THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Towards Entrepreneurial Engineering Pedagogy

Exploring the Unsettled Trajectories of Entrepreneurial Projects

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Abstract

Background: Contemporary perspectives on engineering education have featured repeated calls for development of entrepreneurial ways of practicing engineering among engineering graduates, and entrepreneurial engineering pedagogy has recently become a burgeoning research topic. Previous work on entrepreneurial engineering pedagogy has proposed engaging students in self-directedly framing and tackling of real-world projects, in connection to external stakeholders. While there are empirical accounts of such *entrepreneurial projects* in engineering education, little is known about how educators design and implement such projects and how students experience them.

Purpose: The thesis investigates entrepreneurial projects as a pedagogical framework in engineering education and sets out to *i)* inductively identify pedagogical models for designing and implementing entrepreneurial projects in engineering curricula, and *ii)* to study these pedagogical models in action, particularly challenges and how they are mitigated through scaffolding.

Methodology: The three studies presented in the thesis employ qualitative research approaches based in multi-case study and ethnographic methods in learning environments where engineering students are engaged in entrepreneurial projects. In the first study, educators were interviewed regarding the pedagogical models they use to infuse entrepreneurial experiences into project-based courses. The second two studies draw on in-depth ethnographic data, with an interest in what students deem challenging about entrepreneurial projects and how teachers provide continuous and contingent support.

Findings: Three pedagogical models for designing and implementing entrepreneurial projects were identified, all underpinned by an ambition to engage students in co-creating new knowledge together with external stakeholders. Tensions between students' habitual ways of taking on curricular projects and the ways of practicing espoused by teachers were identified, causing students to struggle with connecting to externals and with sense-making the projects in light of their previous experiences. As such, the pedagogical models seemed to offer *unsettled trajectories* towards knowledge co-creation. Teachers were found to navigate these trajectories through arranging opportunities for reflection upon and negotiation of disciplinary practices.

Conclusion: While previous work has put forth self-directed and impact-seeking projects as integral for supporting an entrepreneurial way of practicing engineering, the studies presented in the thesis suggest that students do not necessarily move seamlessly into taking on such projects. The thesis calls both for more ethnographic investigations and for more cross-case analyses of how engineering students are engaged in curricular knowledge co-creation, and how the unsettled trajectories of entrepreneurial projects are experienced by students and scaffolded by teachers.

Keywords: engineering education, entrepreneurship, pedagogical models, project-based learning, situated learning, scaffolding

List of appended papers

Paper 1: Hagvall Svensson, O., Adawi, T., Lundqvist, M., & Williams Middleton, K. (2019). Entrepreneurial Engineering Pedagogy: Models, Tradeoffs and Discourses. Paper submitted to and under review in *European Journal of Engineering Education* in April 2019.

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. An earlier version of this paper (listed under other relevant papers) was presented at the 45th European Society for Engineering Education (SEFI) Conference 2017.

Paper 2: 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*.

Sole contributor in conceiving, carrying out and writing up the study.

Paper 3: 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*. Was awarded best research paper.

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-author.

Other relevant papers

Journal paper:

Kohn Rådberg, K., Lundqvist, U., Malmqvist, J., & Hagvall Svensson, O. (2018). From CDIO to challenge-based learning experiences – expanding student learning as well as societal impact? *European Journal of Engineering Education*, DOI: 10.1080/03043797.2018.1441265

Conference 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*

Burden, H., Steghöfer, J.P., & Hagvall Svensson, O. (2019). Facilitating Entrepreneurial Experiences through a Software Engineering Project Course. Paper accepted and to be presented at 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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Last but not in any way least, thank you **Maja**, my Kathy with a K.

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1. Introduction

Having spent a few years in an engineering education research community and an entrepreneurship education research community, and teaching entrepreneurship in an engineering context, I focus this thesis on *entrepreneurial projects* as a pedagogical framework. I position entrepreneurial projects as an area of common interest, seeing that scholars in both communities have looked to *project-based learning* with hopes that it may better prepare students for the complexities and ambiguities of professional practice (Jones and English, 2004, Pittaway and Cope, 2007, Mäkimurto-Koivumaa and Belt, 2016, Wheadon and Duval-Couetil, 2017, Cooper et al., 2004). In the engineering education context — the main setting for this thesis — a salient argument is that an entrepreneurial way of practicing engineering is needed (Byers et al., 2013), and that this is best developed, or can only be developed, through action-taking, team work, working with real problems, conceiving new solutions, and collaborating with stakeholders (Creed et al., 2002, Mäkimurto-Koivumaa and Belt, 2016, Wheadon and Duval-Couetil, 2017). Further, it is argued that project-based learning (Blumenfeld et al., 1991, Helle et al., 2006) is a relevant pedagogical framework (Goodyear, 1999, Nunes and McPherson, 2003) to be utilized, because it may engage students in self-directed learning and connect them with authentic professional practices beyond the classroom (Mäkimurto-Koivumaa and Belt, 2016). This argument is in line with the premises of a *situated view of learning* (Lave and Wenger, 1991, Brown et al., 1989), asserting that becoming a professional is a matter of participating in professional communities, and consequently, that learning should not be separated from authentic practice.

As will be detailed below, I align my investigation with a *broad approach* to entrepreneurship education (Ball, 1989). Consequently, what is put under investigation in this thesis is not project-based entrepreneurship courses given to engineering students, but rather project-based engineering courses that by virtue of making certain real-world connections and putting students in certain roles can qualify as entrepreneurial. Before elaborating on the types of projects that are intended, and the purpose and approach of the thesis, I will anchor the focus on entrepreneurial projects in considerations related to engineering education and entrepreneurship education.

1.1. The entrepreneurship educator's stake: developing entrepreneurial pedagogy

In the entrepreneurship education community, the entrepreneurial project serves as a particular answer to a practical problem: *How do we foster an enterprising culture through education across all disciplines?*

Entrepreneurship can be and has been embedded into curricular activities with a number of different goals (Mwasalwiba, 2010). Heinonen and Poikkijoki (2006) outline three main goals: learning to understand entrepreneurship, learning to become entrepreneurial, and learning to become an entrepreneur. Entrepreneurship has traditionally been taught primarily at business schools, with a focus on learning *about* the new venture creation process and about business planning (San Tan and Ng, 2006, Neck and Greene, 2011). However, in the last decades, entrepreneurship education has increasingly been discussed as a campus-wide responsibility (Laukkanen, 2000), focusing on fostering more enterprising individuals in all disciplines (Gibb, 2002). This aligns with what has been called a broad approach to entrepreneurship education — in contrast to a narrow one, which focuses specifically on the development of capacity for starting up new businesses (Ball, 1989). In a broad approach, entrepreneurship in non-business education is recast as aiming towards developing an entrepreneurial

way of practicing one's profession (Sarasvathy and Venkataraman, 2011, Bacigalupo et al., 2016). This is relevant for all graduates in that all contemporary work requires flexibility, management of uncertainty, and marshalling of resources (Bacigalupo et al., 2016), and it is useful for organizations and societies, recognizing that non-business students are experts in their respective fields, and hold unique potential in finding new ideas and solutions which are of professional and societal relevance (Hynes, 1996, Brand et al., 2007, Dutta et al., 2011, Levenburg et al., 2006).

Entrepreneurial pedagogy, then, is concerned first and foremost with learning to become entrepreneurial and how an enterprising culture can be fostered through education, rather than learning about entrepreneurship or learning to become an entrepreneur. In discussions of entrepreneurial pedagogy, attention has primarily been given to educational format rather than specific content (Fayolle and Gailly, 2008, Neck and Greene, 2011, Blenker et al., 2011, Mäkimurto-Koivumaa and Belt, 2016). Entrepreneurial pedagogy is often discussed in terms of learning *through* entrepreneurship, building on experiential and student-centered learning (Robinson et al., 2016), to engage students in entrepreneurial experiences. Experiential learning emphasizes (i) learner-controlled activities, (ii) engaging the learner's whole 'self', and (iii) facilitating teaching and learning activities corresponding to real practices beyond the classroom (Boud, 1989). Project-based learning has frequently been recognized as a precursor for such experiential learning (Cooper et al., 2004, Pittaway and Cope, 2007).

1.2. The engineering educator's stake: fostering entrepreneurial engineers

In the engineering education community, the entrepreneurial project serves as a particular answer to a closely related practical problem: *How do we prepare engineering students for the future of professional practice?*

Here, fostering an entrepreneurial way of practicing engineering is increasingly recognized as a key consideration for engineering educators, responding to an engineering practice of ever-growing complexity (Yemini and Haddad, 2010, Yasuhara et al., 2012) where capacity for innovation, initiative and ability to communicate and collaborate is considered to be of absolute importance. As such, there is an increasing interest in entrepreneurial pedagogy in engineering education. An entrepreneurial way of practicing engineering has been characterized by having *curiosity* about the rapidly changing landscape of engineering practice with a critical eye towards accepted solutions, a capacity for making *connections* in order to integrate information across sources and analyze inter-connected risks or consequences, and having an ambition to *create value* through identifying unexpected opportunities and persisting through and learning from failure (Rae and Melton, 2017). To foster such a way of practicing engineering, recent debates have centered on broadly changing the way in which engineering is taught (Kriewall and Mekemson, 2010) towards *entrepreneurial engineering pedagogy*, an entrepreneurial pedagogy tailored to the engineering discipline, discussed by some authors in terms of entrepreneurially minded (engineering) learning (Gerhart and Melton, 2016, Wheadon and Duval-Couetil, 2017, Rae and Melton, 2017).

