Co-constructing Expertise

Competence Development through Work-Integrated e-Learning in joint Industry-University Collaboration

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Preface

Today, I can look back on my 23 years within University West with appreciation, and gratitude, and especially reflect upon the last five years as a PhD student. In the beginning it was frustrating to become a student after years of lecturing and project management. I had to re-learn and take another position. Eventually I found that it is a privilege to spend full time and years on only one study. Enthusiasm, frustration and motivation have been a cyclical mix, not to mention all then pressure from others evaluating my work. Becoming the life-long learner and realizing that I am in the back seat and not driving the car (teaching) is a reflecting process for continuous competence development in so many senses. Wow, everybody should have that opportunity.

I am not sure when my interest to instruct, teach or making inquiries really started. Perhaps it was when mother told me that I disturbed my two younger brothers when asking them about how things are connected, or when I constantly tried to instruct them. After high school I had a hard time to find my path, it never occurred to me that an academic career was something even possible, growing up in an entrepreneurial family in the 70s. Our talks at the dinner table concerned the importance of hard work, not to take anything for granted in life, and to earn money. My father used to say, “to be good in economics doesn’t hurt”. He was running a small welding firm, always worrying about the employees’ salaries.

In 1995, a couple of years after graduating the Systems Science program in Uddevalla, Rolf Dahlberg, prefect, hired me, thank you. He saw the potentials of former students and promoted me to educate elementary school teachers in MS-office and basic IT. I became hooked by the adults’ energy for new learning. I was teaching them new things, and I learned a lot! Later on I wanted to get out of the class room, and became engaged in regional development projects, digital broadband services and distance education, especially within the RIV project. What an innovative team we were Lennart Bernhardsson, Karin Bergenlid and Karin Jansson and all the RIV coordinators in Fyrbodal. Afterwards, Lars Hillefors, employed me at the central administration to coordinate the Swedish net university facilitation at University West. Distance learning was developing on-line and through the regional learning centers. After some years, I started working at the engineering department, and yet again I had to transform through new learning, trying to learn production technology. A new knowledge field, and a new culture. To open up your own ideas and try them out, asks for braveness and a culture that enhance sharing and mutual constructing. Everyone can develop their expertise if we support and believe in a life-long learning journey. Stay motivated and encounter challenges!
Acknowledgements

I was one of the first PhD students’ accepted in the University West’s new vital research environment Learning in and for the new working life, LINA. The studies were carried out within the vital research environment Production Technology West (PTW). The research studies have mainly been funded by the Knowledge Foundation (KKs) through the MERIT project and the still on-going ProdEx project, thank you. I am grateful for the support and encouragement from colleagues, external partners, friends and family. All of you together, made me come to an end – thank you!

Thank you, Liselott Lycke, former prefect at the Engineering department, Professor Per Nylén and Ass. Professor Anna-Karin Christiansson, for the opportunities you provided, and for having faith in me, when I entered the research group at PTC in 2008. Per, you supported and challenged me to become a PhD student, I am grateful for your confidence in me.

I sincerely thank my whole supervising team for your support, guidance and encouragement. Professor Lars Svensson, main supervisor, I am really grateful that you pushed me to become a PhD student. I honestly thank you for your patience to let me decide on my own, but also the presence when I really needed your guidance. You have a unique theoretically and methodologically knowledge within the interdisciplinary jungle of informatics, learning and engineering, that is priceless.

Thank you Linn Gustavsson-Christiernin, co-supervisor, for your analytical eye and readings during the first year of the studies. Lennart Malmsköld, co-supervisor, thank you for taking over, and for bringing a sharp eye from the industry. Your support during my application in Primus will guide my future work. Thank you Kristina Eriksson, co-supervisor, I am deeply and eternally grateful for all your help and confidence in me personally and in my work. Especially thanks for all the time of constantly readings, proof readings, co-authoring, and small talks when I really needed it. Your engineering skills during field work was invaluable. Maria Spante, co-supervisor, dear thanks for your dedication and personal support during the last year. Your way of positioning my work and explicate what I really mean, helped me finalizing.

Thank you, Professor Gunnar Bolmsjö, my manager and ProdEx project leader, for sharing your in-depth knowledge and for considering my critical eye as a resource when managing the project. Ingrid Elison, operating project leader, thank you for entering the project in halftime, and for fuel it with industrial learning content and guidance.
I am especially grateful for all of you research teacher experts making the MERIT and ProdEx effort come true; Fredrik Danielsson, Bo Svensson, Kristina Eriksson, Jari Repo, Tomas Beno, Linn Gustavsson-Christiermin, Mats Larsson, Kenneth Eriksson, Mahdi Eynian, Anders Nilsson, Ulf Hulling, Andreas Gustafsson, Mattias Ottosson, Anders Appelgren and Svante Augustsson. I also thank the project administration, Victoria Sjöstedt and Eva Bränneby and the ICT support, Caroline Andersson and Michael Kleber. Thank you all precious PTW colleagues for being there in a supportive engineering research environment.

A special thanks to Jörgen Sörensen, senior HR manager at GKN Aerospace, for supportive ideas, recruitment of practitioners, and marketing of the project in the company network. Thank you, all collaborating and participating companies, managers and practitioners.

A special and dear thanks to Kristina Johansson, Assistant research director in LINA. Your knowledge in work-integrated learning, and supportive doctoral teaching created a new learning trajectory for me. Always caring and supporting in every sense. Also, a special thanks to Kristina Sandström for insights into cooperative education and networks.

Thank you, Professor Yrjö Engeström and Ass. Professor Annalisa Sannino for a wonderful collaboration, valuable advice, and co-authoring.

Thank you, LINA-PhD doctoral colleagues for being there, for joyful learning, discussions, breaks, after works and conferences; Annika Andersson, Anne Algers, Anna Sigridur Islind, Camilla Seitl, Helena Vallo, Linnéa Åberg, Katarina Cederlund, Karin Högberg, Livia Norström, Marie Westerlind, Tuija Viking, Said Morad Babaheidari, Sara Willermark and Ville Björck. Many thanks to all senior researchers in the LINA-crew and colleagues at the School of Business, Economics and IT.

Thank you dear friends, for precious support and joyful dancing, sports, travels, and friendly talks, you mean so much. Thank you my two dear brothers and families. Thank you my Norwegian relatives. And thank you my dearest daughter, always supportive, you mean everything to me, and I love you for who you are. My love Ingemar, you came into my life with warmth, dedication and true interest. Thank you for all your patience and trust.

Monika Hattinger

Trollhättan, January 2018
Populärvetenskaplig sammanfattning

Nyckelord: Kompetensutveckling, e-lärande design, lärande, samproduktion, tillverkningsindustri, expertkunskap, knutarbete, expansiv transformation, gränsöverskriderande

Den här avhandlingen är tvärvetenskaplig och utgår ifrån de utmaningar som den ökade digitaliseringen, automatiseringen och robotiseringen ställer på tillverkningsindustrin och det kontinuerliga behov av kvalificerade operatörer och ingenjörer som uppstår. Digitaliseringen utmanar också universitets tillgänglighet och öppenhet till extern samverkan genom ett anpassat och flexibelt e-lärande som riktar mot industrins kunskapsbehovs som stöd för kontinuerlig kompetensutveckling.

Studierna i avhandlingen utgår ifrån digitaliserings utmaningar och studerar inter-organisatoriska samarbeten, aktiviteter och former för gemensamt kunskapsbyggande med målet att stärka och utveckla nya kompetenser, genom integrerade e-lärandeformer för framtidens industriella transformation. Övergripande syfte är att undersöka hur ömsesidig konstruktion av kunskap utvecklas genom lärandeformer mellan flera aktörer i en gemensam e-lärandepraktik mellan industri- och högskola. Forskningen sker inom en ny typ av kollaborativt utbildningskoncept utvecklat inom projektet ProdEx. Projektet omfattar ett industrinätverk i samverkan med en regional högskola, i en longitudinell design- och implementeringsprocess av flexibelt- och arbetsintegrerat e-lärande.

Forskningsansatsen bygger på en kollaborativ aktionsorienterad ansats som mixats med fem delstudier, vilka genomfördes från januari 2013 – våren 2016. I delstudierna var fyra perspektiv centra, per för kunskapsutvecklingen; industrichef (produktionschefer och HR-chefer), praktikers (operatörer och ingenjörer), forskningsaktiva lärare (forskarlärare) och den specifika kursenheten. Specifikt intresse berörde hur dessa aktörer gemensamt och över tid samkonstruerar produktionskunskap och aktivt tillför erfarenheter till utveckling och design av en ny e-lärandepraktik. Ett 20-tal tillverkningsföretag inom främst flyg- och bilindustrin har deltagit. Studierna omfattas av ca 50 chefer, 200 kursdeltagare och 10-tal forskningsaktiva lärare i design-processen av 18 flexibla kursmoduler omfattande 2,5 högskolepoäng. Åmnesområdena är industriautomation, maskinbearbetning, förhandlingsteknik i företag samt ingenjörsverktygskurser med Matlab och FEM.

Med stöd av kultur-historisk aktivitetsteori blev förhandlat knutarbete (negotiated knotworking) ett centralt teoretiskt begrepp och ett arbetsverktyg som användes

Resultaten från de olika delstudierna bidrar till en bredare förståelse för hur samkonstruktion av kunskap i en e-lärandepraktik stödd av iterativa designcykler bidrog till en starkare kunskapssyn och standardiserade kurser. Case-baserade uppgifter (real cases) och digital labbar stödjer integration av teori och praktik, i en ömsesidig lärandeprocess genom aktivt deltagande mellan praktiker och forskarlärare. Tekniska och pedagogiska misstag som uppstod i de initiala kursmodulererna var enklare att övervinna än den kvarstående utmaningen att företag och chefer kontinuerligt stödjer anställdas möjligheter till kursdeltagande, även utan direkta kurskostnader. Kompetensmatchning av industribehov kontra tillgänglighet och spetskompetens vid högskolan är en ständig adresserad utmaning. Genom kursdeltagandet utvecklade praktikerna ett mer kritiskt förhållningssätt till kunskap och genomströmningen var hög. De visade engagemang genom att aktivt delta i en samkonstruktions- och lärandeprocess. Samkonstruktion av kunskap blev en tvåvägsinteraktion som också ställde krav på forskarlärare att konstruera ett kunskapsinnehåll, med relevant nivå och att designa kollaborativa utbildningsmetoder som aktivt engagerar och involverar praktikers erfarenheter.

