalization* of industry practices, and *polarization* of academia and industry. Put briefly, naturalization of industry practices took the form of constructing value for customers as the primary goal for software engineering and constructing practicing engineers as appropriately focused on creating value. Deficitization of students and of academia took the form of constructing them as overly focused on technical and educational rigor, that is, as inappropriately valuing structure, clarity, and meticulousness in engineering and engineering education. Finally, polarization took the form of emphasizing the differences between industry and academia, constructing activities in the two domains as being worlds apart. These discursive strategies were employed in the classroom in order to renegotiate the local order of discourse (Fairclough 1992), in effect renegotiating the legitimacy ascribed to the learning environment and the students' engagement in the course. Finally, we found that students mostly reproduced, rather than rearticulated, elements of these discursive strategies at the end of the course. Taken together, these observations suggest that the teachers were successful in their authenticity work; it did indeed serve to

[27] Importantly, and in accordance with our discursive and socio-cultural perspective, we do not view these linguistic patterns as completely strategic and intentional. As we discuss more in the paper, we recognize Jonas and Frank as reproducing common assumptions found in research literature on engineering education.

legitimize their teaching method and gave students a vocabulary with which to relate their experiences in the course to their future professional practice. However, our analysis also illuminated that their authenticity work simultaneously jeopardized the space available for voicing critical reflections regarding the nature of engineering and engineering education.

The findings suggest that teacher talk about teaching methods, while well-intended, can have unintended consequences. Specifically, our findings suggest that critical thinking about engineering and about engineering education can be difficult to achieve in settings where there is a strong agenda to make connections to a specific version of professional engineering practice, as it is constructed for instance by educators, industry representatives, or – indeed – engineering education researchers. While teachers are often encouraged to bolster student engagement through talking about their teaching methods and emphasizing their strengths – for instance talked about in terms of "mitigating" student "resistance" to active learning (Tharayil et al. 2018)[28] – these assertions seem based in the assumption that doing so only means changing students' individual perception of engineering and of specific teaching methods. Our findings, however, suggest that engaging in authenticity work can be viewed as working towards discursive and, in effect, ideological reform. In short, we argue that teachers and researchers should be mindful of the way in which such cultural changes impact what professional and academic ideals are implicitly communicated to students.

In terms of research implications, we suggest that research on how students and teachers talk within and about engineering education would additionally benefit from drawing on critically reflective modes of discourse analysis. Specifically, we encourage researchers to critically scrutinize and reflect on implicit constructions of engineering and engineering education in talk and text on the topic of teaching methods. In terms of practical implications, we suggest that teachers may draw on critical pedagogy (see e.g. Breunig 2009) to develop discursive strategies for authenticity work that does not jeopardize opportunities to think critically about engineering and engineering education.

[28] We may note here that viewing "resistance" to learning as something to be "mitigated" by teachers is common in the higher education literature but that there are alternative ways in which to think about students objections to learning activities where this "resistance" is not viewed as only negative and illegitimate (Winkler and Rybnikova 2019, Abbot and Cook-Sather 2020).

5.2.4. Reflecting on my inquiry into cultural patterns and processes

In the last three papers, we primarily draw on and contribute to a culture-oriented style of problematization. In Paper 3, while I position my inquiry as a way to improve on how a specific teaching method is implemented, the theoretical development and findings point to the significance of learning context in determining the trajectory of students' learning experiences. Here, both students' individual conceptions and their shared ways of thinking and interacting can be seen as aspects of the setting in which learning takes place. Relating these findings to the overarching focus of the thesis – that is, proposed problems in engineering education and how they may be conceptualized – the findings again suggest that teaching methods *alone* do not determine educational outcomes. As such, exclusively analyzing educational designs will only get us so far in trying to account for proposed problems. Similarly, adopting new teaching methods will only get us so far in trying to improve engineering education.

In Papers 4 and 5, we focus fully on cultural patterns and processes, constructing these as integral to shaping learning trajectories. In Paper 4, we saw that while the shared interpretative repertoires with which students made sense of learning activities facilitated certain learning experiences and ways of interacting, they simultaneously served to close down alternative possibilities. In Paper 5, we found that the discursive strategies that the teachers drew on to legitimize their learning environments indeed also shaped students' engagement, learning experiences and – by extension – educational outcomes. However, while such teacher talk can thus be productive, it may simultaneously close down alternative pedagogical possibilities and might even teach students things that are problematic (e.g., learning not to question assumptions about engineering and engineering education).