1.3. Entrepreneurial engineering pedagogy through entrepreneurial projects

Drawing from scholarship in both engineering education and entrepreneurship education, recent accounts have put forth entrepreneurial engineering pedagogy as building on action-taking, team work,

working with real problems, conceiving new solutions and collaborating with stakeholders (Creed et al., 2002, Mäkimurto-Koivumaa and Belt, 2016, Wheadon and Duval-Couetil, 2017, Gerhart and Melton, 2016). Specifically, *project-based learning* has been put forth as a relevant pedagogical framework for facilitating such entrepreneurial engineering experiences in engineering education (Mäkimurto-Koivumaa and Belt, 2016). Mäkimurto-Koivumaa and Belt (2016) argue that project-based learning is preferable to problem-based learning:

> PBL [problem-based learning] is potentially effective as it emphasises students' participation and involvement in the learning process. However, being a structured method, it may not be the optimal solution for building a space for play and invention. Project-based learning may be more appropriate for EE [entrepreneurship education] as it allows more flexibility for the realisation of actual learning situations. […] projects typically aim to create concrete artefacts that are easier to comprehend. Projects should be organised so that they are experienced as students' own, that is, are associated with ownership. Project-based methods may also include typical activities for real-life projects, such as project planning, goal setting, reporting, making presentations, meetings and negotiations. (p. 521)

Such deliberations exemplify an interest in curricular *entrepreneurial projects* in engineering education. In line with a broad approach to entrepreneurship education (Ball, 1989), what is intended with entrepreneurial projects is not project-based entrepreneurship courses given to engineering students, but rather project-based engineering courses that by virtue of making certain real-world connections and putting students in certain roles can qualify as entrepreneurial. A salient feature of entrepreneurial projects is that they should be student-framed and aim towards moving into action — that they have real impact outside the classroom (Lackéus, 2016, Wheadon and Duval-Couetil, 2017), for example by incorporating external practitioners (Hynes and Richardson, 2007), such as small-business owners or practicing engineers, acting as stakeholders in the students' projects. These stakeholders can be introduced by the teacher (Pittaway and Cope, 2007), or by the students from their personal networks (Blenker et al., 2012).

1.4. Problem statement and research questions

Entrepreneurial engineering pedagogy, as construed in previous work, is a tall order for engineering educators, as it requires them to strive towards student-directed projects at the same time as seeking to connect students' projects to contexts and communities beyond the classroom. While a general philosophy of entrepreneurial engineering pedagogy has been outlined and there are in-depth descriptions of entrepreneurial engineering courses and programs to be inspired by (e.g. Ochs et al., 2001, Creed et al., 2002, Soares et al., 2013), less work has focused on comparing the different pedagogical models (Goodyear, 1999, Nunes and McPherson, 2003) teachers can draw on in designing their courses. Consequently, the tradeoffs teachers face in deciding between pedagogical models have not been investigated. Investigating such pedagogical models may serve to guide educators in designing entrepreneurial engineering courses.

Further, there is a fair amount of positivity associated with entrepreneurial projects in engineering education, but few accounts of their challenges. In contrast, educational research has shown that project-based learning – and other similar experiential approaches – poses high demands on students and may therefore lead to frustration and confusion, rather than meaningful participation, if students are not given proper support (Reiser, 2004, Kirschner et al., 2006, Hmelo-Silver et al., 2007). Indeed, Täks et al. (2014), in their study of how engineering students experience studying entrepreneurship, found that the students experienced considerable frustration before getting accustomed to a more self-directed way of

learning, being very different from the approach taken in other courses. These findings are echoed by Günzel-Jensen and Robinson (2017) and Neergaard and Christensen (2017) who found that students' lack of experience with entrepreneurial learning activities can act as a barrier to participation in entrepreneurial projects. Based on these findings, there is need to understand how teachers can support engineering students when engaging in entrepreneurial projects. Such support has been discussed in many types of complex learning environments in terms of *scaffolding* (Reiser, 2004, Van de Pol et al., 2010), i.e. contingent interventions initiated by teachers during the learning processes responding to learners' need for support, e.g. through supervision. However, needs for scaffolding and scaffolding strategies employed by teachers in entrepreneurial projects have not been investigated in previous work on entrepreneurial engineering pedagogy.

Consequently, this thesis sets out to *i)* inductively identify pedagogical models for designing and implementing entrepreneurial projects in engineering curricula through a multiple case-study and *ii)* to study these pedagogical models in action, particularly challenges and how they are overcome, through ethnographic inquiry.

The thesis will address the following research questions:

RQ1: What pedagogical models do engineering educators use to design entrepreneurial projects in engineering education curriculum?

RQ2: What challenges do students face in taking on entrepreneurial projects?

RQ3: How do teachers scaffold learning in order to mitigate barriers to participation?

The thesis draws on three appended papers to discuss these questions. In the first paper, three pedagogical models used to design and implement entrepreneurial projects are put forth, building on a qualitative multiple case study. Further, the second two papers present two ethnographic investigations of students engaging in curricular entrepreneurial projects, studying two of the three pedagogical models in action.

1.5. A transdisciplinary approach

I have conducted research in two disciplinary settings and discourses: engineering education and entrepreneurship education. While this thesis aims to integrate the two discourses through a transdisciplinary approach, only one of the appended papers (Paper 1) is explicitly aimed at this intersection. The two remaining papers have been undertaken within an engineering education discourse and an entrepreneurship education discourse, respectively. Broadly, both fields can be understood as *discipline-based educational research*, in which "the scholarship of teaching in higher education is not divorced from the content of the discipline being taught" (Healey, 2000, p. 173). Accordingly, scholarship into engineering education and entrepreneurship education should be situated in the disciplinary practices and discourses of engineering and entrepreneurship respectively, while also drawing from educational theory, see Figure 1. This thesis is concerned with curricular entrepreneurial projects in engineering education, and as such, draws on theoretical and empirical work within entrepreneurship education research, engineering education research, and educational research. A deliberate attempt has been made to draw extensively from education theory and research, as both the engineering education research and entrepreneurship education research communities have lamented the lack of such connections (Streveler and Smith, 2006, Borrego et al., 2008, Jones et al., 2014, Kyrö,

2015) and argued how this hampers theory building and the capacity of studies to make contributions to a broader educational research community.

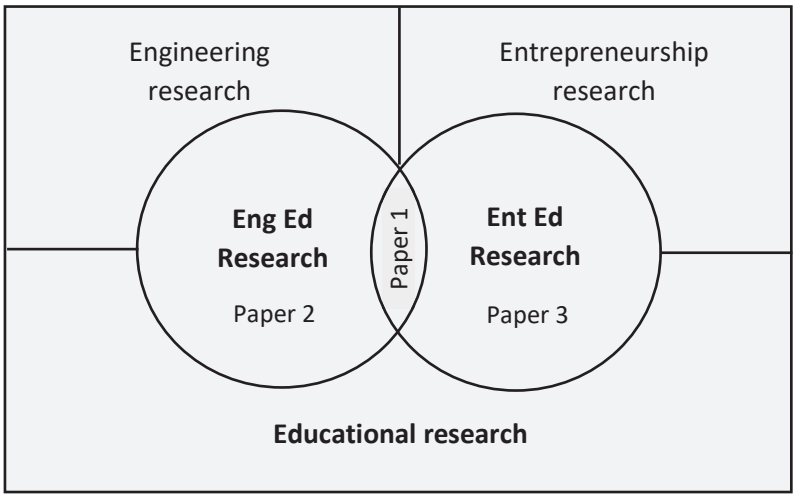

Figure 1: *The position of the papers in relation to two fields of discipline-based educational research: engineering education research and entrepreneurship education research.*

1.6. Overview of thesis

The rest of the thesis is structured as follows. First, three key theoretical constructs will be introduced in further detail in the theoretical framework: pedagogical models, situated learning, and scaffolding. This theoretical framework is primarily based on concepts from educational research. Next, the methodology and methods are described, followed by a short summary and description of the interconnectedness of the appended papers. An integrative discussion of the research questions is then put forth, starting from a summary of the findings presented in the appended papers. As such, apart from framing the three appended papers, the thesis is also putting forth a cross-case discussion not presented in the papers. In this discussion, I suggest that unsettled trajectories towards knowledge co-creation are inherent to entrepreneurial projects. That is, pedagogical models for the design and implementation of entrepreneurial projects offer starting points and mechanisms that can move students' projects towards knowledge co-creation, but continuous and contingent navigation through purposeful scaffolding is needed to achieve this ambition. I go on to outline contributions, limitations, and implications for research and practice in relation to entrepreneurial engineering pedagogy, and entrepreneurial pedagogy in general. The thesis closes with an outlook on future research.

2. Theoretical framework

In this chapter, three main theoretical constructs are introduced – pedagogical models, situated learning and scaffolding – which both act as a backdrop to how I approach the research questions and also provide analytical tools for an integrative discussion of results across the appended papers.