Medan tidigare forskning har diskuterat problemen med att korsa gränser mellan industri och högskola, visar resultaten i avhandlingens studier att det sker gränsöverskridande aktiviteter när företags- och högskoleaktörer tillsammans konstruerar kunskap i en e-lärandepraktik. Samkonstruktion av kunskaper förutsätter ömsesidigt förtroende, ”sideways learning” samt interaktivt och dubbel-riktat lärande.

Huvudbidraget i avhandlingen, samkonstruerande expertis, förutsätter att tre nivåer av aktiviteter sker mellan aktörer. Att ha insikt i andras syften och praxis (relationell kompetens), att ha förmågan att omvandla och lösa praktikproblem och bygga gemensam kunskap (distribuerad expertis) och slutligen, att ha förmågan att aktivt och ömsesidigt samkonstruera kunskap som man agerat och reflektator över i praktiken för framtida arbetsintegrerad transformation (samkonstruerad expertis).
Abstract

Title: Co-constructing Expertise – Competence Development through Work-Integrated e-Learning in joint Industry-University Collaboration

Keywords: Competence Development, e-Learning design, Learning activities, Co-construction, Manufacturing industry, Expert knowledge, Knotworking, Expansive Transformation, Boundary crossing

ISBN: 978-91-87531-75-0 (print)

This thesis is inter-disciplinary and proceed from the ongoing challenges of the increased digitalization, automation and robotization that impact the manufacturing industry’s emergent need of high-qualified practitioners. Digitalization also challenges universities to open up to external collaboration and to design blended e-learning targeting industry knowledge needs. The studies take up on such challenges and explore inter-organizational collaborations and forms of knowledge construction to strengthen engineering competences integrated in work in a way that enables manufacturing companies to remain effective and to be prepared for future industrial transformations. The objective is to explore how mutual construction of knowledge emerge through learning activities between multiple actors in a joint industry-university collaborative e-learning practice. The empirical setting is a new type of collaborative course concept developed within the project ProdEx. The project comprise a network of industries and one university in a longitudinal design and implementation process of blended and work-integrated e-learning. This initiative was explored with a collaborative action research approach integrated with five studies, from four perspectives, the industry managers, the practitioners, the research teachers and the course unit.

Negotiated knotworking, from cultural-historical activity theory, became a central theoretical concept and a working tool to examine how managers, practitioners and research teachers together negotiated production technology knowledge content and e-learning design towards future workplace transformations. This concept was used to further understand how co-construction of knowledge was developing over time into a richer concept. The results contributes to a wider understanding of how co-construction of knowledge in an e-learning design practice was developing into stronger relations between actors and into more stable courses. Real learning cases and digital labs support theory-practical intertwining of mutual learning of active participation between practitioners and
research teachers. Initial e-learning technology failures and pedagogical mistakes in the courses were easier to overcome, than issues concerning continuous company support for course participation. Matching industry competence needs with university research fields is continuously challenging. Practitioners’ aiming for personal continuous competence development on university level created critical and high-qualitative performances and valuable engagement throughout the process of co-construction of knowledge. The knowledge co-construction became a two-way development, pushing research teachers to active involve and consider practitioners’ industry experiences concerning learning content, pedagogical strategies and e-learning forms.

While earlier research has discussed the problems of crossing boundaries between industry and university, overall findings show that industry and university actors are crossing boundaries when they mutually co-construct knowledge in an e-learning practice. Co-construction of knowledge entail mutual trust, sideways and interactive learning in a collaborative context. The main contribution suggested in the thesis is that co-constructing expertise entail three levels of activities among actors; to have insight into the purposes and practices of others (relational expertise), the capacity to transform the problems of a practice and together build common knowledge (distributed expertise), and finally the capacity of mutually co-construct knowledge acted upon in practice towards work-integrated transformations (co-constructing expertise).
Appended publications

This thesis is based on the following appended publications:


*Author’s contribution*: Main writer and substantial idea generator. Formulated aim of the study, and designed interview guide. Performed most data collection and some with one co-author, and critical literature review of content. Discussing analysis with co-authors and made revisions. Sole presenter at the conference.


*Author’s contribution*: Sole writer and initiated the conception of the study design. Performed most data collection and some with one co-author. Critical literature review of content. Discussing theoretical choice and analysis with co-authors. Drafting the work and improving it critically for intellectual content.


*Author’s contribution*: Main writer and performed equal contributions to the work with co-author. Formulated aim, design and performed data collection in collaboration with co-author. Sole critical literature review of content. Discussing phases of analysis and theoretical choice collaboratively with the co-author. Drafting the work and improving it critically for intellectual content and correspondence with the journal.

*Author's contribution:* Main writer and substantial contributor to the conception of the study design. Design and performance of data collection in collaboration with co-author. Analysis and final version of manuscript were discussed in supervisor group. Drafting the work and improving it critically for intellectual content. Sole correspondence until approval of the final version, and sole presenter at the conference.


*Author's contribution:* Initiated the conception of the study design. Formulated study aim, interview guide, collected the data with assistance from a colleague. Individual choice of theory and critical literature review. Made sole analysis, theoretical choice and discussing with supervisor group. Drafting the work and improving it critically for intellectual content. Was invited by international co-authors later in the process, meaning late co-authoring into final submission.
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Paper I. Digitizing work: Organizational Work-Integrated Learning through Technology Mediated Courses in Manufacturing Industry

Paper II. E-learning Readiness and Absorptive Capacity in the Manufacturing Industry

Paper III. Situated and Mediated Engineering Education: Researchers Design Conceptions of e-Learning targeting Industry Practitioners Competence needs

Paper IV. Action Design Research. Design of e-WIL for the Manufacturing Industry

Paper V. From Contradictions to Transformation, a study of joint Work-Integrated E-learning between Industry and University
1 Introduction

This chapter introduces the research approach and problem background to the thesis, then follows the aim including research questions, and finally the structure of the thesis.

The objective of this thesis is to explore how mutual construction of knowledge emerge through learning activities between multiple actors in a joint industry-university collaborative e-learning practice. The knowledge embraces both production technology knowledge and design-related knowledge in an e-learning design process of formalized courses, which is organized in joint collaboration between a network of manufacturing companies and one university. The studies departure from the challenging problem of exploring and designing inter-organisational learning activities that are constructed for strengthening engineering competences and integrating them in work practice, in a way that enables companies to remain effective and to be prepared for future industrial transformations (Susskind, 2016; Susskind & Susskind, 2015).

1.1 Research background

The increased digitalization (Castells, 2010; Tseleitis, Domingue, & Galis, 2009), industrial automation and robotics (Ford, 2015; Koren, 2010), pressure industry companies to expand and transform future professions to be able to cope with new production systems, virtual manufacturing and digital services (Engeström, 2015; Susskind, 2016; Susskind & Susskind, 2015; Virkkunen, Mäkinen, & Lintula, 2013). Today, when the industrial workplaces become more effective, it pressures practitioners’ to continuously perform future-oriented development of integrating robotics, automation and other data-driven technologies into their workflows. For such new demanding tasks, practitioners need new competences and deeper expertise to be able to increase knowledge of future-oriented methods for machining, technical computing and simulation-based design (Karlsson, et al., 2013; Romero et al., 2016).

When the production systems in the factories transform due to increased digitalization, then the operators and engineering tasks also changes and thus other use of practitioners’ unique abilities to innovate, collaborate and adapt to new emerging situations evolve (Frey & Osborne, 2017). However, this situation put diverse pressures on both the individual and the workplace organisation. Practitioners become forced to handle new challenging tasks such as knowledge-based reasoning within a knowledge-intensive production, instead of performing...
manual operations. Engineers need to continuously advance their capabilities and specialization of computational models and simulation, logic reasoning and programming in robotics and advanced industrial automation systems (Ford, 2015; Koren, 2010).

The increased digitalization and the pressure of re-configuration factories, posture transformative changes in production work, and hence pushes industry management and practitioners to constantly re-learn and to learn new knowledge, and also knowledge that is not even there yet (Engeström, 2001). However, such concern does not only justify individual’s own power to progress, neither a single organizations’ responsibility, rather it is a mutual concern among diverse stakeholders’ common efforts together to find ways to support competence development as part of a changing society. These efforts are essential for strengthening expert knowledge and expertise, in order to prepare the company organisation and the employees for meeting future risks of dismantled professions (Susskind & Susskind, 2015).

There are many types of efforts and activities industries can make to improve their employees’ competences. They can actively support knowledge development through formalised education or through informal learning integrated in work practice (Fischer, 2000). Companies can also actively collaborate with external educational and research institutions or universities through diverse forms of co-production of knowledge (Fenwick, 2012; Jasanoff, 2004). Co-production however, is not a consistent concept, from neither epistemological views nor its use in practice, rather it comprises a wide area of making identities, making institutions, making discourses, and making presentations (Jasanoff, 2004). Co-production on practitioners’ levels, meaning in practical use and development are rather scarce and does not guarantee a prosperous and mutual outcome. Instead it is more often stated on a policy level that the co-production discourse at present promotes universalized claims and ideals for all aspects of beneficial equal partnerships, and benefits for all actors included and future effectiveness (Fenwick, 2012). But, co-production as an overall goal in itself does not guarantee prosperous development (Jasanoff, 2004).

From a university perspective the increased digitalization and following the new knowledge requirements to open up the university and start co-production with external organizations, challenge the university to reach out for new target groups, and developing, on-line education into more integrated, blended and flexible forms to support continuous professional and lifelong learning (Govaerts & Baert, 2011; Servage, 2005; Svensson, 2004). However, university programs are usually traditionally designed for individual purposes, for fulltime on-campus education, and have long planning horizons for developing curricula, course content, and routines. Strategies and actions for an immediate capacity to meet
practitioners specific knowledge needs are often problematical (Kirkwood & Price, 2014). Given the challenges of meeting professional development through e-learning education and finding collaborative forms of co-production, universities need to readjust their educational strategies from the delivery paradigm, towards education targeting new types of learners. Hence, they need to find new ways of approaching, designing and implementing blended e-learning forms supporting both individual purposes and work organizations increased competence requests (Porter, et al., 2014; Prince, 2004). In addition, integrating manufacturing organizations’ engineering knowledge needs, are pedagogically and technically hard (Billett, 2002; Dubois & Long, 2012; Lahn, 2004; Thompson, 2016; Tynjälä & Häkkinen, 2005). Especially demanding is the pedagogical and technical work of digitizing engineering knowledge, e.g. laboratory and machine dependent tasks, and broadcasting 3D applications (Bourne, et al., 2005).