Accordingly, findings from Papers 3-5 provide additional support for the assertion that contingent patterns of social interaction determine learning experiences and educational outcomes. Furthermore, they contribute to the pool of empirical findings regarding how cultural patterns and processes in engineering education can serve as barriers to learning, showing how they play a role in the (re)production of education problems. In Paper 4 and 5, the dominance of specific patterns of discourse over others is illuminated as a central mechanism in bringing about such adverse effects. Here, again, we find indications that different interests and different educational objectives can come into conflict with one another, forcing educators to make trade-offs and prioritizations as they engage with educational problems and educational development. For example, in Paper 5 we illuminate that the goal of

enculturating engineering students into contemporary engineering practices may come into conflict with the goal of developing critically reflective engineers.

6. Discussion

Before moving ahead to discuss findings and theoretical development taken together, I want to reiterate the background of this thesis: There are many aspects of engineering education continuously put forth by educators and researchers alike as being problematic, states of affairs that seem difficult to change despite prolonged efforts and despite educators' best intentions. Here, working to supply tools and perspectives that teachers and educational developers can employ as they try to improve engineering education is clearly an important task for engineering education researchers. In this context, it is regrettable that the assumptions we make in attending to educational problems and educational development often remain implicit.

In this thesis, I have characterized two styles of problematization often drawn on in engineering education research, viewing educational problems as caused by inadequate teaching methods or as caused by problematic cultural patterns and processes. Furthermore, I have presented findings from my empirical work focused on teaching methods and cultural patterns and processes within engineering education. Two aspects of these findings are particularly relevant to consider when continuing to interrogate how educational problems and educational development is conceptualized and approached in engineering education research.

First, the findings demonstrate how both teaching methods and cultural processes may act to constrain learning experiences and outcomes, thus directly connecting them to the production of educational problems. These findings suggest that if we want to develop research-based responses to educational problems, we need to investigate both teaching methods and engineering education culture. Likewise, we need to develop tools and perspectives on working with both educational redesigns and cultural change. To do so, more complex inter-relationships between teaching methods, culture, and educational outcomes need to be imagined, that is, more complex than constructing educational problems as caused only by teaching methods or cultural processes. An important question in this context is how research focused on teaching methods and research focused on culture can be strategically combined.

Second, the findings demonstrate that there are usually prioritizations, trade-offs and – indeed – value-judgement involved in teaching and educational development. Unfortunately, these value-judgements are not always recognized and are, conversely, sometimes even actively obscured by rhetorical strategies employed

when talking about engineering education and its problems. An important question in this context is how engineering education research can help teachers and educational developers to interrogate and navigate the normative aspects of attending to educational problems.

These two questions are explored further below, relating both to findings from the appended papers and to perspectives on educational development presented in previous work. After having explored these questions, I then turn to discuss theoretical and practical implications of my work, outline some its limitations, and – finally – look forward to future research. As has been the case for major parts of this thesis, I here focus primarily on my work taken as a whole and discuss it at the level of problematizations drawn on engineering education research.

6.1. Combining the two styles of problematization

Recognizing that both teaching methods and cultural processes shape educational outcomes, research strategically combining a focus on teaching and culture is well-positioned to produce findings that can help teachers and educational developers to improve engineering education. As has been previously indicated, it is not uncommon for engineering education researchers to give at least some attention to both teaching methods and contextual contingencies in their investigations. However, what can be found through such investigations depends critically on what is foregrounded – that is, constructed as main or independent factors – and what is backgrounded – that is, constructed as (just) mediating or moderating factors. Another crucial characteristic of such combinations is how thickly each aspect is theorized. Below, I outline and reflect on two alternative combinations, relating both to previous work and my own investigations in Papers 3 and 4.

A first alternative is to take teaching methods as a main explanatory factor and to position cultural processes as having a mediating or moderating role in shaping learning experiences and outcomes. See Figure 4 for a stylized model of this approach. In Paper 3, I drew on such a combination of teaching methods and cultural processes in positioning students' difficulties with doing entrepreneurship as a moderating variable in experiential learning.

Constructing the relationship between teaching methods and educational outcomes in this way is not uncommon, and investigations structured in this manner is sometimes referred to as serving the purpose of opening up the "black box" of teaching methods (see e.g. Stöhr and Adawi 2018). As compared to constructing educational problems as dependent on teaching methods and

teaching methods alone (see Figure 1 in section 3.1), combining a focus on teaching methods with a focus on some contextual and/or social dynamic in this way facilitates further specification of the relationship between teaching and educational outcomes. In such investigations, it is possible to move beyond statements such as "Teaching method X has the (undesirable) effect A" to statements akin to "Teaching method X has the (undesirable) effect A, given the condition B". Similarly, through such investigations, educational design recommendations can be further specified, working towards statements akin to "If you want A, and you believe that you are in a situation B, then you ought to do X" (Niiniluoto 1993, p. 12). As such, teachers can be better guided on how to take the particularities of their specific context into consideration when striving towards bolstering specific educational outcomes.