2.1. Pedagogical frameworks, pedagogical models and project-based learning

Pedagogical frameworks serve to organize thinking and acting in education (Goodyear, 1999, Nunes and McPherson, 2003). The value of pedagogical frameworks is that they may contribute to awareness and intentionality in the design of learning environments, in the sense 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" (Nunes and McPherson, 2003, p. 496). Pedagogical models, which are put in focus in this thesis, mediate between philosophical considerations regarding the nature of learning, and the day-to-day practicalities of educational practice, see Figure 2. As such, pedagogical models are used to enact philosophies of learning, and can at the same time act as organizers for and ways of thinking about classroom practices. A pedagogical model "does not contain direct prescriptions for action, but it puts some forms of possible action into the foreground and others into the background" (Goodyear 1999, p. 5)

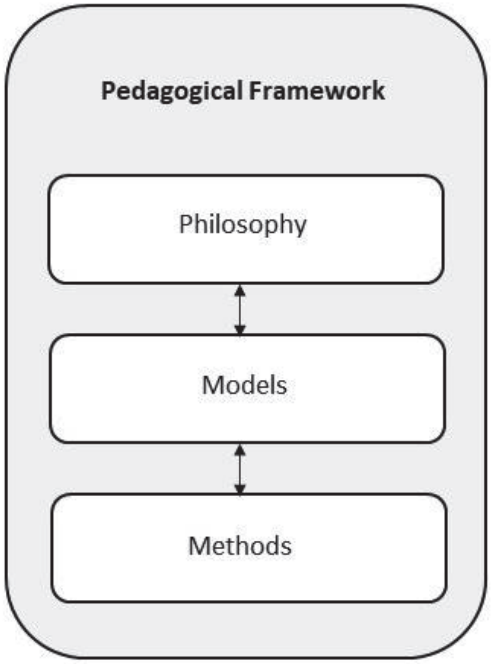

Figure 2: *Pedagogical frameworks as comprised by fundamental underpinning assumptions regarding the nature of learning and knowledge, day-to-day teaching methods and pedagogical models at an intermediary level. Adapted from Goodyear (1999)*

Project-based learning has been conceptualized both as a pedagogical framework (Helle et al., 2006) and a pedagogical model (De Graaf and Kolmos, 2003). Although being widely discussed and used, project-based learning is not a unitary concept with a single all-encompassing definition, and in practice

is somewhat difficult to distinguish from problem-based learning (Morgan, 1983, De Graaf and Kolmos, 2003, Helle et al., 2006). However, most authors agree on two underlying principles: learners engage with a driving problem or question, and learners produce a series of artifacts connected to the driving problem or question (Adderley, 1975, Blumenfeld et al., 1991). Artifacts, material and immaterial, serve to externalize learners' thinking and solutions, i.e. act as vessels for their knowledge construction. Artifacts are shareable and may serve as mediators in learner-learner, learner-teacher, and learner-stakeholder interaction and collaboration (Papert, 1993). In a professional education space, such as engineering education, artifacts created through project activities can thus be understood as mediators between students and engineering knowledge and practices.

In this thesis, project-based learning is considered a pedagogical framework which is usually associated with a number of *types* of projects, which are in turn considered to be pedagogical models. Different projects put students, teachers and practitioners in different roles with different responsibilities, and entail the solving of everything from smaller tasks to the taking on of large challenges that extend over time. Types of projects are usually distinguished by who formulates the driving problem or question to be tackled by students, if it is students or teachers (De Graaf and Kolmos, 2003). It has been suggested that it is in this project formulation phase that it becomes clear whether it is a teacher-centered or student-centered project (Kolmos, 1996). A common feature of complex and student-centered projects, which are under examination in this thesis, is the use of "real" or "realistic" problems and questions as the starting point or driver for learning (Blumenfeld et al., 1991). Which problems are to be considered "real", and to whom they are "real", is, however, not an unproblematic question and necessitates an introduction of a situated perspective on learning which is usually used to underpin project-based learning in terms of philosophical consideration regarding the nature of learning.

2.2. Situated learning: three metaphors

Situated learning starts from assertions that knowledge and learning are situated in practice (Brown et al., 1989, Lave and Wenger, 1991). From a situated perspective, knowledge is socially negotiated, and therefore a property of communities of practice that are engaged in their own reproduction, rather than of individuals. Examples of such communities of practice include professional engineering communities or networks of entrepreneurs. Learning from a situated perspective is viewed as *participation* in the ordinary activities of these communities. It is usually these activities that are deemed "real" or *authentic* (Brown et al., 1989), and it is the problems that are relevant for such communities that project-based learning seeks to engage students in solving.

A participation metaphor for learning differs from the dominant view of knowledge as something to be *acquired,* as something installed in the mind of individuals (Sfard, 1998). Instead, from a situated perspective, being knowledgeable can only be judged in terms of acting in accordance with established ways of practicing and by speaking the language of the specific community of practice. As such, "the permanence of *having* [knowledge] gives way to the constant flux of *doing*" (Sfard, 1998, p. 6). A fundamental assumption of this metaphor is that while our material world could potentially be considered objectively "real", our *experiences* in and with it are socially, historically and culturally constructed. Accordingly, while the material world can be experienced in isolation from other people, the meaning we ascribe to experiences cannot be understood as such. Rather, assumptions that knowledge can be neatly transferred across contexts is problematized through situated perspectives on learning. Note that learning as participation, learning as becoming a member of a community of practice, lays out assumptions as to what learning *is* rather than how it comes about. For instance, it is

often contended that humans learn through social interaction. As pointed out by Sfard (1998), applying a participation metaphor for learning instead means that learning is viewed *as* ongoing social interaction.

In terms of pedagogical models, the acquisition metaphor underpins the traditional lecture-based curriculum, where teachers "give" students knowledge by telling them about the world, and students adopt perspectives that have already been unveiled by others. Such a pedagogical model has been criticized for divorcing concepts from contexts where students can apply them, contexts in which students can become skillful professionals and build their professional identities (Barab and Duffy, 2000). The participation metaphor, on the other hand, underpins apprenticeship-based education. Here, students learn by working together with skilled members of a trade or profession, gradually taking on more complex tasks and becoming a skillful member themselves. Internships in professional organizations is a common way to enact such an idea.

While acquisition and participation as metaphors, and their corresponding pedagogical models, have been widely discussed and used, Paavola and Hakkarainen (2005) offer a critique which questions their theoretical relevance and analytical value for entrepreneurial projects, because neither metaphor rightly captures learning in innovative communities:

> The acquisition approach and the participation approach *can* both be developed so that they take innovative aspects into account, but it can be argued […] that this is not where these approaches are at their best, as we shall now elaborate. The acquisition approach presupposes pre-given structures of knowledge that an individual learner is guided to assimilate, or construct. […] The participation approach, in turn, focuses on increased mastery of a community's knowledge without a deliberate effort for transformation. Since the model focuses on adaptation to existing cultural practices, it does not prompt one to pay any special attention to creative changes in these practices (Paavola and Hakkarainen, 2005) (p. 538-539, emphasis in original)

Instead, they propose a third metaphor for learning that this thesis will rely on: learning as collaborative *knowledge creation*. From this perspective, learning is viewed as a process of deliberately attempting to create and develop new artifacts, conceptual and material, in "striving to advance beyond present knowledge" (Paavola and Hakkarainen, 2005, p. 545). In the knowledge creation metaphor, individual initiatives are analyzed in relation to the communities in which they interact. Learners are viewed as putting their perspectives "in" and "on" the artifacts that they create, entangling their perspectives with their projects. Through collaboratively shaping artifacts together with other community members, new concepts, ideas and practices may emerge and established ones may be transformed.

Translating the knowledge creation metaphor to a pedagogical model, Paavola and Hakkarainen (2005) argue for putting students in connection with community experts, together with whom students may take on deliberate attempts at creating new ideas and solutions. As such, knowledge co-creation projects are distinguished by entangling both students' perspectives and the perspectives of more established members of communities of practice, see Figure 3. In entrepreneurial projects in engineering curricula, these representatives could be, for instance, a practicing engineer or small business owner. In discussing such pedagogical models, Barab et al. (2000) assert that such collaboration, if successful, can serve to situate projects in both students' previous experiences and the perspectives of professional communities, and that central to such a pedagogical model is "the emergence of a learning context that is neither, and is both the classroom and the community of practice" (p.43).

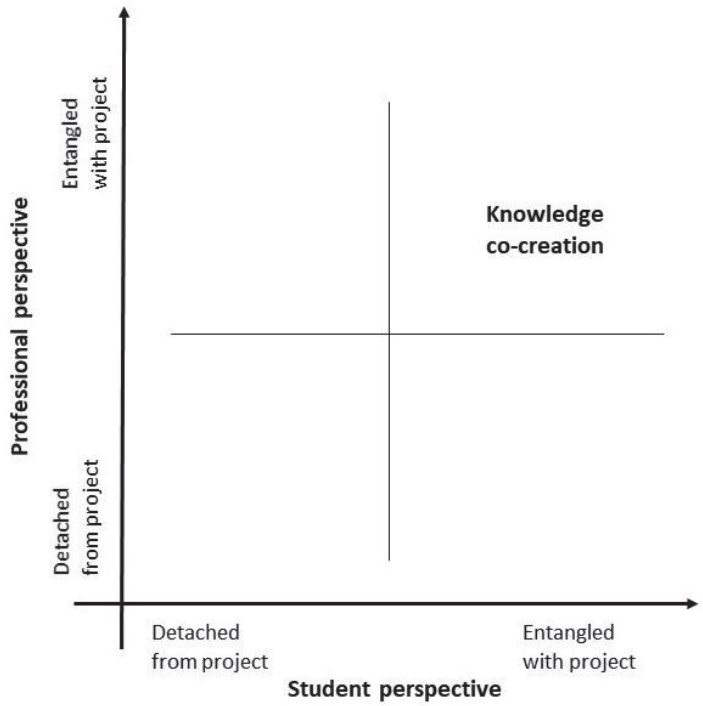

Figure 3: *A knowledge co-creation view of learning, situating curricular projects in both students' and practitioners' perspectives.*

2.3. Students' experiences and need for scaffolding

A salient critique of project-based learning and other pedagogical frameworks that argue for highly contextualized learning activities is that they pose significant challenges for students and risk not providing sufficient support for their learning (Kirschner et al., 2006). Briefly, such educational formats, if wrongly implemented, make assumptions that students without support are able to participate meaningfully in performing tasks that demand expertise that are outside of their reach. Reiser (2004) highlights some reasons for why participation in disciplinary project activity is troublesome for novices. Firstly, problem-solving strategies, social interaction practices and discourses used by experts are unfamiliar to students, and secondly, students tend to focus on outputs rather than understanding and on surface aspects of knowledge rather than implicit structure.