**Exploring knowledge construction in a new educational practice between industry and university**

In summary, increased digitalization creates opportunities, but also challenge and push industries and universities into new forms of collaborations and specifically into co-production, which may create tensions, role-definitions, power-relations, cultural differences etc. Consequently new types of inter-organizational boundaries are shaped and crossed (Akkerman & Bakker, 2011a). Research in this thesis takes place at the inter-organizational boundary of work and higher education.

An underlying assumption brought into the thesis work is that the two concepts of co-production and work-integrated learning postulate that through combining theory and practice, i.e. intertwining academic research-based knowledge with industry experience-based know how, expert knowledge and successful learning will be reached. As such, this thesis deals with the intertwining of engineering workplace knowledge and the educational and research knowledge at the university in forms of facilitating co-production. Traditionally, research teachers are favoring disciplinary research knowledge (declarative and general), however they also need to be members of the professional practices and to integrate workplace experiences (Boyer, 1990). Moreover, in the workplace, the industry professional practitioners’ procedural knowledge needs to be theoretically applied in order to increase their expertise (Corbett & Anderson, 1994). This thesis is exploring such dualistic challenges in a process over time, of which I prefer the concept of co-construction of knowledge. Following this argumentation, the entrance of this thesis work, is to capture both activities at the systemic intersection between the industry and the university, and the learning activities between research teachers and workplace engineering practitioners.
The project ProdEx – Expert in Production Technology

The five studies included in the thesis focus in particular on mutual knowledge construction in learning activities taking part in the longitudinal and joint collaborative competence development project, ProdEx. These learning activities are broadly capturing the production technology knowledge, the learning design knowledge, and the identification and exploration of practices in the intertwining process of teaching and learning. Learning design knowledge is the knowledge that universities and teachers are developing for a concrete unit of learning, meaning the knowledge they need to design and implement such as a course, a curriculum, a digital learning task etc. (Beetham & Sharpe, 2013; Koper, 2005). The study of best practices are related specifically to the engineering specific subject field intertwined with approaches for stimulating work-integration. The project comprises a longitudinal design process of new types of e-learning courses targeting industry practitioners’ knowledge needs and designed at advanced academic level, see Figure 1. ProdEx is a collaborative adventure between a network of industries, and one university, in the western part of Sweden. The project outset goal is that co-production of knowledge between industry and university will support expert competences within production technology.

![Figure 1. Four educational models for professional development](image)

ProdEx is the context in which this thesis departure for exploring e-learning activities in various forms and content, organized to support co-production of knowledge between different actors (managers, research teachers and
practitioners), and on the boundary between the two stakeholder organizations, an industry network and one university. In the lower left corner in Figure 1, post-secondary practical education is found. The lower right corner show post-secondary higher vocational education (Yrkeshögskola, YH). In the upper left corner one finds distance and on-line education on university level targeting individual learning needs. These adult educations are established forms in Sweden. The industry-university collaborative concept that ProdEx offers is a new type of educational practice, delineated within this thesis.

1.2 Aim and Research Questions

This thesis aims at contributing to takes part within the interdisciplinary fields of information systems design, Work-Integrated Learning (WIL) and production technology. Expert knowledge within production technology and e-learning design are two intertwined processes of which the studies departure. The objective of this thesis is to explore how mutual construction of knowledge emerge through learning activities between multiple actors in a joint industry-university collaborative e-learning practice. The study focus on emerging processes between multiple actors (industry managers, research teachers and industry practitioners) within the two stakeholder organizations, the industry and the university, in which they give implications for an e-learning design process.

The overall research question is: How is production technology knowledge mutually constructed among multiple actors in a joint e-learning design process between industry and university?

The overall research question includes the following research questions:

1) What are the learning conditions and the e-learning readiness in manufacturing companies that will affect the design of work-integrated e-learning?

2) How do expert research teachers approach a new e-learning situation with experienced engineering practitioners in the manufacturing industry?

3) How can e-learning courses be designed to support competence development and work-integrated learning?

4) How is knowledge mutually constructed between expert research teachers and practitioners into expansive learning?

5) How is industry management supporting practitioners’ new knowledge from e-learning interventions into expansive transformation in the workplace?

The methodological approach used in this thesis is action research and specifically a collaborative practice research approach on the overall program level interrelated with four case studies and one action design study (Mathiassen, 2002).
Cultural-Historical Activity Theory, (CHAT) is applied as a theoretical perspective on a general level (Engeström, 2001; 2015), together with mainly related socio-cultural theories within the specific studies. The studies, research questions and papers are illustrated in Table 1.

Table 1. Overview of the studies, related RQ:s and papers.

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<th>Study</th>
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The five research studies included in the thesis explore mutual knowledge construction of expert knowledge circling practitioners and research teachers’ collective activities and perspectives, including practical engineering experiences, problem solving, best practice and future engineering demands. Three main concepts are in focus: e-learning activities, co-construction and knotworking. E-learning activities and co-construction were initial concepts (co-production was set by the ProdEx project, but I prefer the concept of co-construction). About halftime through the thesis work in 2015, knotworking gradually became an important concept to further understand and analyse learning activities and relations to co-construction. Knotworking was introduced by Engeström (2008) and is referring to tying, untying and retying of separate threads of activity in temporary teams.

The research teachers are experts within their specific knowledge subjects, and act as both teachers and researchers, hereafter labelled research teachers or researchers. The practitioners are experienced experts in the workplace and are labelled practitioners or (course) participants. They are occasionally and theoretically described in the thesis as learners. The industry company managers comprise mainly production technology managers and human resource managers. These three types of actors are experts in their specific field, however not explicated as such throughout the thesis. Experts and expertise are part of the research focus further developed within the thesis, specifically from socio-cultural perspective (Lave & Wenger, 1991) and activity-theory (Engeström, 2001; 2015).
1.3 Thesis outline

The first part is divided in seven chapters including references, and the second part includes the appended publications. After this first introduction chapter, the chapters are structured as follows:

2. Related research, includes co-production, industry transformations, engineering knowledge, adult learning approaches and e-learning technologies.

3. Theoretical framework, includes central theories and concepts used.

4. Research context and project, describes the ProdEx project and the stakeholders.

5. Research design and findings, includes the overall action research combined with the five individual studies’, the methodological approach and the findings. It ends with a short summary results.

6. Analysis and discussion, analyses the results of the thesis project, and discuss the holistic thesis analyzed results.

7. Conclusions, describes contributions to theory, practice, gives methodological considerations and ends with future work.
2 Related Research

This chapter is an overview of related research. First the concept of co-production and related concepts is outlined, then follows a short introduction to the transformation of manufacturing industry and the interdisciplinary field of engineering competences. Thereafter follows learning theories of socio-cultural learning, work-integrated and workplace learning. Finally e-learning and learning technologies, are described.

Efforts with learning and educational projects across industry and university seem to be a powerful way of integrating theory and practice as an intertwined co-productive process. Tynjälä (2008) put forward that scholastic learning should adopt specific features of workplace learning and workplace development of expertise. Furthermore, workplace learning needs to be developed by utilizing strong features of scholastic learning. However, to reach efforts of integrating and producing powerful knowledge development by combining an academic culture with the workplace culture is built on different theoretical underpinnings. In this thesis, research focus on the integrative boundary of e-learning design and co-construction of engineering expert knowledge between workplace and university, embracing a broad area of research and approached from a learning perspective. This research overview gives a background on the complexity of professional competences, experience-based learning and e-learning in and between the workplace and university.

2.1 Co-production - an Evolving Concept

The concept of co-production was commenced in the ProdEx project from the outset, however co-production is an evolving concept that have implications for practice and can be understood from diverse theoretical perspectives. The short discussion below ground this complexity of the two aligning concept co-production and co-construction.

Co-production can be conceptualized in many different ways (Needham, 2008), but its discussions pose important questions about the changing nature and value of professional work, expertise and knowledge (Fenwick, 2012). Co-production involves collaborative actions and mutual activities. However, how, in what forms, when, with whom, or on which organizational level depends on various knowledge views (epistemological) and traditions (Jasanoff, 2004). Fenwick (2012) is questioning how policy documents within public services underline the potential of co-productive arrangements to build social cohesion, citizen
empowerment, however what actually happens in the concrete practices of such arrangements is less well known. Jacoby and Ochs (1995), rather address co-construction as the constitution and interpretation of culturally and historically situated social interactions. They refer to co-construction as the joint creation of a form, interpretation, action, activity, identity, institution, skill, ideology, emotion, or other culturally meaningful reality. However, they also stress that the co-prefix does not necessarily entail or support interactions. A negotiation, for example, in which the parties express disagreement, is nonetheless co-constructed.

Jasanoff (2004) professor in Science and Technology Studies, (STS), argues that the concept co-production is to be understood and used variously due to different epistemological views and through its historical traces. Co-production is not only a simple phenomenon of social and political interests, rather it is symmetrical with interests in social dimensions of cognition and understandings, and at the same time related to material connections of social formations. “Co-production offers new ways of thinking of power, highlighting the often invisible role of knowledges, expertise, technical practices and material objects in shaping, sustaining, subverting or transforming relations of authority.” (Jasanoff, 2004, p. 4)

Jasanoff (2004) and her colleagues outline four historical traditions contributing to the idiom co-production. The first tradition concerns emergence and stabilization of new objects or phenomena. The second on controversy, viewing practices and processes by which one set of ideas gains control over competing ideas. The third concern intelligibility and portability of products of science and technology across time, place and institutional contexts. The final fourth tradition examines the cultural practices of science and technology in contexts that provide them with legitimacy and meaning. Furthermore, it is concluded that co-production entail constant intertwining of the cognitive, the material, the social and the normative. It is equally about concrete physical things as ideas. It handles how people organize or express themselves, what they value and how they assume responsibility for their inventions. Therefore, co-production circle wide areas such as making identities, making institutions, making discourses, and making presentations.