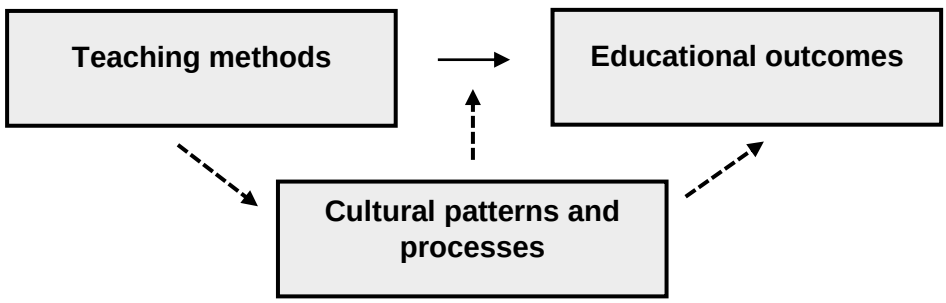

Figure 4: A stylized conceptual model constructed in and through research accounting for learning (and educational deficits) in terms of teaching methods mediated/moderated by context and social dynamics

In moving forward with such research, the findings presented in this thesis suggest that it would be useful to adopt a cultural vocabulary in theorizing social dynamics and contextual contingencies. Approaching established social dynamics as being potentially meaningful for students and teachers – as opposed to being coincidental or based in misunderstandings or inability – facilitates further understanding of why certain social dynamics are observed in a specific setting. Moreover, a cultural analysis may provide further insight into how social dynamics are interlinked in a complex whole, how they may be changed, and/or why there might be legitimate reasons for not changing them.

A promising second alternative, is to approach a combination from the cultural side, that is, to foreground the role of cultural patterns and processes in shaping educational outcomes and producing educational problems. Here, teaching methods may be understood as a mediating or moderating variable. The major

difference here is that cultural patterns and processes are recognized for their *direct* consequences for educational outcomes, as well as their direct role in the production of educational problems. See Figure 5 for a stylized model of this approach. This approach is particularly promising in light of the uneven status of teaching methods-oriented and culture-oriented research in extant work. In Paper 4, I drew on such a combination, describing how teamwork unfolded in student groups on a technical bachelor's program as a consequence of pre-established social norms and salient interpretative repertoires, finding how a set of team development activities designed to intervene in the process of forming social norms seemed to reinforce rather than challenge them.

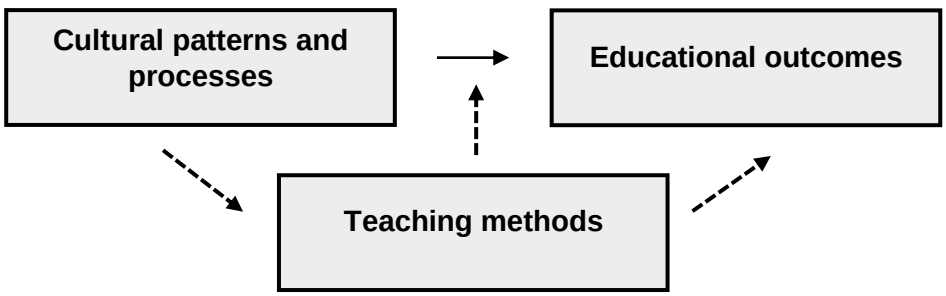

Figure 5: A stylized conceptual model constructed in and through research accounting for learning and educational deficiencies in terms of cultural patterns and processes mediated/moderated by intentional interventions by teachers

Beyond constituting a needed alternative to teaching methods-oriented research, research following such a combination can also serve as a complement to certain exclusively culture-oriented research projects. Specifically, such investigations may serve as a complement to culture-oriented research that studies everything that goes on in a certain learning environment, where no specific interventions made by teachers or educational developers is zoomed in on (cf. Figure 2 in section 3.2.). In some culture-oriented research, teachers' actions are not necessarily considered in light of pedagogical intentions and can appear completely unreflective and unintentional, completely shaped by social structures. In critiquing parts of extant work taking a cultural perspective on educational problems, Philip and Gupta (2020) argue that we need to "move beyond assertions that historical, social, political, and economic processes shape and influence individuals in some underspecified or overly deterministic manner" (p. 196). That is, in studying engineering education as a cultural process, we need to stay aware that "people are always repurposing tools, reimagining themselves, renegotiating relationships, and improvising with practices and ideologies that may appear otherwise static and inevitable" (p. 196). In research addressing

educational problems and change, such assertions seem particularly important to keep in mind, seeing as a one-sided emphasis on the structural determination of educational outcomes affords little focus on the agency of educators and reformers. If this relationship between structure and agency is not properly addressed, culture-oriented research risks giving little input on how educators and reformers may act to try to take control of their situations.