To mitigate such challenges, it is usually argued that — rather than simplifying tasks — it is necessary to provide continuous and contingent support for student learning, i.e. *scaffolding* (Wood et al., 1976, Collins et al., 1988, Hmelo-Silver et al., 2007, Van de Pol et al., 2010). Reiser (2004) introduces scaffolding as follows:

> The term scaffolding has traditionally been used to refer to the process by which a teacher or more knowledgeable peer assists a learner, altering the learning task so the learner can solve problems or accomplish tasks that would otherwise be out of reach (p. 274)

With the tools and strategies provided by scaffolding interventions in hand, students can solve more challenging problems independently in the future. In scaffolding, in order to build towards future more self-directed performance,

> it is important to stress the dual aspects of both (a) accomplishing the task and (b) learning from one's efforts, that is, improving one's performance on the future tasks in the process. If learners are assisted in the task but are not able to understand or take advantage of the experience, the assistance will have been local to that instance of scaffolding but will not have provided support for learning. Thus, scaffolding entails a delicate negotiation between providing support and continuing to engage learners actively in the process (Reiser, 2004, p. 275)

Van de Pol et al. (2010) highlight three key characteristics of scaffolding: (i) scaffolding should be *contingent*, that is, based on and adapted to students' responses to learning situations; (ii) scaffolding should be continuously *faded*, that is, support should be gradually decreased as students develop capacity to perform self-directedly; and (iii) the responsibility for performance should be gradually *transferred* from teachers to students.

2.4. Summary and integration of concepts

In the thesis, I approach entrepreneurial projects as a pedagogical framework, i.e. an organizer of thinking and acting in education, which is associated with *i)* certain theoretical underpinnings and assumptions regarding the nature of learning and knowledge, *ii)* certain pedagogical models that may be used to design and implement curricular projects in engineering education and with *iii)* certain pedagogical strategies and methods that are applied in day-to-day activities as projects unfold. I distinguish entrepreneurial projects from project-based learning in general by suggesting that they are specifically underpinned by a knowledge co-creation view of learning. That is, while I recognize the value of all three learning metaphors outlined in situated perspectives on learning, I contend that a knowledge co-creation view of learning is especially fruitful for entrepreneurial projects because this metaphor puts focus on deliberate and collaborative attempts to create new solutions, new ideas and new knowledge. Further, I use scaffolding as an analytical lens to approach the pedagogical methods and strategies that are used in day-to-day classroom activities in order to support students as they are taking on entrepreneurial projects.

3. Methodology and methods

In this chapter, I will introduce the epistemological perspective underpinning the methodology and the specific methods for data collection and data analysis drawn on in the appended papers.

For the sake of clarity, I will restate the research questions:

RQ1: What pedagogical models do engineering educators use to design entrepreneurial projects in engineering education curriculum?

RQ2: What challenges do students experience in taking on entrepreneurial projects?

RQ3: How do teachers scaffold learning in order to mitigate barriers to participation?

3.1. Epistemological perspective

To generate relevant and applicable knowledge, I have grounded my inquiry in the actual settings where the findings could be used, i.e. learning environments that use entrepreneurial projects as a pedagogical framework in engineering education, and I have taken the perspective of the people that I believe the findings could be useful for, i.e. the teachers and students in these settings. Being interested in the "multiple worlds" (Guba and Lincoln, 1982) that students and teachers construct through interaction and sense-making, rather than a single objective reality, the studies in the thesis all employ a *qualitative* research approach to study aspects of entrepreneurial projects. Qualitative research is a broad term encompassing a range of more specific approaches such as ethnography, phenomenology or grounded theory, underpinned by an interest in in-depth understanding of human experience, behavior and social interaction. Qualitative inquiry is usually associated with *interpretivist* assumptions rather than positivist ones, where the "interpretivist … assumes that identifiable social groups construct coherent systems of belief and action from intersubjective meanings" (Eisenhart, 1988, p. 103), and data collection is aimed at exploring these systems of belief and action.

Accordingly, when investigating pedagogical models, the studies presented in this thesis aims to understand entrepreneurial projects in terms of how teachers perceive them, and specifically their intended course designs. Similarly, in exploring challenges that students face in entrepreneurial projects, the papers discuss what students perceive as salient challenges, i.e. what they themselves feel they are struggling with. Scaffolding, being a reciprocal student-teachers process, is considered in terms of student-teacher interaction. In contributing to the problematization of entrepreneurial projects, I am specifically interested in *conflicting* perspectives and potential barriers to interaction, i.e. incoherence between the system of beliefs and actions between students and teachers. That is, aspects of interaction in these settings signified by students and teachers struggling to construct a coherent set of beliefs and action.

To move towards such an understanding, my approach can broadly be described as speaking to teachers and students and observing them in action, asking them what they are and have been doing, what they are thinking and feeling, and why. As will be outlined in Section 3.3. and 3.4., describing the methods applied in the appended papers, some of this talk has been more structured, in the form of interviews, and some of it less structured, in the form of informal interactions during e.g. workshop or supervision sessions. I have observed students and teachers while they are (inter)acting in the classroom and studied the artifacts that they produce, e.g. course descriptions and project reports.

A key premise and first consideration for conducting these studies was the identification of learning environments in which engineering teachers and students could be considered engaged in entrepreneurial projects.

3.2. Seeking out entrepreneurial projects and empirical settings

To identify empirical settings in which to study entrepreneurial projects, a purposive sampling strategy was employed (Robinson, 2014), seeking out those projects in engineering education that could be considered in line with previous work on entrepreneurial experiences in engineering education (Mäkimurto-Koivumaa and Belt, 2016, Gerhart and Melton, 2016, Wheadon and Duval-Couetil, 2017). As outlined in the introduction, the thesis takes a broad perspective on entrepreneurship, rather than a narrow one. Accordingly, it was not evident at the outset of the thesis work what kind of curricular activities to look for, lacking a clear conceptualization of entrepreneurial projects to draw from. Rather, the sampling gradually unfolded, and was driven by temporary sensitizing concepts (Blumer, 1954, Bowen, 2006). Sensitizing concepts were introduced by Blumer (1954), and he defined them in the following way:

> A definitive concept refers precisely to what is common to a class of objects, by the aid of a clear definition in terms of attributes or fixed bench marks […] A sensitizing concept lacks such specification of attributes or bench marks and consequently it does not enable the user to move directly to the instance and its relevant content. Instead, it gives the user a general sense of reference and guidance in approaching empirical instances. Whereas definitive concepts provide prescriptions of what to see, sensitizing concepts merely suggest directions along which to look. (p. 7)

Sensitizing concepts applied at the outset of the thesis work included value creation, uncertainty, student-centered learning, reflection, and transformative learning, inspired by previous work (Lackéus, 2016, Mäkimurto-Koivumaa and Belt, 2016, Wheadon and Duval-Couetil, 2017). Accordingly, these concepts acted as placeholders and provided direction in seeking out empirical settings in which to study entrepreneurial projects. Through the gradually converging sampling strategy, my conception of entrepreneurial projects was gradually narrowed down and made more substantive.

The unfolding sampling of projects co-evolved with an educational change initiative at Chalmers University of Technology (Chalmers), the ENG-project. This project aimed at further infusion of entrepreneurial experiences in undergraduate education, and was initiated in 2015. Chalmers is located in Gothenburg, Sweden, and hosts 28 undergraduate programs spread over seven educational areas, spanning e.g. architecture, chemical, electrical, civil and mechanical engineering. A project group was put together with representatives of every educational area at Chalmers, led by representatives of the Department of Technology Management and Economics. Accordingly, the project group gathered experience in teaching a wide range of general engineering courses and entrepreneurship courses to engineers. The project group was tasked with supporting the development of existing courses, through workshops and interventions with teaching faculty, in order to support the facilitation of entrepreneurial experiences in more courses.

As a pre-study for the ENG-project, a mapping of entrepreneurial experiences offered through courses at Chalmers was undertaken by the project group, primarily through interviewing program heads across campus. The mapping was presented at a national conference for engineering education development (Lackéus et al, 2017), and indicated project work with external interaction as strong candidates in terms

of empirical settings providing entrepreneurial experiences to students. The mapping also put the project in contact with teachers responsible for arranging entrepreneurial projects.

3.3. Identifying pedagogical models

To study the ways in which entrepreneurial projects are designed and implemented in engineering education, I conducted a multi-case study (Merriam, 2009, Crowe et al., 2011) involving seven project-based courses, based on interviews with teachers. This study is presented in **Paper 1**. The aim of the study was to identify pedagogical models (Goodyear, 1999, Nunes and McPherson, 2003, Wickman et al., 2018) for entrepreneurial projects, and the underlying design principles of these pedagogical models.

Following a purposive sampling strategy with sensitizing concepts as outlined in Section 3.2., course documentation for all courses at Chalmers (N = 1268) were read, identifying a sample of 120 courses as potential settings for entrepreneurial experiences. Among these courses, 17 were chosen, striving for variation in subject area, class size, number of ECTS-credits and format of learning activities. The main teacher for each course was contacted, and 14 agreed to be interviewed. The interviews were geared towards obtaining a better understanding of *i)* the intended learning outcomes, *ii)* the nature of the learning activities and assessment, *iii)* the challenges faced by the students, *iv)* the strategies employed to scaffold student learning, and *v)* the perceived learning outcomes and tangible outcomes/by-products of the projects. The interviews were semi-structured, which allowed further inquiry into the topics and experiences voiced by the teachers. After the interviews, 7 courses were included in the final sample[1]. The interviews ranged from 50 to 90 minutes, were audio-recorded and the most important parts were transcribed verbatim.