Two strands of research literature can be separated into constitutive and interactional (Jasanoff, 2004). Constitutive concerns the ways in which stability is created and maintained, mainly for emergent phenomena, in particular places where knowledge is made, for instance within a research laboratory. Such studies seek to understand how particular states of knowledge are arrived at, and held in place. It focuses on the emergence of new facts, things and systems of thought. The interactional approach, by contrast, is less openly concerned with metaphysics and more with epistemology, that is, less what is, and more of how we know about it.
It concerns more knowledge conflicts that have already been defined, for practical purposes, into the natural and the social.

I would argue for that this thesis mainly follows the *interactional* approach, which means to explore *how* co-production is facilitated from a process-oriented view. With this follows that I seek to understand how knowledge in a process is constructing, rather than to define its end. The process-orientation, includes both the subjects and tools, and the *cultural practice* of science and technology in which I delineate meaning and learning among stakeholders. Jacoby and Ochs (1995), address such knowledge stance as *co-construction* with emphasize on culturally and historically situated social interactions. The engineering research and practitioner context, in which the studies have been conducted, can however be described as mainly belonging to the *constitutive strand*, in which practitioners, researchers and managers favor facts and final products as the main stream for explanation and knowledge production, and not as open-ended.

There are various concepts relating to co-production found in research such as co-creation in human resource and educational studies (García-Peñalvo et al., 2013), co-creation for market and consumer value (Prahalad & Ramaswamy, 2004) and in communication studies (Jacoby & Ochs, 1995). The growing body of studies are using the concept co-construction drawing upon the Vygotskyan tradition of relational development (Goldstein, 1999), and furthermore in user-and technology centered studies (Oudshoorn & Pinch, 2003). However, once I in literature research combine co-construction with either ‘engineering’ or ‘manufacturing’, studies mostly seem to concern the constitutive strand of knowledge drawing on facts and macro-perspective. Hence applying an interactional approach within a manufacturing context seem scarce. Furthermore, the axiom of co-construction especially apply well to STS combining users and design research, for instance within the strand of socio-material studies that aim to intertwine socio-cultural use and design of artifacts, through concepts such as imbrication (Leonardi, Nardi, & Kallinikos, 2012), and entanglement (Feldman & Orlikowski, 2011; Orlikowski & Scott, 2008). However, these studies do not in particular include a learning view throughout design and use.

The concept of *co-construction* contextualizes sharing, and giving from two or more perspectives and involves a social space in and between individuals, and across individuals and technological artifacts that prosper positive engagement and a certain excitement of new knowledge and learning (Goldstein, 1999; Rice, 2002; Weinberger & Fischer, 2006). Built on these arguments co-construction is further used instead of co-production, because the main object of study are the mutual learning activities that are constructed throughout the e-learning design process. When co-production is mentioned it is related to the ProdEix project. Co-production used in the interview study guides, see Appendix A, B, D and E.
2.2 The Transformation of Manufacturing Industry

The industrial revolution and furthermore the entrance of the information and digital society have transformed and revolutionized the manufacturing industry conditions (Burke, 2012; Castells, 2010; Koren, 2010). When machines took over in order to reduce time, labor no longer appeared so much to be included within the production process; rather the individual became more of a watchman and regulator to the production process itself (Wood, Bruner, & Ross, 1976). The smart machine of increased automatic control, which was made possible by a combination of intelligent sensors, replaced the worker’s body and smart systems whose artificial intelligence replaced the worker’s tacit knowledge (Zuboff, 1988). The factory vision was to speed the process control into one data system to manage parts or an entire process from one central location, and thereby eliminating the need of workers (Zuboff, 1988). However, time was made available for operators and engineers’ for problem solving and other advanced decision-making.

The manufacturing industry in Sweden, is facing a global market competition and are constantly pressured to adjust the production system to consumer demands. In a knowledge-based economy, manufacturing companies therefore constantly need to strive for a cost-effective production of low machine- and technology costs, meanwhile deliver high quality products and costumer services (Schmiede & Will-Zocholl, 2011).

Challenges of increased robot assembly and automatization require new types of knowledge applicable to both an immediate work practice and for future adaptation (Ford, 2015; Koren, 2010). With an increased digitalization, the development of new combinations of physical production and services is able to match the specialized customization demands. However, when more product models and smaller series is to be produced in the same production system there must be a higher and faster flexibility, which asks for a more flexible production and automation. Consequently, more product models and smaller series produced in the same production system lead to increased demands for flexibility and short lead times. Such fast re-configurations need highly skilled personnel that quickly are able to adapt to and make use of new digital applications for everyday work practice. Today, the production system in general is highly automated and most engineering work therefore focus on monitoring and controlling the production system. Engineering work and knowledge is also about problem solving, continuous technological development and improvement among many other things. However, reality is still far from an effective and fully digitalized work environment and competences need to be strengthen continuously. Even if we
see an increased automation and digitalization, the engineering work is still very locally bounded. Knowledge-intensive work pressure operators, engineers and manufacturing companies to assess new expert knowledge and adapt to changes that imply short-term flexibility instead of long-term perspectives (Schmiede & Will-Zocholl, 2011). For instance, models that used to be made on the drawing board, is now to be designed using CAD systems for modelling digitized 3D models and to create digital mock ups that can be simulated for future functions of the specific components and the complete product as a virtual prototype (Schmiede & Will-Zocholl, 2011).

The use of modern technologies has fundamentally transformed the work of engineers engaged in product development processes in modern manufacturing companies. Engineering methods have changed from step-by-step procedures to much more modularized simultaneous engineering (Schmiede & Will-Zocholl, 2011). The various phases of the product development process that overlap the preceding and the following phases, and as mentioned before, speeds up product changes and shorten lead times. For engineers this means that they are responsible for different components, parts, etc. of different projects in various phases of the product development process.

2.3 Engineering Knowledge and Competences

The situation for manufacturing companies of continual competition require capacities to absorb new knowledge to survive. Collaboration between different professions, and skills in the production chain, can reinforce such knowledge development, but conditions for this type of collaboration can also be understood as competitive threat (Richey and Autry, 2009). Accordingly, when companies are performing challenging tasks, inter-firm collaboration is not always a feasible solution due to inherent risks of bringing out valuable knowledge. From this perspective, co-production over organizational boundaries may enhance “dangerous” knowledge construction. However, in modern society and by bringing the concept of co-production of knowledge in front as concept that empower change and innovation, there are other questions to be asked. Do knowledge have organizational boundaries, and how are knowledge contextualized?

The engineering discipline comprise a broad range of specialized fields of engineering, each with a more specific emphasis on particular areas of applied science, technology and types of application (Committee, 2008). It is a discipline of acquiring and applying scientific, mathematical, economic, social, and practical knowledge. Engineering professionals have variously knowledge related to advanced problem solving, building and using machines, to design and build
structures, devices, systems, materials and processes that safely realize improvements to the lives of people (Committee, 2008; Dym, et al., 2005; Itabashi-Campbell, Perelli, & Gluesing, 2011; Madsen, Bilberg, & Hansen, 2016; Walther, et al., 2011).

Not only must an engineer have high engineering know how, but also other competencies and skills for acquiring expert engineering knowledge. These competencies are for instance operational management, leadership abilities, general IT usage, and social skills such as communication and interaction that are vital for the workplace setting. To be a competent engineer with high skills and knowhow, request both theoretical and practical knowledge. The problem-focused learning, with open-ended problem solving is important factors of engineering knowledge in education (Godfrey & Parker, 2010; Walther et al., 2011).

However, the ability to solve problems creatively is identified as one of the imperative competencies for graduating students by engineering associations worldwide (Belski, Adunka, & Mayer, 2016). In their study of 46 engineering experts, they found that 1) knowledge outside of the individual’s professional domain plays important role in attaining creative solutions in their day-to-day engineering work, 2) learning creativity methods and problem solving heuristics is more important than acquiring additional discipline knowledge, and 3) the problem solving stage of identifying and understanding a problem is the key to a creative solution.

In Dunsmore, Turns, and Yellin (2011) study of engineering student conceptions of engineering, they stressed the importance of both content knowledge skills such as understanding engineering science fundamentals, design and manufacturing processes and soft skills such as communication skills, multidisciplinary systems perspective, understanding the context in which engineering is practiced and the importance of teamwork. Result from the study show that students find engineering education lacking training in soft skills and practice-related tasks.

These two recent studies claim that soft skills, practice-related tasks and creativity as important skills for performing expert engineering work, for both practitioners and students. Hence, they therefor need to learn from each other. This is in line with American Society of Civil Engineers (Committee, 2008) stressing a shift from only communicating technical content knowledge into educating for broader competencies that concern employees’ values and beliefs. Consequently, engineers need comprehensive competences to continuously improve and strengthen their abilities in the working process (Downey, 2009).
When the university are designing for engineering education targeting industry practitioners, the practice-based soft skills does not seem to be challenging, rather something expert practitioners can bring into the education as part of co-construction of knowledge and learning. But, for the university, there are other important topics in engineering research and knowledge of concurrent and complex phenomenon following the development of industrial modeling and simulation that need to be included into a formal learning situation (Malmsköld, Örtengren, & Svensson, 2012). The techniques and the skills required to learn and master the underlying theories of such knowledge are often limited in the industry, while experience-based expertise and practical skills (such as the skills mentioned above) are often broad. This means that practitioner-oriented university education does not in particular need to include soft-skills development which is the case for campus education targeting novel young students.

Consequently, within the engineering work environment, learning is fundamental as products and processes are constantly changing due to technology, innovation, economic factors and the encompassing influences of society and culture. The engineering workplace provides a rich environment for exploring learning where an organization can offer highly structured courses to informal conversations between co-workers and allow for continuous creation of both formal and informal learning activities (Lawton, et al., 2012). But advanced knowledge creation strain manufacturing companies to search for new ways of not only strengthen organizational and production system processes but also to invest in the engineering staff through education and learning integrated in the workplace or collaborate with the university.

So there are specific challenges permeating engineering education that stems from specific requirements in mathematics, science learning and professional practices (Johri & Olds, 2011). To meet the industry need of flexible learning and work-integrated learning, even more challenges occur. Creating engineering courses online, to attract, and retain participants in engineering education, there are also new forms for educational setup to be addressed (Bourne, Harris, & Mayadas, 2005; Russell & Posada, 2011; Todd, et al., 2001). To improve the current online engineering education, Bourne, et al. (2005) suggest that: 1) the quality of online courses need to be comparable to, or even stronger than campus courses, 2) courses should be available when needed and accessible from anywhere by any number of learners, and 3) topics across the broad spectrum of engineering disciplines should be available.