Additional sets of research possibilities are afforded by centering engineering education research on purposeful interventions made by teachers while at the same time seeing these as interventions into an existing social field. While culture-oriented research *in general* can help teachers and reformers reflect on existing social arrangements, a focus on specific purposeful interventions can help to locate *specific* aspects of how they – or others – approach engineering education and stimulate more concrete reflections. Furthermore, combining these perspectives can help in studying unintended consequences of actions imbued with pedagogical purpose, including unintended consequences of ongoing attempts to intervene in cultural processes. This can again make research-informed recommendations and reflections more detailed.

6.2. Interrogating value-judgements in educational development

Findings from the appended papers additionally suggest that in order to support teachers and educational developers in their efforts to improve engineering education, it is not enough to make the interrelationships between teaching, culture, and educational outcomes more explicit. It is also necessary to develop tools and perspectives focused on interrogating and navigating the value-judgements involved in educational development. Before discussing how such value-judgements have been treated in extant work, I first describe the role educational research can play in this context, drawing on an oft-cited line of argumentation presented by Biesta (2007).

6.2.1. The technical and cultural role of educational research

Borrowing two terms from De Vries (1990), Biesta (2007) argued that educational research can play both a *technical* role and a *cultural* role in informing educational decisions and development. First, the technical role here refers to the ability of educational research to develop techniques, interventions, and strategies to make educational practice more *effective* in bringing about a certain set of educational outcomes. Engineering education research focused on educational problems has often positioned itself in this manner, striving to make educational practice more effective – through developing and evaluating teaching methods (Prince 2004, Freeman et al. 2014, Deslauriers et al. 2019) – and educational development more effective – through developing strategies for

successful implementation of reform initiatives (Clark et al. 2004, Borrego and Henderson 2014). Foregrounding this ambition casts engineering education research as an applied field of research (Niiniluoto 1993, Romme 2003), close to the field of engineering itself. This idea is encapsulated, for instance, in talk about developing a more "evidence-based" educational practice in engineering education (Wankat and Bullard 2016, Bubou, Offor, and Bappa 2017).

Biesta (2007) argued, however, that this is not the only role educational research can – or, indeed, should – play in informing educational decisions and development. Biesta summarizes the insufficiency of educational research serving just a technical role as follows:

> evidence-based education seems to favor a technocratic model in which it is assumed that the only relevant research questions are questions about the effectiveness of educational means and techniques, forgetting, among other things, that what counts as 'effective' crucially depends on judgments about what is educationally desirable (p. 5)

Seeing as prioritizations among different potentially desirable outcomes are often involved in educational development, not only questions of effectiveness, educational research can also play a cultural role in informing educational decisions and development (De Vries 1990). That is, educational research can help teachers and educational developers reinterpret and reimagine engineering education practice, including the social arrangements and value-judgements on which it is based. This is a particularly important role for engineering education research to play in light of the value-conflicts teachers and educational developers can encounter in their work, and in light of the value-negotiations they need to engage in.

That is, engineering education research attending to educational problems can ideally help teachers and educational developers become both effective and critically *reflexive* as they go about teaching and reforming engineering education (Bleakley 1999). More than informing effective educational design decisions, engineering education research can help actors question their own as well as others' assumptions about engineering education, including assumptions perpetuated in policy and – indeed – in engineering education research.

6.2.2. From values-obfuscation to values-clarification

Regrettably, research drawing on the dominant style of problematization, focused on teaching methods, is not well-positioned to engage with the value-judgements involved in educational development. Conversely, rhetorical

strategies employed in extant research writing may even serve to obscure the normative dimensions of educational development.