The data was analyzed through an *inductive thematic analysis* (Braun and Clarke, 2006), focusing on pedagogical models and teachers' arguments for why they designed the projects in a certain way. That is, the data was approached with a general analytical interest, but codes were not decided beforehand but gradually emerging and refined from close and iterative reading and classifying of the entire data set. The resulting codes were sorted and sifted iteratively until a number of themes emerged in relation to pedagogical models used and their underlying instructional design principles.

3.4. Studying pedagogical models in action

Having studied teachers' intended course designs, and they way in which they perceive their teaching, I wanted to move on to understand students' learning processes in these settings. As such, the studies put forth in **Paper 2** and **Paper 3** were primarily aimed at studying the identified pedagogical models for entrepreneurial projects in action, and the in-situ experiences of students and teachers interacting in learning environments built around entrepreneurial projects. In these studies, I followed students' learning over time, and their experiences as the course activities were unfolding.

[1] Half of the courses were excluded from the final sample because of a lack of connection and interaction with external practitioners, using smaller task-oriented projects. This exclusion indicates difficulty of assessing the nature of learning experiences and its alignment with entrepreneurial experiences starting from only course descriptions.

3.4.1. Paper 2

In **Paper 2**, I studied an undergraduate entrepreneurship and business design course (7.5 ECTS) with approximately 35 students, in which students undertook a business idea development project through repeated interaction with external stakeholders. This is a piece of insider action research (Alvesson, 2003, Mercer, 2007), where I systematically studied students' experiences in a course I was involved in teaching together with two colleagues in order to continuously better address barriers to student learning.

The data presented in **Paper 2** is drawn from the first course iteration (out of three) that I was involved in. I spent 17 hours observing the classroom, across 7 sessions, and 10 hours lecturing and facilitating exercises, across 4 sessions. My observations were documented in field notes, and I wrote short teaching reflections notes during and after the sessions in which I facilitated exercises or lectured. I collected supplementary material from exercises done in class, e.g. workshop sheets created by the student groups. I conducted 8 follow-up interviews with students spread across the different teams. The interviews were geared towards understanding how the students had experienced working with their projects, and discussing excerpts from the reflective text was used to facilitate further inquiry into students' interpretations of events. In preparing the paper, I again surveyed the entirety of students' reflective writing (approximately 200 pages of text) to re-familiarize myself with the reflection assignments students had put forth going through the project[2].

3.4.2. Paper 3

In **Paper 3**, I studied an undergraduate software engineering course (7.5 ECTS) with approximately 60 students, in which students undertook a software development project in collaboration with an external stakeholder. The course was identified in the study presented in **Paper 1**, and was chosen for further investigation on the basis of repeated interaction with stakeholders, providing repeated opportunities for reflection and being a "normal" course – in the sense that it catered to a substantial number of students (rather than a select few), was mandatory and of a standard 7.5 ECTS credit size[3].

Studying this learning environment, I used ethnographic methods from a position of non-participating observer. This resulted in 23 hours of classroom observation. Specifically, I observed introductory workshops where methodology was introduced, review and supervision sessions where students, teachers and stakeholders met, and the final presentations when students showcased their applications and interacted with invited industry guests. These observations included informal interactions with students, asking about their perceptions of the course. Further, I conducted 10 follow-up interviews, asking students from different teams to tell me more about how their particular project had played out and how they had experienced the learning environment. Also seeking an understanding of how the teachers had designed the course, and their intentions with different course activities, both teachers involved in the course were interviewed before the course started. Further, one of the teachers acted as my main informant, with whom I had repeated informal interactions before, during and after most observation sessions. This interaction continued after the course iteration I had observed had ended, and a follow up meeting was held with the two teachers eight months later. In this meeting, the teachers explicated changes they had already made and intended to make going forward to adapt the course to the opinions voiced by students in the course evaluation process. Both classroom observations and interactions with the two teachers were documented in field notes.

[2] In giving the course, I administered these reflection assignments, read them, and gave formative feedback to the students.
[3] The standard size of courses at the university in which the study was undertaken.

An inductive thematic analysis (Braun and Clarke, 2006) was used in both cases, focusing on challenges and barriers to learning in Paper 2 and on scaffolding strategies and tensions in the scaffolding process in Paper 3.

4. Summary of appended papers

The three appended papers are summarized below, primarily focusing on the empirical results that inform my subsequent discussion in relation to the overall research questions of the thesis.

4.1. Paper 1

Title: ***Entrepreneurial Engineering Pedagogy: Models, Tradeoffs and Discourses***

The paper seeks to identify pedagogical models for enacting an entrepreneurial engineering pedagogy through project-based learning, and their underlying instructional design principles. The paper draws on a multi-case study encompassing seven project-based engineering courses, as outlined in Section 3.3. The following research questions were investigated:

- What *pedagogical models and methods* do engineering educators use to infuse entrepreneurial experiences into project-based courses?
- How do the educators *motivate* their instructional design choices in terms of the quality of the students' learning experiences?

Three distinct pedagogical models for designing and implementing entrepreneurial projects were discerned: (1) learning through student-framed and user-oriented projects, (2) learning through client-framed and student-driven projects, and (3) learning through co-creation platform projects. These are described in Table 1. The pedagogical models are distinguished by their starting points for learning, or more specifically the question of who is primarily shaping the underlying questions and problems that direct the project. In student-framed projects, the students were given an open-ended task, for example to conceive a new product design or a new business idea, and in the first phase of the projects, students were to frame this task, for example in terms of finding a context or user group for which to tailor their ideas or a problem which they could work towards solving through their projects. In the client-framed projects, students were given similar open-ended tasks, but a specific contextualization was provided through arranging an external stakeholder who presented a problem or set of problems relevant for engineering work in their organizations. In the co-creation platform projects, project formulation and contextualization were more emergent, in that the course project was done in conjunction with a platform and environment with ongoing activity at the university, for example a research group or center, with built up connections to many different stakeholders and contexts, and connections between students' projects and these networks were formed and matched gradually.

The teachers motivated their choice of student-framed or client-framed projects in terms of two instructional design principles that underpin the models: making learning personal and making learning professional, see Figure 4. In short, student-framed projects were seen as a way to contribute to student ability to independently frame and take on projects. This may allow them to connect to their own interests, strengths and networks, thereby seeing to that the projects are personally meaningful for students. Conversely, client-framed problems were seen as a way to show students how professional engineering is really practiced and to focus on aspects of engineering problems that are purposeful to create a real product or solution that is of value to someone else, thereby making learning more professional.

***Table 1**: Three pedagogical models for the design and implementation of entrepreneurial projects in engineering curricula, distinguished primarily by their project formulation phase.*

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.

The findings suggest that making learning personal and making learning professional are key in entrepreneurial projects; that is, seeking to connect with students' previous experiences and entangle them in the creation of new solutions/artefacts and seeking to connect with practitioners and entangle their perspective are both key in entrepreneurial projects. This is line with assertions that entrepreneurial engineering pedagogy should be both student-framed and seek external impact (Mäkimurto-Koivumaa and Belt, 2016, Wheadon and Duval-Couetil, 2017), and it supports the notion that entrepreneurial projects may be underpinned by a knowledge co-creation view of learning (Barab et al., 2000, Paavola and Hakkarainen, 2005).

However, the findings also indicated that there are tradeoffs between competing goals in entrepreneurial engineering pedagogy. The educators voiced concerns that the instructional design principles can be at odds with each other, especially when working from a student-framed or client-framed (rather than jointly framed) project formulation phase. Specifically, some of the educators argued that if students are allowed to direct their attention freely, they will not focus on aspects of engineering that are relevant for professional practice, for instance by over-embellishing technical details rather than seeking an understanding of what customers want. As such, situating entrepreneurial projects in students' previous experiences can come at the expense of connecting to practitioners with which to co-create new solutions or artefacts. Personal and professional learning seemed to be less conflicting in the co-creation

platform projects, but these in turn demanded significantly more resources and they are not necessarily in reach for the individual educator.

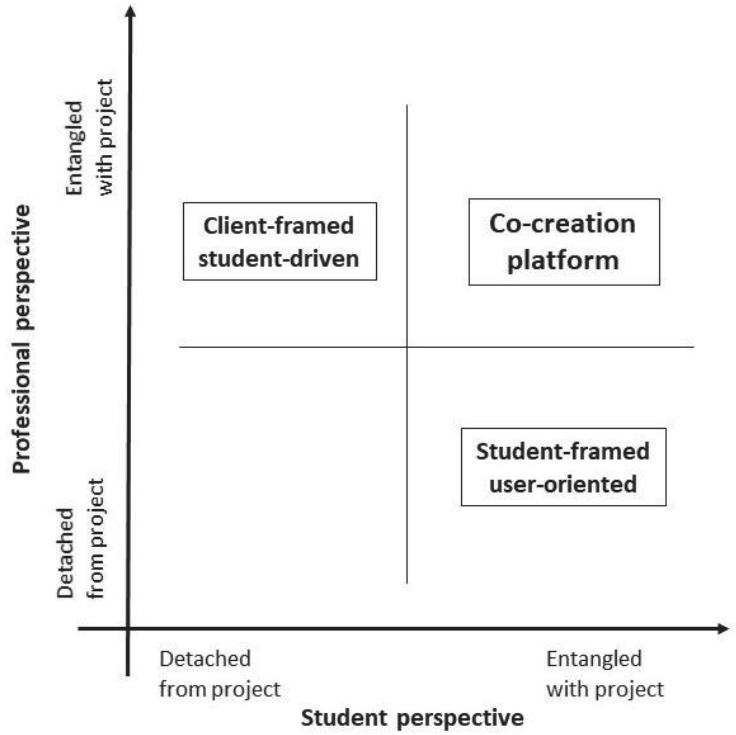

Figure 4: *An illustration of how the three pedagogical models tap into two different instructional design principles in the project formulation phase. Note that the client-framed model is not necessarily totally detached from students' perspective, but it less tangibly brings the student perspective to bear in shaping the project, and conversely for the student-framed model.*

Starting from these findings, the two following papers seek an in-depth understanding of how and why such tradeoffs between students' perspectives and a professional perspective occur in entrepreneurial projects, and what teachers can do to mitigate them.