Engineering knowledge, competences and skills both in the workplace and within the university raises gaps and opportunities. Cultural differences (Kunda, 2009), competence differences, emphasize on soft skills versus engineering content knowledge, creativity versus knowledge of facts, and practical ways of conducting
work versus new automated work functions transforming engineering work into monitoring. Johri and Olds (2011) therefore stress there are three distinguishing characteristics of engineering learning considering situated learning perspectives; use of representations, alignment with professional practices and the emphasis on design for engineering education. These characteristics frame the qualities of the course design in this project.

2.4 Experience-based and Socio-Cultural Learning

Many of the learning theories center individual learning and then the context in which the learner is situated, especially concerning learning outside school meaning life-long learning and experiential learning. Established theories usually emphasize personal reflections of learner’s experiences (Eames & Cates, 2011; Fenwick, 2000; Kolb, 1984; Schön, 1983; 1987). There is however some differences and the historical traces have had an impact on how we today view learning in modern professions. Schön (1987) describes reflection-in-action and reflection-on-action and Kolb (1984) presents an experiential learning cycle of both cognitive abstraction and experimentation. Another view is presented by Mezirow (1997) foundation of transformative learning as a learning process where the learner questioning his or her assumptions through critical meaning making reflections. These theories engage individual learning (Tynjälä & Häkkinen, 2005).

Dewey (1938) a pragmatist and known as a philosopher and educational reformer in the early 2000th century, considered ‘thoughts’ to be a product of interaction between the organism and the environment in sharp contrast to that times ideas. He put forward that thoughts presents a mirror of reality. One of his contributions is commonly labelled “learning by doing”, as a process of do, reflect and apply. Dewey’s philosophy was that experiences arise from the interaction of two principles: continuity, stating that all experiences (past and present) carries forward and influence future experiences and decisions (Dewey, 1938, p. 35), and interaction, referring to the objective and internal conditions of an experience (Dewey, 1938, p. 42). He claimed that experiences is a dynamic two-way transaction process; “An experience is always what it is because of a transaction taking place between the individual and, what at the time, constitutes the environment” (Dewey, 1938, p. 43).

Experience-based “learning by doing” (Dewey, 1938; Kolb, Boyatzis, & Mainemelis, 2001) is also in line with Ellström (2001) who describes two modes of learning, adaptive and developmental learning that are related to assimilation and accommodation. He applied this by the “work and learning process lens” including the tasks to be performed, the methods to be used, and the results to
be reached. Within this process, *adaptive learning* (assimilation) is mainly routinized and automated work actions performed through in logical format and as a known and secure work situation where the worker/learner uses earlier experiences to perform tasks. This kind of work tasks are guided by reduce of variation and uniformity for an effective process. *Developmental learning* (accommodation), on the other hand, focus work conditions and objectives that are not known or not assumed to be known. The worker/learner therefore need to carry out plans and try new and challenging experiences and have to act on intuition rather than logical analysis. Through engaging with others, i.e. collective actions and learning, will requiring risks taking, and acceptance for failure, in order to test out different approaches to completing a task or a project asserts that experiential learning demands explicit knowledge, which cannot be obtained through pure (practical) experiences (Ellström, 2001; Svensson, Ellström, & Åberg, 2004). Rather, the learner needs some knowledge about the task and the working process to be identified and interpreted with new experiences. Learning therefore includes both practical experimentation and cognition as active reflections. The key learning process for experiential learning discourse is “cognitive reflection on concrete experiences” (Fenwick, 2000). Expansive learning by Engeström (2001), relates to this “learning space” of individual actions (including the two modes) in relation to work conditions. The dimension of routine work is required for an accommodative learning process to be reached where reflective (assimilative) practice can take place.

### 2.4.1 Situated learning

Theorists of situated learning, describe learning as knowledge construction based on a social process within a *communities of practice* (Lave and Wenger, 1991; Wenger, 1998). *Situated activity* is portrayed as learning within a community of practice (Lave & Wenger, 1991; Wenger, 1998; Brown, Collins and Duguid, 1989). Communities of practice are informal groups of people, or workers sharing a mutual interest, locally or in a peer-to-peer interaction. Lave (1991) described situated learning emphasizing “that learning, thinking, and knowing are relations among people engaged in activity in, with, and arising from the socially and culturally structured world” (p.67). Learning occurs within a social situation, cannot be dissociated from it, and is only understood within the context in which it occurs (Eames and Cates, 2011).

A common broad description is that *all* action, cognition, and learning is situated, whether in informal contexts or in school (Lave & Wenger, 1991; Suchman, 1993). Learning is defined as a process of constructing meaning from activity and experience. Individuals learn as they participate in and interact within a community through its history (cultural values, rules), tools (objects, technology, languages), and images within joint activities (Fenwick, 2000). Learning in a situation is intimately intertwined with the particular community, tools, and
activity of that situation (Lave and Wenger, 1991). The learner actively negotiates own perception with the external world; primary meaning making and takes ownership of learning as engaged participation (Dabbagh, 2005). The teacher’s role is not to develop individuals but to help them participate meaningfully in the practices they choose to enter (Fenwick, 2000). In digital learning situations, knowledge acquires through mediated forms of interaction and enculturation into a community of practice (Dabbagh, 2005). Knowing and knowledge distributes in the world and into social practices, rather than as a shift of mental structures of learners (Johri and Olds, 2011).

2.5 Workplace and Work-Integrated Learning

Earlier approaches have for instance studied worker-oriented competences, as a set of attributes possessed by workers, meaning knowledge, skills and abilities required for effective work (Sandberg, 2000). Problems with such studies are that they produce descriptions of competences that are too general and abstract. Work-oriented approaches on the other hand, mostly identified work activities essential for accomplishing a specific task and then transform those activities into personal attributes, but also with the result of too general descriptions of competence. Sandberg (2000; 2014) discusses problems with such rationalistic and dualistic approaches of separating workers (individuals) and work, in which work activities are independent of and separated from the workers who perform them. Even if they contribute to our understanding of competences, they become problematic when performing studies that aim to grasp competences needed and integrated in work. The problems with such separation of descriptions are that they do not describe if and how workers use these attributes during performance of work. Sandberg (2000) therefore argues for an interpretive approach built on phenomenology that stipulate workers and work as one entity, and competences are thus the meaning the work takes on for the worker in the experiences of it. He proposes a multimethod-oriented approach, which involve aligning personal attributes with work activities, as a more adequate method for comprehensive analysis of defining and exploring expertise required integrated in work practices.

Learning in the workplace takes place in the context of use and application, simultaneously, and is in a concrete way embedded in everyday problem-solving (Billett, 2000; 2001a; 2001b; 2002; Brown & Duguid, 2001; Tynjälä & Häkkinen, 2005). This type of learning can be described as informal learning. Informal learning can be described as incidental (a side effect of intentional work) and intentional (mentoring, practicing skills etc.) (Tynjälä & Häkkinen, 2005). However, these efforts are usually not enough to strengthen workers and organizations. Tynjälä and Häkkinen (2005) refers to Slotte et al. (2004) acknowledging informal and formal learning as equally important elements of
learning at work. They mean that informal learning is not enough because firstly, learning happens without conscious efforts and bring forth tacit knowledge, and also outcomes that are not intended. Secondly, new knowledge is produced rapidly so that informal learning alone cannot ensure that knowledge and skills of organization’s and people will keep up. Therefore, they suggest that planned education and learning situations can exploit informal learning effectively, to turn tacit knowledge into explicit knowledge and to integrate conceptual knowledge and practical experience. Consequently, Tynjälä and Hääkinen (2005), suggest that to be successful, school learning may adopt features of workplace learning and of the development of expertise, and correspondingly, workplace learning may be developed by utilizing features of formal school learning.

Work-integrated learning is typically described as a combination of education and practice in the workplace. Learning is described as activities in the workplace environments in which knowing and learning are co-constructed through ongoing and reciprocal processes (Billett, 2001b WIL can be defined as an umbrella term for a range of approaches and strategies that integrate theoretical knowledge with the practice work within a purposefully designed curriculum (Patrick et al., 2008). It has the potential of providing direct and significant benefits for students, workplaces, universities, and in turn, a wider community. Learning integrated in the workplace can be built on practical tasks and work situations with the aim to serve organizational goals. Work-integrated learning, WIL is therefore in this thesis viewed as an integrated combination of engineering education with engineering workplace practice on equal grounds for qualitative learning and knowledge development (Billett, 2001b; Eames & Cates, 2011; Engeström & Hannele, 2007; Trede, 2012; Tynjälä, 2008).

2.6 E-learning and Learning Technologies

The complexity of designing e-learning within higher education is traditionally built on individual students’ progression of intertwined learning technologies and online pedagogy. For example what type of learning content is applicable, theory versus practice-based tasks and cases, how to blend physical meetings with online activities, and synchronous versus asynchronous interactions when designing for collaborative e-learning targeting workplace needs. (Boud & Middleton, 2003; Cheng, et al., 2012; Govindasamy, 2002; Lahn, 2004; Michalski, 2013; Servage, 2005; Tavangarian, et al., 2004).

Today higher education institutions variously design and implement e-learning and distance education applied to the professional learning environments, for intentional and organized e-learning activities (Kahiigi et al., 2008; Simões, Rodrigues, & de la Torre, 2013; Singh & Hardaker, 2014). Some initiatives have
tried to be successful but been ignorant the workplace as a prosperous setting for learning (Lahn, 2004; Michalski, 2013). E-learning technologies, applications, digital learning material, web-conferencing systems, video etc. offer a complexity hard to grasp, and the new digital framework do not itself apply for qualitative learning (Tavangarian et al., 2004). The technology provides us with more and more options, but making them work together with learners in dispersed environments and integrated in work, may cause difficulties (Govaerts & Baert, 2011; Kahiigi et al., 2008; Servage, 2005; Tynjälä & Häkkinen, 2005).

The teacher role, pedagogical issues and administration are also important factors to consider for the complete learning situation. Interactive technology, is supposed to enhance collaboration and communication but has to some level changed the behavior of us humans as social individuals, and is therefore affecting our workplaces and working conditions (Taras, Bennett, & Townsend, 2004). Consequently, e-learning systems, in themselves, do not always succeed in real problem solving and learning. Rather a broader description of e-learning ought to include scholastic distance education traditions (higher education) that focus on digital learning material organized in a didactical learning situation with communication learner-teachers (Laurillard, 2006; Luckin et al., 2010). The learner should not only interact with the learning content alone, but also in cooperation with other practitioner’s or experts within the organization or in other network organizations (Govaerts & Baert, 2011).