This tendency, which we may call *values-obfuscation*, is particularly pronounced in research drawing on a teaching methods-oriented style of problematization. Here, instructional reform is often made out to be a necessary response to developments in the engineering profession, positioning the adoption of new teaching methods as a way to keep up with the times. Common arguments here include that there is a "increasing pace of change" (Mitchell 1998, p. 23) in technological industries, which implies that engineering graduates need to become increasingly "innovative, flexible and entrepreneurial" (Grimson 2002, p. 33), which in turn implies that new teaching methods should be adopted. In reflecting on such arguments, Dishon (2021) notes that "such a framing conceptualizes education mainly in instrumental terms, as a form of reaction to external developments in society, at the expense of education's traditional role of shaping society" (p. 166). We noted a similar tendency to conceptualize education in instrumental terms in the talk of the two teachers in Paper 5 as they attended to educational problems. The main normative assumption in that case was that engineering educators should help to perpetuate engineering as it is currently done outside of academia, rather than act to critically scrutinize established engineering practices and help their students to do the same. While we could see this case as an exception to the rule, it seems reasonable to suggest that we should be mindful of the prioritizations and value-judgements built into all course designs and all educational reforms (Cuban 1990, Shulman 2005, Biesta 2007). Here, Simon (1987) reminds us that "[t]o propose a pedagogy is to propose a political vision" (p. 371).

The risk that these value-judgements and political visions are obscured in discussion of educational development points to the importance of educators, educational developers, and – indeed – engineering education researchers developing an aptitude for interrogating questions of what is educationally desirable as seen from multiple perspectives. Here, it may be useful to suspend educational decisions and engage in teasing out the value-judgements at hand, that is, to engage in *values-clarification*. Interrogation the specific example of responding to an increased pace of change by fostering more flexible and innovative graduates, for instance, it is possible to imagine a few alternative responses. First, we could consider whether an increased pace of technological change, regardless of what this change consists in, is necessarily something we want to contribute to. Second, we could consider whether developing personal flexibility is the best or most fair way to help students manage contemporary

working life (see e.g., Gillies 2011 for a critique of this idea). Having openly considered such alternatives, we may well still proceed to conclude that it is desirable to emphasize fostering innovative, flexible, and entrepreneurial graduates. However, this decision-making process has then, ideally, become more open to communal deliberation.

6.3. Implications for engineering education research

The primary implications of the thesis relate to research aiming to understand educational problems in engineering education as well as research and aiming to support educational development. In this context, findings from the appended papers and the critical scrutiny of previous work undertaken in this comprehensive summary suggest that there is a dual value in adopting a vocabulary of cultural analysis when investigating engineering education practice.

First, recognizing and investigating cultural patterns and processes as shaping educational outcomes can help develop new strategies for engineering education development, which have otherwise mostly focused on reforming teaching methods (Stolk, Somerville, and Chachra 2008, Henderson, Beach, and Finkelstein 2011, Rodriguez-Mejia et al. 2020). The take-away here is not that teaching methods play no part in determining educational outcomes and that theories of educational problems should not take educational design into consideration. Instead, the findings suggest that when inquiring into educational problems in engineering education, both teaching methods and cultural processes need to be taken into account. However, given the so far dominant status of a teaching methods-oriented style of problematization, engineering education researchers might additionally benefit from rethinking the *relative* significance of teaching methods and of cultural processes in shaping educational outcomes and producing educational problems. Here, imagining and investigating more complex interrelationships between teaching, culture, and educational outcomes is important.

Second, adopting a vocabulary of cultural analysis may be useful in developing tools and perspectives for clarifying value-judgements and managing value-conflicts involved in educational change. Here, engineering education research can do more to help teachers and educational developers develop critical reflexivity in their work. This is an underexplored area of engineering education research, particularly when comparing to the general field of higher education pedagogy, where this has been emphasized more strongly (Henderson et al. 2008).

Recognizing that the assumptions made when attending to educational problems have a variety of consequences, it is important that engineering education researchers sharpen their critical reflexes and are mindful of their rhetorical strategies when reading and writing about problems in engineering education. The central question set out by Bacchi (2009) in her work on policy analysis is useful in this context, encouraging researchers to not take accepted problem definitions for granted, but instead ask: "What is the problem represented to be?". Recognizing that a teaching methods-oriented style of problematization currently dominates the field, this critical reflex is particularly useful when reading about instructional reform and new teaching methods. Here, we may be mindful that we could make other assumptions as to what is missing in engineering education, for instance, a continuous interrogation into cultural and contextual conditions for learning. Furthermore, it is useful to keep in mind that it might be possible to reimagine, and perhaps renegotiate, the implicit value-judgements on which educational reform agendas are based.