4.2. Paper 2

Title: ***Exploring Students' Transition into Experiential Entrepreneurship Education: Challenges and Learning***

The paper sets out to understand students' transition into participating in a student-framed, user-oriented project course. The paper builds on insider action research in a project-based entrepreneurship and business design course, as outlined in Section 3.4.1. The following research questions were investigated:

- What challenges do students face in transitioning into experiential entrepreneurship education?
- How do these challenges relate to students' process of developing an understanding of how to take on learning in experiential entrepreneurship education?

In the course, the students framed their projects by reflecting upon their resources and networks and generated a first business idea, which they then were to develop and move towards realization by contacting practitioners and get their input. However, four specific challenges to student engagement were found: (1) coming up with an idea, (2) engaging external actors, (3) pivoting, and (4) managing the openness of an entrepreneurial project, see Figure 5. The study found that students often struggle with understanding and coming to terms with the role they are encouraged to take on in entrepreneurial projects, because it breaks with both what they have come to expect of school and with how they have imagined entrepreneurial processes to play out. For instance, many students reported that they struggled to see the value in contacting potential users without having a finished idea or product to "sell" to them. Others talked at length about struggling with coming to terms with having to fundamentally revise their ideas if faced with critical feedback from potential customers or stakeholders with expertise, for instance arguing how such an unpredictability was not usually part of their curricular projects. As such, it did not seem evident for students how they should sense-make the experiences they get in entrepreneurial projects, connect them with their previous experiences, and come to terms with the ways of practicing that the teachers espoused. This struggling to sense-make activities also seemed to be associated with not engaging in them, for instance by not contacting external stakeholders.

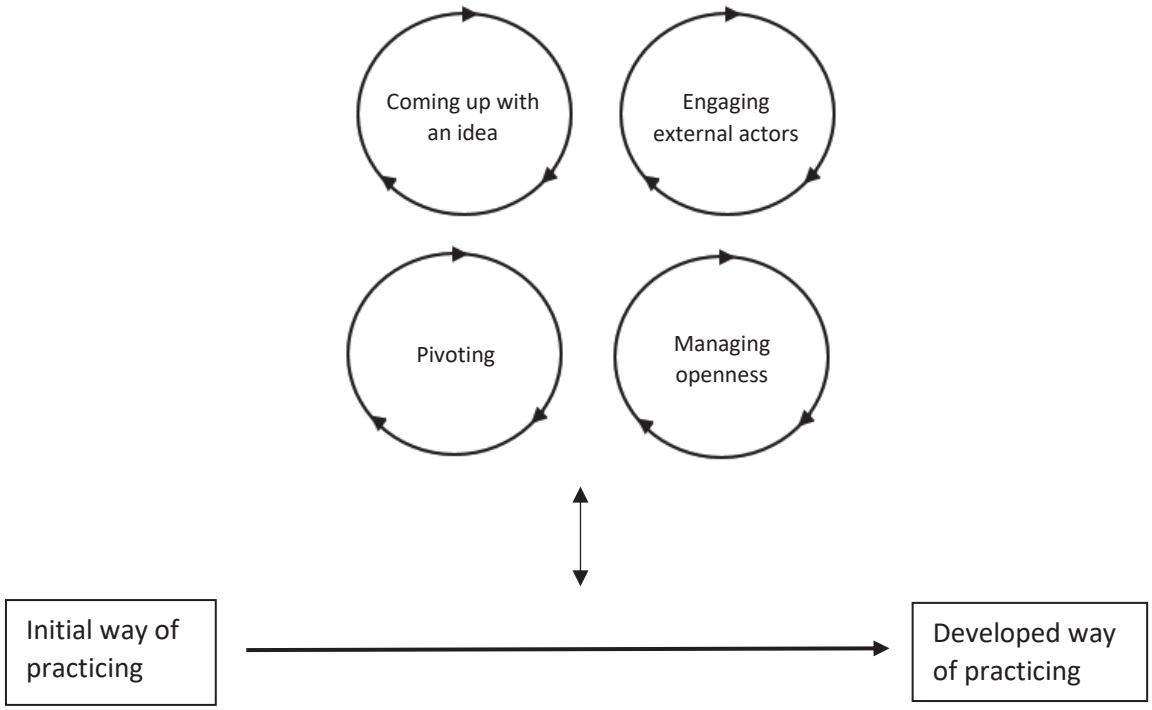

Figure 5: *Four critical and recurring challenges students struggled with in starting to engage in their entrepreneurial projects, and their relation to a process of re-shaping their use of disciplinary practices.*

In relation to Paper 1, the findings suggest that achieving a connection to students' previous experiences is not to be taken for granted even if the project starts from a student-framed project formulation phase. That is, even if students are allowed to frame and contextualize their projects, their expectations of professional practice and habitual way of taking on projects may stand in the way of engagement and a sense of ownership of the inquiry. The findings suggest that students are not necessarily accustomed to the ways of practicing that are expected in entrepreneurial projects, that there is need for proper

scaffolding of students' learning, and that this scaffolding should take into consideration the expectations students have on disciplinary practices and on curricular activities. As the findings indicated that students in their reflective writing articulated new ways of understanding professional practices, the paper proposes that teachers should arrange recurring opportunities for reflection and sense-making of experience in order to help students overcome narrow conceptions of disciplinary practices and themselves as disciplinary actors.

Starting from these findings, Paper 3 seeks further understanding of the tensions that can arise between what students expect from disciplinary practices and the ways of practicing that are espoused by teachers, and what teachers do to mitigate these tensions.

4.3. Paper 3

Title: ***Investigating the Dynamics of Authentic Learning in a Project-based Engineering Course***

The paper sets out to understand scaffolding challenges in a client-framed, student driven entrepreneurial project. The paper draws on an ethnographic study in a project-based software engineering course, as outlined in Section 3.4.2. The following research questions were investigated:

- What strategies do teachers employ to manage tensions between ways of working that they and their students deem meaningful?
- What strategies result in students agreeing or disagreeing on what are authentic or meaningful learning experiences?

In the course, the students were presented with a problem by a client, which they then were to make their own and shape a software application in relation to. However, the study highlights that the project proved challenging for students to undertake, finding how adopting a customer orientation and solving technical concerns self-directedly were deemed especially challenging by students. Similar to the findings in Paper 2, the teachers reported how they perceived the students to take on disciplinary activities in a way which they did not deem purposeful, for instance by putting much time into extra add-ons and "nice to have's" instead of engaging in understanding the fundamental needs of the client and negotiating what they could deliver to the client in a short time-frame. A particular aspect of these challenges was that students and teachers disagreed on how the project should be undertaken. The findings indicated that the ways of practicing espoused by the teachers were initially experienced as unintuitive by students. Thus, achieving a genuine connection to a professional perspective is not to be taken for granted even if the project starts from a client-framed project formulation phase.

The tensions between the students' and teachers' perspectives seemed to build a certain skepticism and resistance in the learning environment that teachers need to manage. The paper shows how teachers in this case mitigated tensions through arranging recurring opportunities for targeted *negotiation* of disciplinary practices. That is, through workshop activities and supervision, the difference between the student perspective and the disciplinary perspective as conceived by the teachers was brought to the surface and critically discussed. For instance, during an introductory role-playing/simulation exercise, one of the teachers argued explicitly that the students were asking the wrong kind of questions to the client, and explained his view that customers do not care about technical details. Such attempts to argue for a new way of approaching disciplinary activities recurred during supervision sessions as the projects were unfolding. Through these *strands of negotiation* and the continued interaction between students

and teachers, some tensions were resolved, while others remained unresolved and characterized by frustration and disagreement between students and teachers at the end of the course, see Figure 6.

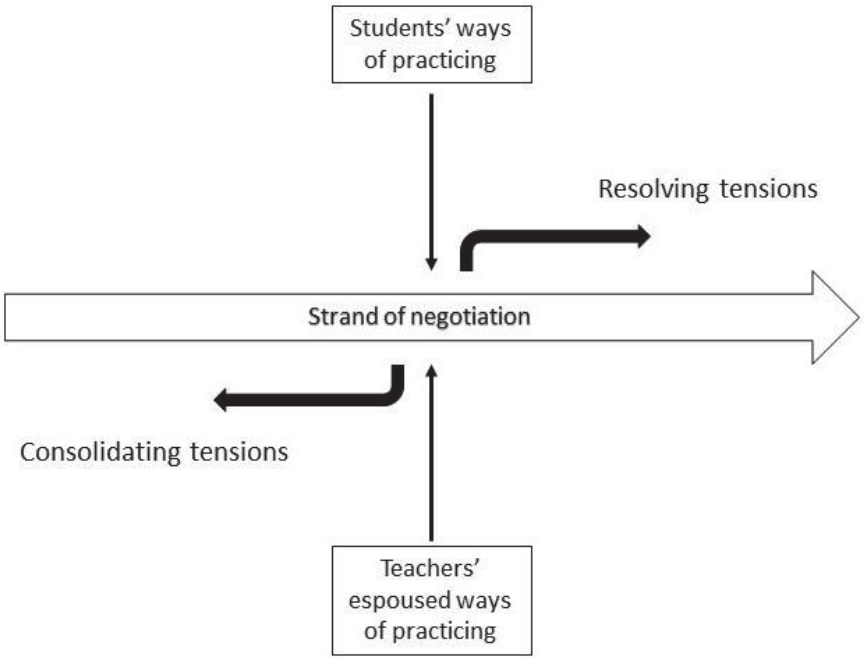

Figure 6: *Strands of negotiation teachers and students engage in over the course of the entrepreneurial projects, leading in some cases to resolution of tension between students' and teachers' perspectives, and in some cases to frustration and disagreement*

Moving beyond the suggestion in Paper 2 that teachers need to arranged opportunities for sense-making of experiences in entrepreneurial projects to help students connect with project activities, this paper suggests that teachers may also need to actively engage in shaping how students view and take on professional practice, i.e. engage in argumentation and negotiation regarding what ways of working are purposeful and why.