Recent research on the teacher role in on-line education settings, suggests both pedagogical and technical approaches in an intertwined process to enhance learners knowledge progress (Drlik & Skalka, 2011; Mishra & Koehler, 2006). Teachers need to consider a variety of media technologies and pedagogical approaches mixed with physical meetings. Such types of e-learning courses are more focused on constructivist, collaborative, student-centered pedagogy, and global scale (Hiltz & Turoff, 2005). An the online course content should be attractive and useful with examples, case studies, short exercises, i.e. the course plan and assignment requirements should be clear and well clarified; the content should be reasonable and avoid excess; more video and graphics might improve interactivity and the schedule should be well planned (Violante & Vezzetti, 2012).

Accordingly, an e-learning course can be designed to be either instructor-based (cognition) and/or self-directed in a situated learning practice (Hotho, et al., 2014; Johri & Olds, 2011; Wenger, 1998). In the work of designing e-learning material, examinations, instructions, digitalization of lectures (video production), teachers or instructors technological knowledge is a key factor for aligning their pedagogical ideas as an integrated part in a digitized course and through various digital communication tools. It also includes instructor-led and peer-interaction, in synchronous interactions (Clark & Mayer, 2016).
Today new learning systems are more integrated with internet and social media as a common source of knowledge and communication. The early development of learning management systems, LMS, used to be the only learning platform for delivering learning material digitally. However, new e-learning technologies and applications rapidly develop and teachers find it more easier to design, and produce their own learning system, and digitize learning content (material) (Laurillard, 2013). Through the easiness of using new technology, a teacher or instructor, can design effective learning situations and materials towards individual learners need, integrated into work practice hours, and blended (Beldarrain, 2006; Larsen, Visser-Rotgans, & Hole, 2011; Macdonald, Bullen, & Kozak, 2010). The broad opportunities are however also hard to encapsulate for a design team and for the teachers to master. The tools and learning technologies, throughout the thesis besides the production technology systems to be mastered was of mainly fourth kinds; LMS, web-conferencing, content production systems (e.g. Camtasia), and open educational resources (OER).

A learning platform, LMS was used for distribution of learning material, communication and interaction. This system is referred to as either the LMS or DisCo (Distance Courses). The LMS is the university specialized designed system used for all education, including campus education. This platform unify all other learning resources and is the main entrance for the learner to get into the course finding curriculum, instructions, files, e-mail, etc. The second type of systems were web-conferencing for on-line discussions, interactivity, screen sharing, application sharing (for instance to share Matlab) etc. The third broad field of inquiry for designing blended e-learning are systems for digitizing learning content, for instance Camtasia. It is a software to make recordings of the screen and allowed collection of a rich record of actual computer work activity in its natural work setting. It is an effective system for producing target learning material (content) within a courses that are open and participant target, including video instructions, lectures, learning how to performing programming step by step etc. Fourth, to find and use open educational resources, OER, applicable for a specific subject field. These e-learning technologies must, throughout the design of the engineering courses apply to the production technology systems that is part of the knowledge process within the engineering field. Consequently, gaining a collective view of e-learning is a complex and heterogeneous task considering the IT artifact itself, the in-built didactics in learning content and functionalities in the learning platform (Michalski, 2013).
3 Theoretical Framework

This chapter presents the theoretical framework Cultural-Historical Activity Theory, CHAT, including concepts used and applied within the thesis. Related theoretical approach of learning mechanisms at the boundary is shortly presented. Finally, absorptive capacity and e-learning readiness are shortly presented, especially applied in Study I.

Cultural-Historical Activity Theory, CHAT, is a theoretical framework which helps to understand and analyze the relationship between the human mind (what people think and feel) and activity (what people do). CHAT is outlined as a general theoretical framework, framing the whole project for this thesis.

3.1 Cultural-Historical Activity Theory – CHAT

Cultural-Historical Activity Theory, CHAT, concentrates on social learning activities and future learning expansion. The unit of analysis is social activities (Engeström, 2015) built on mediated action (Vygotsky, 1978). The theory moves the focus of exploration of individuals to exploration of activities, in relation to the context and the intended focus (Edwards, 2005a).

The social learning context and the individuals are not separated but part of interacting activity systems who shares the same objective (Engeström, 2001). Traditionally, learning is manifested (expressed in discourse, patterns of talk, and discursive actions) as changes in individuals (the subject), meaning the learners’ behavior and cognition, meanwhile expansive learning is manifested primarily as changes in the object of the collective activity (Engeström, 2010; 2015). The object of activity can be seen as the real motive of activity, as the basis for its existence (Leontév, 1978). A CHAT approach studies the collective objects as fundamental to understand a continuing why of actions, and typically aims for thorough changes in established forms of activities (Engeström, 2001; 2015). For instance, in this thesis it means that the goal-oriented curriculums defined by the university and set from the beginning, are unambiguous, and not negotiated among the target group. Therefore, I am not in particular evaluating learning outcome in relation to curriculums, because this is not the motive of this thesis, rather the studies focus on the activity as the ongoing construction of the object among multiple actors. Practitioners and researchers discursive manifestation of contradictions, negotiations and motives are related to the construction of the object. The object is thus unstable, evolves through history, ambiguous and holds potential for
change (Engeström, Engeström, & Kärkkäinen, 1995, pp. 67-70; Miettinen & Virkkunen, 2005).

The CHAT frameworks core perspective is on the metaphor: *expansion*. Learning expansion means that learning by acquisition or even learning by participation is qualitatively different from expansive learning. Expansive learning is argued to expand learning into transformations and to make learners grasp new knowledge, meaning what is not yet there (Engeström & Sannino, 2010). Hence, professional knowledge is not only acquired through participation, rather knowledge construction is a dynamic process of negotiation with others when working on complex problems that are shaped by multiple motives (Engeström, et al., 1995). From this argumentation all learning is not expansive.

CHAT notifies *technology as a mediating artifact* with traces of historical attributes in and between individuals in joint object-oriented activities in activity systems (Engeström, 2001). This theory enclose systems on different levels and formations, including individuals, artifacts, rules, communities in a processes of sideways learning towards collective objectives (Engeström, 2001; 2015). Actions and activities in and between the systems is seen as individual’s collective work on the object under influence of the mediating artifact (for instance technology, documents and rules). Activity is realized by means of actions, and actions can be taken by an individual or it may be collaborative, accomplished by a group. Learning activity is a particular historical form of learning.

Cultural-historical activity theory is both a method and a theory for grasping the essence of an object by tracing and reproducing theoretically the logics of its development (Engeström, 2008). It has been used widely, especially for studies in large projects, over periods, comprising different organizational levels and multiple actors. In his early work in 1987 (Engeström, 2015) he took a stance to theories of learning acquisition. He meant that such “standard theories” focuses the process where a subject (traditionally an individual, more recently possibly also an organization) acquires some already identifiable knowledge or skills in such a way that a corresponding, relatively lasting change in the behavior of the subject may be observed. It then becomes obvious that the knowledge or skill to be acquired is itself stable and reasonably well defined. For instance, there is a competent ‘teacher’ who knows what is to be learned. However, when studies are interesting in learning in work organizations this assumption fail, because workers and organizations are the time learning something that is not stable, not even defined or understood ahead of time. Hence, Engeström’s prime concern is interventionist research to promote systemic learning, for example, enabling groups of workers to question how the system is shaping opportunities for action and thinking. Nonetheless, his framework has considerable potential for
researchers who are interested in how conditions for learning are created and in what is learnt (Edwards, 2005b).

The expansive learning theory formulated in 1987 by Engeström (2015) offers a broad framework to analyze studies. From a holistic perspective and specifically in the last two studies (Study IV and Study V) this thesis apply the theories approach concerning object-orientedness, technology-mediated actions, and learning expansion. The e-learning activities including the design-orientated development work are boundary crossing activities between institutional boundaries that creates learning at the boundary which are further developed by Akkerman and Bakker (2011a; 2011b), in which they align to activity theory. They specifically emphasize learning mechanisms as helpful tools to theoretically analyze the practitioners and researchers activities in this thesis project. The common concepts of subject, object and activity within CHAT form the base of the analysis. The further developed concepts of manifestation of contradictions, knotworking and expansive transformations serve as helpful tools to understand the course situations (the specific learning situations), in which activities progress towards expansive transformative actions.

Today, within the further developed CHAT framework, formative interventions are sites of collaborative generation of possibility knowledge. “Modeling the activity system in interventionist efforts reveals the potential of internal contradictions as drivers of transformation.” (Sannino & Engeström, 2017, p. 3)

### 3.1.1 The origin of CHAT

The cultural-historical activity theory (CHAT) can be understood as the “zone of proximal development” representing the area of capabilities and distance between the need for guidance (of the teacher) and support (to the learner) in problem-solving and the ability to undertake a task autonomously. CHAT was rooted by the Russian psychologist Vygotsky (1978) during the 1920-1930s and further expanded by his learner Leontév. They formulated a theoretical concept that went beyond the current thoughts of psychoanalytical and behavioristic traditions into a triangular model of tool-mediated and object-oriented actions. The model developed throughout an expansive process of three generations (Engeström, 2001).

First generation centered Vygotsky’s ideas of cultural mediation of actions, meaning that the individual could no longer be understood without his/her use or production of artifacts. Objects became cultural entities and the object-orientedness of action became the key to understand individual psyche. Leontév questioned earlier cultural-historical approach to be too individualistic and a discourse of vertical development toward “higher psychological functions”,
instead he proposed a collective activity view, evolving into the second generation. During this time, internal contradictions as dynamic power for change developed within the activity systems, and was empirically applied in the Soviet Union. Cultural diversity resulted in a consciousness about the dialectic relationship between an individual action and a collective activity. In current third generation, Engeström (2001), states that there is a “need to develop conceptual tools to understand dialogue, multiple perspectives, and networks of interacting activity systems.” (p. 135). Accordingly, the model is expanded into including at least two or more interacting activity systems where boundary crossing activities can occur.