In Paper 3, I proposed that theoretical triangulation – or, using a simpler term, strategic perspective-taking – is one way in which researchers may build such reflexivity into their empirical work. While I in the paper proposed that cognitive, socio-cultural, and critical theories of *learning* taken together are useful when studying difficult learning situations, I here additionally want to stress the value of relating to competing theories of *education* when addressing educational change. While there are many connections between theories of learning and theories of education, they are not exactly the same. Specifically, a language of learning, learning objectives, intended learning outcomes and strategies for facilitating learning does not necessarily afford discussions of educational institutions, traditions and purposes (Biesta 2004). Specifically, relating to a variety of perspectives on education and educational research can be useful when interrogating normative assumptions embedded in engineering education research. This may include, for instance, assumptions made in research writing about the nature of engineering education practice (e.g., a set of modular teaching interventions vis-à-vis a cohesive social and cultural system) as well as its purpose (e.g., fostering engineering scientists, engineering managers, and/or engineering citizens, cf. Stonyer 2002).

6.4. Implications for engineering education practice

The most straightforward implications for practice concerns engineering education institutions' continuous work with development and reform. Painting one picture of contemporary reform agendas, Graham (2018) interviewed 178 actors involved in the running of "world-leading" engineering programs, asking

about the global state of the art and the future of engineering education. The main reform tasks that Graham sets out for engineering education institutions is to start delivering active learning "at scale", that is, to intensify current efforts towards teaching methods reform. Watson and Froyd (2007) put forth an important question to consider in this context: "Should the magnitude of current interventions be significantly increased or should they be fundamentally altered?" (p. 20). There is no doubt that it may be beneficial to scale up reform efforts focused on teaching methods, however, as has been shown and argued in this thesis, this will not be enough. Rather, engineering education institutions may also benefit from *diversifying* their efforts to improve, engaging in both curricular redesign and projects fostering cultural change and community building.

A second area of practical implications concerns helping engineering educators make their practice both effective and critically reflexive. Given that teaching methods have enjoyed a considerable status and legitimacy in extant work, it seems especially important to also supply educators with tools for thinking critically about teaching methods and tools for reflecting on the particularities of the socio-cultural setting in which they operate. This is an important task for those who work with preparing teachers for teaching, striving to offer multiple perspectives on learning and – importantly – *education* in courses on higher education pedagogy. It is, however, unlikely that this will be enough. Given the limited time available, and the complexity and depth of perspectives available in educational research, theories risk getting treated rather instrumentally in such courses (Loughlin, Lygo-Baker, and Lindberg-Sand 2021). Thus, conditions and incentives need to be put in place so that teachers may deepen their understanding over time, for instance through organizing recurring forums for joint reflection on teaching practices, local (socio-cultural) contingencies, educational reform agendas, as well as educational theory and research.

6.5. Contributions

In this section, I outline the primary contributions of the thesis. First, I describe the contributions made in the appended papers. Second, I describe additional contributions made in this comprehensive summary.

Through my early work, I have contributed to a better understanding of the relationship between educational design choices and some desirable educational outcomes that are often put forth as lacking in engineering education. Through tapping into the experiences of teachers and students, I have illuminated specific design choices, such as who are allowed a say in framing engineering projects, and linked these to specific educational objectives, such as preparing students

for professional practice. Furthermore, I have highlighted some trade-offs that educators need to navigate in designing their courses and have suggested that these trade-offs may be reconciled under the right circumstances.

Through my later work, on a general level, I have contributed to a better understanding of the relationship between engineering education culture and its educational outcomes. Through observing and interacting with students and teachers over time, I have illuminated specific cultural patterns, such as the continuous reinforcement of established social norms, and have connected these to specific educational problems, such as developing collaborative competences among engineering graduates. Furthermore, I have connected the trade-offs and prioritizations teachers face to matters of ideology, suggesting that educational (re)design is not just a matter of effectiveness, but also a matter of prioritizing certain professional and academic ideals over others.

A number of additional contributions have been made possible by discussing these findings taken together in this comprehensive summary. First and foremost, I have elucidated two ways of conceptualizing educational problems that have been frequently and implicitly drawn on in engineering education research, focusing alternatively on inadequate teaching methods and problematic cultural processes. I have discussed these as two "styles of problematization" (Bacchi 2009), introducing an underutilized vocabulary in engineering education research. Using this vocabulary, I have demonstrated tools with which we may deconstruct our own as well as others' talk about what is wrong with engineering education, in order to identify and clarify underlying assumptions. In this context, the four stylized models of research attending to educational problems (see Figure 1, 2, 4, and 5) constitute an additional contribution, together forming a tentative taxonomy which may be used to analyze specific research articles and/or research topics concerned with educational development. The two latter models, furthermore, can serve to guide researchers in designing research projects that combine a focus on teaching methods with a focus on cultural processes.