5. Discussion

In this chapter, the findings of the three appended papers will be synthesized and discussed in relation to how entrepreneurial projects can be understood, designed and scaffolded in engineering education.

5.1. Navigating unsettled trajectories towards knowledge co-creation

In this first section, the results from the three appended papers will be summarized under a joint frame, and related to the research questions of the thesis. Reflecting on the totality of my empirical studies and theoretical deliberations, I interpret my results as indicating that entrepreneurial projects call for *navigation* of *unsettled trajectories* towards knowledge co-creation.

The entrepreneurial projects investigated in this thesis provide different starting points for students' learning, and different conditions for them to connect to and put into action their own experiences, the experiences of practitioners involved, and those of the discipline as represented by teachers. As the projects progressed, the students and the profession were gradually moved closer to each other as students filled their projects with their ideas and resources, made them their own, and connected with externals to shape the direction of the projects jointly. As such, even if entrepreneurial projects start from a project formulation phase that is student-framed or client-framed, the projects can offer *trajectories* towards knowledge co-creation through continued and unfolding interaction between students, teachers and practitioners, see Figure 7. In Paper 1, I identified three starting points to set students on such trajectories, i.e. three pedagogical models for entrepreneurial projects (RQ1 of thesis).

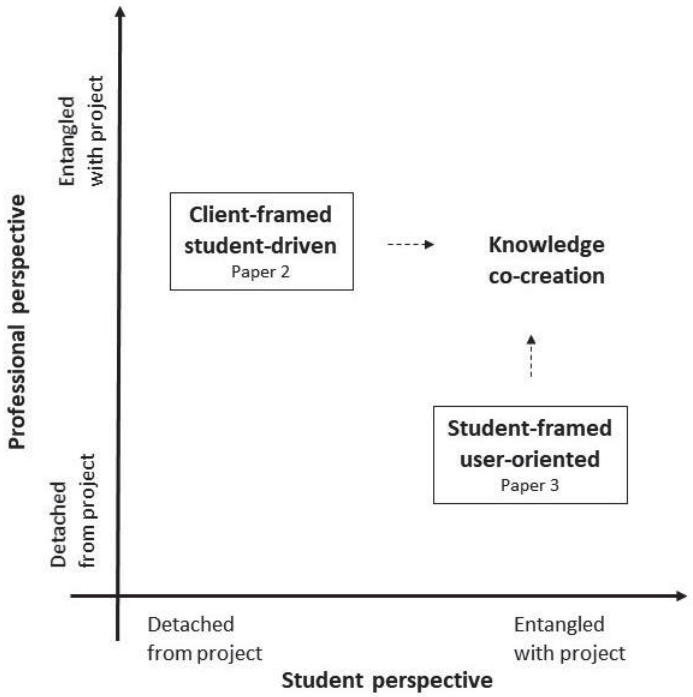

Figure 7: *An illustration of how the two pedagogical models studied in paper 2 and 3 through their project formulation phases offer different starting points for students' projects, which then may move towards knowledge co-creation as the projects unfolds.*

The findings in Paper 2 and Paper 3 illustrate, however, that these trajectories are not stable and orderly. Rather, they are put forth by both students and teachers as *unsettled* and not to be taken for granted. In particular, the students deemed entrepreneurial projects to be challenging and different from what they are used to and from what they expected from professional practices. Salient challenges put forth by the students include managing interaction with external stakeholders and the unpredictability of entrepreneurial projects (RQ2 of thesis). In facing these challenges, the students struggled with both sense-making the experiences they gained through entrepreneurial projects in light of their previous experiences, and struggled with connecting to external stakeholders. As such, not all projects seemed to move seamlessly towards knowledge co-creation and an entanglement of students and the profession.

Accordingly, in the entrepreneurial projects studied here, students and teachers needed to engage in continuous and contingent *navigation* between personal and professional perspectives. To support this process, a first scaffolding strategy employed by teachers was recurring opportunities for reflection (RQ3 of thesis), attempting to reconcile tensions between students' previous experiences and the disciplinary perspectives put forth through making space for consideration, articulation and examination of perspectives. The findings in Paper 2 indicated that reflection may settle some of the ambiguities experienced by students, and settle projects on a trajectory towards co-creation through students coming to terms with interacting with external stakeholders. A second scaffolding strategy included deliberate negotiation of disciplinary practices. While reflection and negotiation may settle some of the tensions between students' and teachers' initial perspectives, my findings indicate that some tensions can end up still unsettled, undecided, as the course reaches its end, and yet others may lead to frustrated locked-in positions and an increased distance between students, teachers, and practitioners, and in effect students and the discipline.

5.2. Contributions

Turning to contributions, I will now sense-make and position my findings in relation to previous work on entrepreneurial engineering pedagogy and entrepreneurial projects.

5.2.1. Designing and implementing entrepreneurial projects

Project-based learning has been recognized as a promising pre-cursor in enacting an entrepreneurial engineering pedagogy (Mäkimurto-Koivumaa and Belt, 2016), but the complexity and structure of curricular projects can range from being small teacher-controlled tasks to being open student-directed processes (De Graaf and Kolmos, 2003), and not any curricular project could be considered entrepreneurial in line with previous work on entrepreneurial engineering pedagogy (Kriewall and Mekemson, 2010, Mäkimurto-Koivumaa and Belt, 2016, Wheadon and Duval-Couetil, 2017). The thesis contributes to discussions of entrepreneurial engineering pedagogy by proposing knowledge co-creation as a metaphor for learning that may underpin entrepreneurial projects, and by identifying pedagogical models used by engineering educators to design and implement entrepreneurial projects in engineering curricula. The pedagogical models highlighted here may guide educators in that they can act as an intermediary way of thinking about teaching, in between a general philosophy of entrepreneurial experiences in engineering education and in-depth descriptions of specific interventions (Goodyear, 1999). As such, they should be evaluated in terms of whether or not they may inspire reflection on and awareness of assumptions and choices we as educators make in designing entrepreneurial engineering courses (Nunes and McPherson, 2003).

Much work on entrepreneurial engineering pedagogy has focused on educational inputs and outputs (Ohland et al., 2004, Souitaris et al., 2007, Duval-Couetil et al., 2016), but has not investigated what happens as projects unfold. The papers put forth in this thesis draw attention to a need for better understanding of learning processes and their dynamics in entrepreneurial projects, specifically the challenges and tensions students face and their effect. Specifically, the findings in Paper 2 and Paper 3 indicate that entrepreneurial projects are, in a sense, not entrepreneurial by default, but need to be gradually filled with meaning through interaction between students, teachers and practitioners, and then the projects can move along a trajectory toward knowledge co-creation. Teachers can use pedagogical models for supporting opportunity for entrepreneurial projects with a project formulation phase in which students and practitioners can put their perspectives "in" and "on" the projects, but also need to provide mechanisms such as continued reflection and continued connection with external stakeholder. Whether or not the projects successfully traverse a trajectory toward knowledge co-creation is, however, not certain. This casts designing and implementing entrepreneurial projects as an ambition that needs to be continuously and contingently strived for as projects unfold.

5.2.2. Needs and strategies for scaffolding

Paper 2 and Paper 3 extend the work on barriers to engagement and the need for scaffolding in entrepreneurial courses (Neergaard and Christensen, 2017, Günzel-Jensen and Robinson, 2017) and in project-based learning (Kirschner et al., 2006, Hmelo-Silver et al., 2007) by showing how interaction with practitioners and management of uncertainty produce unique needs for scaffolding in entrepreneurial projects. The findings support previous work, showing how students do not necessarily agree with teachers on what they deem as relevant ways of taking on professional activity (Günzel-Jensen and Robinson, 2017, Gulikers et al., 2008, Weninger, 2018, Nicaise et al., 2000). The papers put forth in this thesis highlight that the format of learning activities can be experienced as unintuitive and because they are also challenging for students to take on, this can build skepticism and resistance in the learning environment, which teachers need to manage as projects unfold. The finding that teachers and students disagree on what constitutes relevant professional practices and ways of taking on projects puts into question assertions that entrepreneurial projects should build on "real" or "realistic" problems and situations (Mäkimurto-Koivumaa and Belt, 2016, Wheadon and Duval-Couetil, 2017), specifically raising questions of who are to deem projects to be in line with professional activity. Even if teachers perceive projects and problems to be in line with their view of professional activity, they need to engage in articulation and discussion of why and in what sense (Petraglia, 1998).

The thesis illustrates the need for creating space for students to sense-make their experiences as they are taking on entrepreneurial projects, in line with assertions made in some discussions of entrepreneurial engineering pedagogy (Wheadon and Duval-Couetil, 2017) and many accounts of entrepreneurial pedagogy in general (Neck and Greene, 2011, Kassean et al., 2015, Hägg and Kurczewska, 2016, Rose et al., 2018). Specifically, the thesis highlights the value of opportunities for written reflection on team-work, customer interactions, and challenges encountered in project activities. As put forth by Barab et al. (2000), entrepreneurial projects may facilitate a space "that is neither, and is both the classroom and the community of practice" (p.43), a space in between more easily graspable and established practices. Reflection may serve to counter the unsettledness of such spaces and reconcile tensions that may emerge between students' expectations, experiences and intentions and the perspectives put forth by teachers and practitioners.