### 3.1.2 Object of activity and actions

Following Engeström (2015), an activity system consists of a community including individual and collective actions that are mediated by tools, rules and division of labour. The single activity model is focused on the activity being undertaken and helps identify the object (what is being worked on) of the activity and the mediated and cultural tools being used to achieve the object. The activities are never individual, rather components with internal relations to each other towards a mutual object within a shared community. Participants, subjects, have different roles within the division of labor and is referred to both vertical division of power and horizontal division or (work) actions between members in the community. Rules are regarded as conventions and norms within the boarder. The object-orientedness in CHAT can be understood as actions are goal-oriented meanwhile objects of collective activities includes shared motives (Engeström, 2015; Kaptelinin & Nardi, 2006).

Reciprocal relations between individuals, and individuals and the environment are established only through the activities they perform. Through interactions with the surrounding world the individual changes on her own, through needs, motives, competences and personalities, and also her relations to the surrounding world. Changes are built from inside of the individual, but is an ongoing process in relation to a socio-material world and as a part of a historical process. Work is performed collectively in coordination with others. Therefore, a complexity is evolving (Engeström, 2001). Separate work functions are only part of a whole sum and equally considered within a society. However, within CHAT all actions are treated as part of a meaningful context and this context and these processes are treated as an activity or as activities (Engeström, 1999, p.22).
In the *third generation* at least two activity systems, see figure 2, (e.g., when for instance two different contexts or communities are interacting), the collective objects moves from an initial state to a collective meaningful object(s). Object 1, the raw material, (for instance a *practitioner* entering a course), is the constructed object within the activity system. Object 2, is the constructed specimen of a *learner* for instance a tailor-made e-WIL course, and thus an instantiation of the general and constructed object (i.e. object 3) that forms a collaboratively and shared (and mutually designed) understanding of the practitioners learning situation and learning plan.

The activity is collective and focused towards a cultural significant object that shape the motive of the activity and the individual actions within. The relationship between *activity* and *actions* is that the object determines the horizon of individual realized actions within the activity (or the activity system). An activity system constitutes an internal hierarchy of dialectic relations that is constantly reconstructing through contradictions from outside as a base for possible changes. This implies that development is generated as a situated learning approach through the process of legitimate peripheral participation (Lave & Wenger, 1991), emphasizing the individual newcomers journey into being a full member within a community. However, this participation-based approach is argued to be primarily a one-way movement from being a novice into being competent (Engeström & Sannino, 2010). Instead, to reach for expansive learning, the individual needs to distance herself to construct a larger context, by expanding the object of activity. Accordingly, an expansive transformation is accomplished when the object and motive of the activity are reconceptualized to embrace a radically wider horizon of possibilities than in the previous mode of the activity (Engeström, 2001).

In expansive learning, learners learn something that is not yet there (Engeström & Sannino, 2006). Drawing on the full cycle of *expansive transformation*, understood...
as a collective journey through the zone of proximal development of the activity, captures the essence of Engeström’s view;

“*It is the distance between the present everyday actions of the individuals and the historically new form of the societal activity that can be collectively generated as a solution to the double bind potentially embedded in the everyday actions.*” (Engeström, 2015, p. 174)

Engeström and his colleagues take a multiple-view approach, including systems theory, to capture both an individual and contextual view, through networks of interconnected activity systems and expands the analysis both up and down, outward and inward. The activity-theoretical approach emphasizes the object as a concept of actions, outcomes to strive for, and learned together in networks of inter-organizational systems (Engeström & Kerusor, 2007). Expansive learning means to focus on learning processes in which the very subject of learning is transformed from isolated individuals to collectives and networks (Engeström, 2010). The object-orientedness in CHAT, means the object of activity which is not exactly the same as a shared aim, “…because different kinds of activity are distinguished by their objects” (Sannino, et al., 2017, p. 3). The object-orientedness is not only a thing, standing alone, but also tightly connected to human directed actions and efforts. It bears a long historical and cultural life, and cannot therefore only be accounted for by a single actor. Rather, it is rooted with collective motives and negotiations. This means that objects themselves carries contradictions and accordingly changes by actions (Engeström & Toiviainen, 2010). In other words, the object is both resistant raw material and the future-oriented purpose of an activity (Engeström & Sannino, 2010). The theory has been criticized to be too centered at the collaborative processes on systemic level at the expense of individual actions. However, in recent studies it is discussed how individual agency emerge in collaborative contexts between individuals rather than within the individual (Edwards & Kinti, 2010). Hence, changes occur collectively and not only within the individual. Through analysis of manifested contradictions, such changes are able to be traced (Engeström & Sannino, 2011).

The expansive learning processes in which an activity system, for example a work organization, resolves is pressing internal contradictions by constructing and implementing a qualitatively new way of functioning for itself (Engeström, 2001; 2015). The concept of learning activity can only be constructed through historical analysis of the inner contradictions of the presently dominant forms of societally organized human learning (Engeström, 2015). To unfold contradictions as power for change and learning, the first transition is to move from a systemic contradiction to a personally experienced conflict of motives (Engeström & Sannino, 2011). To analyze contradictions several iterative cycles of analysis need to be worked out. The method for identifying contradictions has been further developed within the methodology of formative intervention. Engeström,
Sannino, and Virkkunen (2014) describe a new way of grasping contradictions in an ideal-typical sequence of the epistemic actions in a learning cycle. Manifested contradictions are of four types, dilemmas, conflicts, critical conflicts and double binds (Engeström & Sannino, 2011). In a recent publication of formative interventions for expansive learning and transformative agency, they demonstrate the power of using manifested contradictions as analytical lens throughout an expansive cycle in a design-based research tradition (Sannino, Engeström, & Lemos, 2016). In Study IV (Hattinger, Engeström & Sannino, manuscript), a thorough analysis of manifestation of contradictions on practitioners learning experiences are performed.

### 3.1.3 Knotworking

Recent year’s research on knotworking have emerged as a response to traditional teamwork (Engeström, 2008; Engeström, Engeström, & Vähäaho, 1999; Kangasoja, 2002; Kerosuo, Mäki, & Korpela, 2015). According to Engeström (2008) teams’ traditionally means a number of people gathered to approach a mutual goal and to accomplish a certain work task, however such teams usually lack both context and history. Today, teams are best understood and replaced by forms of fluctuating work in knots, and through knotworking, as a part of a certain context or activities. The notion of knot refers to distributed activities and partially improvised arrangements of collaboration with otherwise loosely connected actors across organizational boundaries.

“It is horizontal and dialogical learning that creates knowledge and transforms the activity by crossing boundaries and tying knots between activity systems operating in divided multi-organizational terrains”. (Engeström, et al., 1999, p. 385)

A movement of tying, untying, and retying together seemingly separate threads of activity characterize knotworking (Engeström, 2008, p. 194). Collaborative knotworking shapes and reshapes to local settings and the center is not fixed and coordinated, rather the unstable knot itself needs to be made the focus of analysis (Engeström, 2008). Knotworking differs from traditional teamwork in the sense that continuity is connected to the object, not the practitioners, because the practitioners and the initiators of knots can change. Hence, the knot of collaborative work is not reducible to any specific individual or organisational entity as the centre of control because the locus of initiative changes from moment to moment within a knotworking sequence. Applying the knotworking model requires a long-term effort to study and establish new practices across organizational boundaries. It is through temporary groups that tasks are completing in a longitudinal process where the deadline is not fixed, in which mutual co-construction of future solutions are developing as challenges.
Engeström (2008) also highlight that knotworking can be seen as the emerging interactional core for co-configuration, meaning that knotworking is a way of organizing work that strives towards co-configuration. The concept of co-configuration succeed from Victor and Boynton (1998) work on innovation- and knowledge driven production. “…Outlines the landscape of learning in co-configuration settings, a new type of work that includes interdependency between multiple producers forming a strategic alliance, supplier network, or other such pattern of partnership which collaboratively puts together and maintains a complex package, integrating material products and services and has a long life cycle.” (Engeström, 2004, p. 13). For further description of the concept co-configuration, see the following references, Victor and Boynton (1998), Engeström (2004), and Virkkunen (2006).

The concept of knotworking is essential for this thesis as a working tool to understand diverse negotiations between stakeholders and actors. To conclude, the activity theory gives a holistic framework viewing the inter-organizational collaboration of higher education and industry companies. The representation of two activity systems, viewing the interrelations and contradictions between them, sketch a view for understanding and discussing the relations and progress of objects, mediating tools, rules, the community, division of labor and so forth, to expand for further development and transformative change.

3.2 Learning while Crossing Boundaries

Boundary crossing is characterized as “horizontal expertise where practitioners must move across boundaries to seek and give help, to find information and tools wherever they happen to be available” (Engeström, et al., 1995, p. 332).

Boundaries and boundary crossing can be used as theoretical lenses to understand learning that align with professional practices outside the university and to implement workplace experiences and expertise as a mutual design process of engineering e-learning education. Boundaries exist between diverse communities, such as groups with different expertise and tasks. Boundaries are inherently unclear in nature because they belong to two or more organizations, and to none of them (Akkerman & Bakker, 2011a). These boundaries can arise and be conceptualized due to various negotiations and contradictions in and between different communities (Akkerman & Bakker, 2011a). Akkerman and Bakker (2011a) review boundary research and draw the attention to boundaries with the potential of learning at the boundary and by crossing boundary as dialogical phenomena that reveal certain mechanisms of learning that develop various sociocultural differences, i.e. discontinuities as functions for identity and practices. They especially consider the nature of dialogical learning mechanisms that may appear through boundary crossing.
Boundary crossing can be movements between institutionalized practices such as school and work. As such boundary crossing can cause discontinuities in interactions between actors, and thereby serve as potential for learning. Challenges in educational practices involve participation and collaboration across organizational boundaries of locations, both within and across institutions. In these contexts, boundaries can cause sociocultural differences leading to discontinuity in action or interaction (Akkerman & Bakker, 2011a). Discontinuities are for instance contradictions that may move into sources for change and expansive learning, by open up a zone of proximal development (Engeström, 2001).

Within engineering education much of the research has been on understanding learning and development within a specific area or practice (Henriksen & Rolstadås, 2010; Johri & Olds, 2011). However, while researchers and practitioners are aligning to new collaborative and inter-organizational situations, new types of boundaries may occur (Akkerman & Bakker, 2011b). In this thesis boundaries are crossed between the engineering higher education and the industry contexts. Hence, to contribute to our understanding of researchers and practitioners expert identities in complex learning situations, boundaries and boundary crossing may apply a dialogical viewpoint that conceptualize movements of practitioners and researchers identity and coordination activities (Akkerman & Bakker, 2011a; 2011b; 2012).