Finally, I have described problems faced by engineering education research in light of the unequal status of a teaching methods-oriented and a culture-oriented style of problematization. Specifically, I have questioned whether the emphasis on developing teaching methods really reflects the relative significance of teaching methods vis-à-vis cultural patterns and processes in producing educational problems. Furthermore, I have identified some common rhetorical figures in teaching methods-oriented research – constructing engineering instruction as uniformly misaligned with effective teaching and positioning the

role of education as one of simply keeping up with the times – and have questioned both the veracity and consequences of the assumptions underlying these rhetorical figures. All in all, I have argued that the way in which we talk about what is wrong with engineering education – not clarifying assumptions and value-judgments – might act as a barrier for productively engaging in educational development.

6.6. Limitations

In the thesis, I have argued that there is an overemphasis on teaching methods in engineering education research. One grounding point for making such an argument has been empirical findings put forth in the appended papers, suggesting that cultural patterns and processes might be just as significant – if not more – in shaping learning experiences and educational outcomes. However, it needs to be recognized that the data collection for the appended papers was conducted primarily in learning environments where teachers had reasonably clear pedagogical intentions with their educational designs. Had the same research been conducted in other learning environments, the teaching methods used in these settings might have been perceived as being a more important bottleneck, the leverage point in which efforts to improve could do most immediate difference.

Furthermore, while I in the thesis have reviewed and analyzed previous work in order to interrogate problematizations in engineering education research, a *systematic* review and analysis of literature has not been put forth[29]. While my analysis here is supported by argumentation and – to some extent – literature review put forth by others (primarily Stolk, Somerville, and Chachra 2008, Godfrey and Parker 2010, Henderson, Beach, and Finkelstein 2011, Rodriguez-Mejia et al. 2020, Strubbe et al. 2020), more definitive claims about the use of a teaching methods-oriented vis-à-vis culture-oriented style of problematization could have been made on the basis of a systematic literature review.

Finally, a cohesive assessment of how educational problems are treated in engineering education research should recognize that research articles are not the only manifestations of engineering education research. Thus, how problems are accounted for in research articles does not necessarily reflect how problems are approached by engineering education researchers in other aspects of their work. Indeed, empirical findings from Beddoes (2011b) point towards inconsistencies

[29] Cf. Beddoes (2011a) who make a systematic literature review focused on problematization of one particular issue, underrepresentation of women in engineering.

between research writing and research talk. After having reviewed problematizations of underrepresentation in engineering education research articles, Beddoes (2011b) compared how this problem had been approached in literature to how 15 engineering educators framed underrepresentation in interviews. While research articles often drew on the argument that increasing diversity is important for economic competitiveness, such arguments were not as often made in the interviews. In short, research articles can be seen as a specific research genre and there might be certain ways to write about engineering education that "educators may feel compelled to perpetuate in publications" (p. 5). As such, while I have identified a need for further reflection on cultural patterns and processes in research articles, this does not mean that engineering education researchers do not reflect on cultural processes and patterns in activities such as advising teachers or evaluating local reform initiatives.

I do not believe, however, that these limitations invalidate the arguments I have made in the thesis. As for the particularities of the research settings: While the empirical investigations pointed towards the significance of cultural patterns and processes in shaping learning experiences and educational outcomes, there is no shortage of research recognizing that culture matters in learning (Lave and Wenger 1991, Gee 2000, Philip et al. 2018, Handford et al. 2019). As for the review of literature: Even if stronger claims could have been made on the basis of a systematic literature review, there is no doubt that there *is* research in which teaching methods vis-à-vis engineering culture is constructed as important factors in creating certain educational problems. As for the relative status of the two styles of problematization, I am, again, not alone in claiming that teaching methods have enjoyed more attention (see e.g., Stolk, Somerville, and Chachra 2008, Rodriguez-Mejia et al. 2020, Strubbe et al. 2020). Furthermore, there is some evidence from systematic reviews that research in the area of science, technology, engineering and mathematics education have focused intensely on developing and evaluating teaching methods (Henderson et al. 2008, Henderson, Beach, and Finkelstein 2011). As for the use of problematizations in research articles vis-à-vis in other research genres: Although research articles may not reflect how problems are approached in all research activities, articles are undeniably an important research genre, with a particularly high status. Furthermore, the value of the observation that researchers, in their articles, often account for educational problems in terms of teaching methods does not completely hinge on the representativeness of research articles for the totality of engineering education research. If there are problematizations that engineering education researchers feel "compelled to perpetuate" (Beddoes 2011b, p. 5) in

their research articles, we still have reason to interrogate why this is the case and what this means for engineering education research.