The findings also highlight negotiation of disciplinary practices as a second scaffolding strategy in entrepreneurial projects, which has not received much attention in previous work on entrepreneurial pedagogy, which has largely cast sense-making as a more neutral and self-directed mulling over of past experiences (Kassean et al., 2015, Hägg and Kurczewska, 2016, Rose et al., 2018). Reconciling

skepticism through negotiation entails that teachers not only give space for reflection, but also actively engage in shaping the way in which students sense-make their experiences and ways of working. Such negotiations may prove integral for countering narrow conceptions of disciplinary practices and roles. Although scaffolding is usually considered in terms of *supporting* learners (Reiser, 2004, Van de Pol et al., 2010), the courses studied in Paper 2 and Paper 3 both illustrate how the entrepreneurial projects opened up spaces for an explicit *questioning* of students' perspective on disciplinary activities. As such, my findings suggest that entrepreneurial projects can indeed build toward new ways of practicing engineering among students, e.g. a more professional or entrepreneurial one, as envisioned by previous work on entrepreneurial engineering pedagogy (Kriewall and Mekemson, 2010, Rae and Melton, 2017). At the very least, different ways of practicing can be illuminated and critically discussed. However, the findings also suggest that the outcomes of these negotiations are not to be taken for granted, and some students may even come to reject and distance themselves from the ways of practicing espoused by teachers. Negotiation thus calls for humility and reflexivity on behalf of the teacher regarding his or her own assumptions and the inclusiveness of the account of professional practices.

5.3. Implications for practice

To foster an entrepreneurial way of practicing engineering among engineering students, my findings suggest that universities should make space for knowledge co-creation between students, teachers and practitioners. A dual strategy can be applied of supporting both *i)* co-creation platforms, i.e. specific electives coupled to physical learning environments and built-up networks, and *ii)* individual educators in facilitating projects with external connection in the mandatory curricula. Contacting external stakeholders and supervising students that do externally connected projects undoubtedly demand extra time and effort on the part of educators, for which they should get extra resources and recognition.

Educators may reflect on what kind of pedagogical models that suit their context, in striving for entrepreneurial projects. In terms of course design, a key concern if involving an external stakeholder to introduce a problem is that students are also given freedom to make projects their own, and introduce and entangle their own perspective in the project. Taking inspiration from established practices in entrepreneurship education, students can be asked to reflect upon and map the team's a priori resources and networks and try to shape the project with this in mind (Sarasvathy, 2009). Conversely, if starting from a student-framed project, there is a need to entangle the professional perspective, e.g. by encouraging students to contact practitioners or consumers to get input on their ideas and the artifacts they produce.

Since students cannot necessarily rely on their usual ways of taking on projects, new strategies need to be introduced and explicated, e.g. through workshops or simulation exercises, when teaching through entrepreneursial projects. New ways of practicing can be introduced early on in the course, tried out in a low-stakes environment, and then unfolded and further sense-made as students are progressing with their projects and have gotten new experiences to connect to. Reflection can be facilitated in a number of ways, e.g. through writing or dialogue. Reflection can in itself be a new activity for students (Moon, 2001), so ideally the purpose of reflection and how it may serve them in the uncertain space in which they have entered can be discussed.

Further, many accounts of experiential learning have reported that instrumental and overly product-oriented assessment of learning may contra-act deep learning (Bernhard et al., 2016, Steghöfer et al., 2016), as it may push students to focus only on the end product, and not their learning process. As such,

students should get recurring formative feedback with which to re-shape their projects, rather than only summative, to support trajectories towards knowledge co-creation rather than contra-act them.

5.4. Limitations and future research

In conducting my empirical studies, I have relied exclusively on qualitative research approaches. While this has provided opportunity to bring to the fore new ways of thinking about entrepreneurial projects in engineering education and the learning processes which they entail, any choice of methodological approach also implies that the findings can only answer a particular kind of questions. In this section, I put forth reflections regarding some of the questions that I could have answered had I chosen another approach, and new questions that arise from my findings – both in relation to opportunities for future research.

5.4.1. Looking deeper into specific entrepreneurial projects

One strategy to extend and complement the work put forth here entails looking deeper into specific entrepreneurial projects. Firstly, the studies put forth here are concerned with students' and teachers' experiences in entrepreneurial projects, but even more could have been done to give voice to students' perspectives. I followed the students as they were taking on entrepreneurial projects, but had no interaction with them before the courses had started or later than a few weeks after the courses had ended. In contrast, I have had extended contact with the teachers in both of the courses I studied in-depth, and have even been involved in teaching one of them. Interviewing or shadowing a few students for a period of time before and after may help to deepen interpretations of how they experience entrepreneurial projects, how they relate them to the curricular and disciplinary activities they are used to engaging in, and long-term effects on their way of practicing engineering. A specific aspect to study further is whether experiences that students struggle to sense-make as they are engaging in entrepreneurial projects are seen in a new light and settled over time, as they engage in new courses or other entrepreneurial activities.

Applying a shadowing technique (Czarniawska-Joerges, 2007) could also complement the studies put forth here in providing an even better understanding of what happens as the projects unfold. In the studies put forth in this thesis, I only observed the classroom setting, and did not follow students as they were working independently in their groups or as they were in contact with externals outside of the university context. Having interviewed students about their experiences of the projects, and having studied their reflective writing, I have had opportunity to inquire into many situations that happened when I was not around, but as Czarniawska-Joerges (2007) notes, there is bound to be situations which students did not deem important or interesting but that would have been illuminating for me to observe.

In order to better understand negotiation of disciplinary practices in entrepreneurial projects, the ways of practicing engineering espoused by teachers need to be better understood. In entrepreneurial engineering pedagogy, there are conceptual accounts starting to map out the idea of an entrepreneurial way of practicing engineering (Rae and Melton, 2017). There are, however, few accounts of what teachers in entrepreneurial projects consider an entrepreneurial way of practicing engineering and the points of negotiation, e.g. during workshops or supervision, where such an espoused way of practicing engineering is acted on by teachers, e.g. through telling students what they should and should not prioritize or how they should think about their projects. In-depth studies of what teachers do to negotiate disciplinary practices in trying to settle students' projects on trajectories towards knowledge co-creation can serve to highlight whether teachers are highly directive in trying to shape students' way of practicing

to align with the "right" (entrepreneurial) way of thinking and practicing, or whether students are allowed freedom to shape their own (entrepreneurial) way of practicing, with the teacher as an instigator of critical reflection on the consequences of the choices they make.

5.4.2. Looking across more courses and contexts

Another overall strategy entails looking across more courses and contexts, and to use for example survey-based approaches to produce quantifiable results. For example, having identified the project formulation phase as a characteristic that may distinguish entrepreneurial projects, I have highlighted three pedagogical models for entrepreneurial projects and two cases describing mechanisms to move students' projects towards knowledge co-creation. There is opportunity to look across more projects and identify other models and mechanisms that may help put students' and practitioners' perspectives "in" and "on" the projects.

Further, I have highlighted tensions between what students and teachers deem relevant disciplinary practices in entrepreneurial projects, especially at the outset of projects. Future work should study how common such tensions are as well as when and to what extent students and teachers experience frustration, confusion, resistance and skepticism in entrepreneurial projects. Such studies may help to understand if (and then why) entrepreneurial projects are experienced as more challenging than project-based learning in general and the nature of the unique challenges they pose. Further, while I have highlighted two important scaffolding strategies employed by teachers to mitigate challenges to participation, this is not necessarily covering the set of scaffolding strategies used across different entrepreneurial projects. While there are some studies discussing scaffolding in entrepreneurial pedagogy (Robinson et al., 2016, Neergaard and Christensen, 2017), it has not received much attention and there is need for a multitude of studies starting from different methodological approaches. Many more aspects of project-based courses, including the ones I have studied, can be interpreted in terms of scaffolding, e.g. the use of technological tools and conceptual frameworks, assessment and feedback schemes, workshop exercises and supervision. Further, the effect and success of scaffolding strategies need to be more fully understood. Such studies may help to understand how common problems of unresolved tensions and consolidated disagreement between students and teachers are.

6. Conclusion

Starting from contemporary discussions of how engineering students should be prepared for professional practice through the fostering of entrepreneurial ways of practicing engineering, the aim of this thesis has been to identify pedagogical models for the design and implementation of entrepreneurial projects in engineering curricula, and to study these models in action. A particular focus has been adopted on the challenges inherent to entrepreneurial projects, and how they are overcome. I have put forth three papers, all drawing on a qualitative research approach focusing on how students and teachers jointly construct and experience entrepreneurial projects.

The thesis has illustrated that while entrepreneurial projects offer different starting points in terms of who formulates the problems that contextualize and drive students' projects, they are characterized by similarly unsettled trajectories towards knowledge co-creation. The thesis extends previous work on entrepreneurial engineering pedagogy by identifying three pedagogical models used by engineering educators to design and implement entrepreneurial projects in engineering curricula. Further, the thesis contributes to an understanding of the challenges and need for support that is inherent to curricular entrepreneurial projects, by outlining how teachers and students struggle with reaching a joint understanding of what to consider relevant disciplinary practices to use in taking on entrepreneurial projects. Opportunities for reflection and negotiation of disciplinary practices have been highlighted as two important scaffolding strategies that help teachers and students navigate the ambiguity and unpredictability of entrepreneurial projects, in order to settle them on trajectories towards knowledge co-creation.

In terms of further research into entrepreneurial engineering pedagogy, I call both for more ethnographic studies and for more quantitative cross-case inquiries. Through such future work, the premises and the effects of entrepreneurial engineering pedagogy may be better evaluated, and as such better guidance may be offered to educators and technical universities that wish to develop an entrepreneurial way of practicing engineering among engineering students.

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