6.7. Future research

Seeing as engineering education research can play an important role in informing educational development, ideally supporting both effective and critically reflexive teaching, there is a clear need for research that further interrogates problematizations in engineering education research. Extant reviews of engineering education research have, among other things, reviewed topics addressed in research articles (Jesiek et al. 2011), reviewed the literature starting from a particular topic (Morelock 2017), and reviewed the use of certain research methodologies (Koro-Ljungberg and Douglas 2008). While Borrego, Foster, and Froyd argued in 2014 that researchers should make their reviews more systematic, and while an increasing number of systematic literature reviews have been published since then, I here also want to emphasize the need for *critical* assessments of engineering education research. Adopting methodologies underpinned by critical theory, such reviews may contribute to 1) elucidating implicit assumptions perpetuated in and through engineering education research and 2) scrutinizing the potential consequences of these assumptions.

As for the critical review that has been undertaken in this thesis discussion, making a systematic version of such a review could give more definitive answers about the implicit assumptions engineering education researchers make when we 1) talk about what is wrong with engineering education, and 2) attend to educational problems empirically. Systematically reviewing the literature on engineering education *reform* from this perspective would be especially useful, in order to directly engage with the questions pertaining to the development of engineering education. While engineering education reforms have been reviewed from a historical perspective (Seely 2005, Jamison, Kolmos, and Holgaard 2014, Edström 2018), and while parts of the literature on *instructional* reform have been reviewed (Henderson, Beach, and Finkelstein 2011), the broader literature on reform initiatives, including those that are cultural rather than curricular, has not been systematically reviewed[30]. Likewise, a systematic and critical review of the research on highly prominent teaching methods seems

[30] At the very least, I could find no such review published in Journal of Engineering Education, European Journal of Engineering Education, International Journal of Engineering Education, Australasian Journal of Engineering Education, or Advances in Engineering Education, when searching Scopus 2021-11-09 for papers that had the terms engineer* AND review* AND (reform* OR change*) in their title, abstract or keywords.

especially timely. Starting from the findings put forth in this thesis, a specific topic to be investigated in such reviews is the extent to which trade-offs, prioritizations and value-judgements have been explored in the context of educational design and development. A tentative hypothesis here is that both 1) possibilities left by the wayside and 2) unintended – as opposed to just intended – learning outcomes of instructional change have not received much attention.

To move these discussions closer to practice, a third important area for future research concerns investigating how engineering educators and educational developers talk and think about educational problems and educational development. The work of Beddoes (2011b) and Breslin and Camacho (2021) constitute some first examples here. Going forward, it would additionally be useful to study the actual consequences of rhetorical strategies employed in talking about educational problems and educational development, in terms of for instance ability to navigate and resolve value-conflicts encountered in reform projects.

A final topic that needs further attention is the support given to teachers in engineering education. As outlined by Henderson et al. (2008), helping teachers to become critically reflective has received much less attention in engineering education research as compared to the general field of higher education pedagogy. It is important to investigate, for instance, what perspectives on learning and education are emphasized in higher education pedagogy courses and what participants and facilitators in such courses construct as the nature and purpose of engineering education pedagogy. A question to be investigated in such work is whether engineering educators are given tools to develop both effectiveness and reflexivity in their teaching practice.

7. Conclusion

The notion that research can be useful in the development of engineering education practice is a rasion d'être for engineering education research. In this context, it is arguably important to develop an awareness of how we – that is, engineering education researchers – think and talk about what is "wrong" with engineering education.

In this thesis, I have outlined and compared two styles of problematization implicitly drawn on in engineering education research, focused on teaching methods as well as cultural patterns and processes. Here, a teaching methods-oriented style of problematization has enjoyed a particularly prominent status in engineering education research, while a culture-oriented style of problematization has only recently gained traction. Through reviewing previous research and presenting the work I have undertaken informed by these problematizations, I have illuminated the implications of putting either teaching methods or cultural patterns and processes center stage when trying to understand the learning that happens, or does not happen, in engineering education.

The findings suggest that both teaching methods and cultural patterns and processes can serve as barriers to achieving desired educational outcomes. As such, strategically combining a focus on teaching methods with a focus on cultural processes is a promising avenue for engineering education researchers to take in trying to inform educational development. The findings further suggest that addressing educational problems often involves making value-judgements, prioritizing certain educational outcomes over others. As such, teachers and educational developers alike may be served by interrogating their own value-judgements as well as those of other actors, making processes of educational development more open to critical deliberation. A first step for engineering education researchers to take in supporting such values-clarification is to be more upfront with the assumptions we make when we talk about what is wrong with engineering education.

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