Four potential learning mechanisms that take place at boundaries can be discerned; Identification, coordination, reflection and transformation. Identification concern differences and to questioning diverse practices and both people and contexts. Coordination handles collaborative and routinized exchanges. Reflection expand one’s perspective on the practices Transformation handles co-development for new practices. Identification is about constructing and reconstructing boundaries, meanwhile the other three are transcending boundaries. Coordination can be seen as counteracting transformation, meaning coordination for practices need to run smoothly while transformation is developed by contradictions (Engeström, et al., 2014). Hence, working and learning to become an expert not only happens within a boundary practice, i.e. at school or in the workplace, but through boundary crossing. Engeström (et al., 1995, p. 319) describes boundary crossing as “…the process of negotiating and combining ingredients from different contexts to achieve hybrid situations”. Researchers and practitioners are boundary crossers once they act upon their respective goals and when they start to understand each other’s diverse motives. This is engaging a process of developing mutual expertise. Identification and reflection are in particular useful mechanisms to theorize the practitioners-researchers interactions, including both their individual thoughts and their different practices.
The course situations are surrounded by coordination activities in formalized learning sessions, aiming for running smoothly. Transformation relates to changes in practice on a more general level and is related to forthcoming expansion.

### 3.2.1 Identity and expertise

Expert knowledge expands not only by individuals’ own cognitive capacity but through their active sharing of personal experiences, cultural-historical experiences from earlier work practice, through negotiated knotworking (Engeström, 2008) and shared tool-mediated actions. *Expertise* as a specific kind of shared interprofessional collaboration therefore becomes the common knowledge advancing in such processes. Expertise is considered both within the system and in the individuals’ abilities to recognize and negotiate its use (Edwards & Kinti, 2010). The central argument is the resources that others bring to problems, can enhance understandings, and will enrich responses (Edwards, 2005a). For example, to construct tasks, solutions and innovations, and then use it in interdisciplinary collaborations. Expertise in workplaces is discussed as a collective feature spread across systems, which is drawn upon to carry out tasks. It is therefore important to move on from a conception of expertise as 'deliberative rationality' to a conception of expertise as purposeful rationality. To know how and when to act relationally foster productive work, and is a further indication that this form of knowledge work is about engaging in a balancing act at organizational boundaries (Kinti, 2008). Identity is therefore seen as a way of describing how people participate in activities, which are in turn located in practices.

Edwards discusses two concepts, relational expertise (Edwards, 2005a; 2010) and distributed expertise (Edwards, 2011; Edwards & Kinti, 2010) from an activity theory perspective. Relational expertise handles working with others to expand the *object of activity* or task being worked on. This is not as a matter of learning how to do the work of others, rather it involves gaining sufficient insight into the purposes and practices of others in order to enable collaboration (Edwards, 2005a). Herein meaning the capacity to take the standpoint of the other knowledge and perceptions and to recognize other professionals understanding of problem solving and work practice to build *common knowledge*. This knowledge can be negotiated in each contributing practice through mediation across organizational boundaries and collaborations. The concept of relational expertise favors openness, curiosity and respect for each other’s view (Ness & Riese, 2015).
3.3 Absorptive Capacity and E-learning Readiness

Absorptive Capacity is defined as a company’s ability to recognize the value of new external information, assimilate it, and apply it to commercial ends (Cohen & Levinthal, 1989; 1990). The theoretical approach of absorptive capacity, was used initially in Study I, when the interest was to study the companies learning conditions, because this approach takes a company perspective of both the internal capabilities in relation to the company capacity, and discuss the importance of using outside knowledge.

Zahra and George (2002) extended absorptive capacity with a new definition; a set of organizational routines and processes by which firms acquire, assimilate, transforms and exploit knowledge to produce a dynamic organizational capability”. They introduced two dimensions: potential absorptive capacity; and realized absorptive capacity. The first dimension focuses on acquisition and assimilation of new knowledge, and the second focuses on the transformation and exploitation of capabilities. The concept is widely used within management research and often refers to organizational learning as a whole and not in particular focuses the learners (see for instance, Sun & Anderson, 2010.)

Absorptive Capacity is a heterogeneous construct and available methods are used with diverse operationalization. To explore the implications of the dual role of research and development (R&D) and R&D investments, Cohen and Levinthal (1990) constructed a simple model of the generation of a firm’s technological knowledge. This mathematical model included a company’s ability to imitate new process or product innovations, and included the firm’s ability to exploit outside knowledge. Interestingly, absorptive capacity also means the ability to learn (Cohen & Levinthal, 1990). Duchek (2013) presented a more practice-based approach of absorptive capacity, which it is used as a qualitatively approach. To define a company’s e-learning readiness, Raymond et al., (2012) proposed an integrative e-learning framework for e-learning assimilation and adoption that empower technological and environmental factors that will give deeper insight into sense making of technological and organizational factors in relation to the e-learning context, and for shaping organizational competencies.
4 Research Context and Project

This chapter summarizes the research context, including the longitudinal projects, the diverse actors, stakeholders and the course subjects.

This thesis takes part within a longitudinal and still ongoing action design research and competence development project initiated in 2013 by a Swedish university in collaboration with a network of manufacturing companies. The overall project aim is to design blended e-learning courses targeting manufacturing industry competence needs and together with the university co-produce industry relevant knowledge to strengthen expert competences for future needs. The initiative is funded by the Swedish Knowledge foundation and has been conducted by two overlapping projects. The university runs and organize the projects. MERIT - Manufacturing Education and Research with Information Technology was the first initiated project during 2013-2015, in which Study I, II and III were conducted. In parallel, the project ProdEx – Expert in Production Technology, was initiated during 2014. The shorter MERIT initiative brought the interest to go further, and the next continuing project, ProdEx, became the longitudinal project that in particular focuses on blended e-learning targeting industry knowledge needs and co-production of expert knowledge. ProdEx will be ongoing until the end of 2019. Hereafter, both the projects are referred to as one project, labelled ProdEx.

4.1 Production Technology West

The project runs by an operating project group of about four researchers, one operational project manager, and the responsible project manager (professor in Robotics) and one administrator, in total seven members. I took actively part as one of the researchers until spring 2016, and thereafter I have just occasionally participated in mutual project activities. The broader project group consists of 16 participants including the members in the operating group and about six additional research teachers (in engineering and computer science), two ICT pedagogues and one ICT technician. This group is responsible for designing and teaching the customized courses. The engineering specializations are within industrial automation, robotization, machining, Matlab and FEM (Finite Element Method).

The project group is situated at the affiliated Production Technology Centre, PTC, to the university, and conduct both research and academic courses within the research environment Production Technology West, PTW. The research team PTW as a whole, works on the development of production processes in the
manufacturing industry. Research focuses on areas such as robotics and automation, including design of highly flexible and reconfigurable robotic systems, cutting processes and sheet-metal forming, and welding and surface coating processes called thermal spraying. PTW is situated at a Production Technology Centre (PTC) in Trollhättan, see Figure 3, which basically is a collaborative partnership between the university, a technology park and the manufacturing industries in the region. PTW disposes of a modern process laboratory with state-of-the-art equipment for thermal spraying, welding, a robotic laboratory and a metal-based additive manufacturing laboratory, with about ten robots and one material characterization. PTW consists of 90 researchers including industrial and university employed PhD students. A multitude of specialties and subject backgrounds provides a creative environment for co-production and reproduction of knowledge, giving PTW a unique structural condition to add significant value for partners and members.
4.2 Manufacturing Companies

In spring 2013, 15 companies joined the project. During coming years some companies did not participate in either company-university meeting, neither contributed with course participants. During autumn 2015 another eight companies were joining and six-seven were still around. Some company had left. Today about 15 companies are active partners in the project. They are mainly within the aerospace and automotive sector, with about 100-2000 employees. The largest company (aerospace sector) with about 2 000 employees is an initial and influential partner for mapping the future competences and for contributing with practitioners on various levels to the project activities such as factory operators, production technicians and managers, purchasers and purchase managers, engineering experts etc. They bring in expertise of machining and materials. One other large company (700 employees) from the automotive sector add valuable knowledge of industrial automation and machine security. The growing company network is currently regionally located within 100 km range from the university and PTC, but the aim is to increase the network nationally over the project time until December 2019.

4.3 ProdEx courses

The courses, are designed in flexible modes and targeting manufacturing industries specific knowledge domains that are directly related to work practice, and emphasizes a collaborative learning format (Cheng, et al., 2012; Govaerts & Baert, 2011; Raymond, et al., 2012). E-learning activities occur on-line, within the industries and at the university. The knowledge included is formalized and designed e-learning content, practical engineering labs and cases, virtual labs, video lectures, video experiments, problem-solving tasks, etc. Research teachers at the university have designed the learning material with a pedagogical approach that integrate practitioners’ and experiences into the learning sessions. They have also been supported by ICT pedagogues and technicians hired within the project. The university push the course development and are designing and running the courses with focus on industry needs. The project comprise two main stakeholders, the industry and the university, and their actors interest to participate in shaping and co-producing knowledge within and around the design and implementation work and competence mapping of knowledge needs.

Actors from the manufacturing companies are CEO’s, production managers, HR managers, operators, production technicians, consultants, purchasers, experts etc., with various knowledge and experiences of engineering. The university stakeholder actors are mainly research teachers and experts with a PhD degree/docent/professor within the engineering production technology fields; mechanic, mechatronic, automation, and mathematics. In addition, other network
institute members and research institutions take part in company meetings. The five studies included in this thesis are described in detail in section 5, Research design and findings. Figure 4, below show the two overlapping projects and the 18 course implementations included in the thesis. The e-learning courses was developed and implemented of 2.5 European Credits (ECTS) at advanced master level. This includes nine different course variants until spring 2016, and in total 22.5 ECTS. The first three pilot courses were in particular designed in cycles described in Study III, see section 5.

![Diagram of projects and course implementations](image)

**Figure 4. Projects and implemented courses 2014-2017**

The 18 courses included about 200 course participants from spring 2014 until spring 2016. This thesis includes and analysis twelve of the 18 courses. Matlab I and Matlab II, FEM I (two times) and FEM II and AU I in spring 2016 (fourth time) are excluded. For more details of the courses see next section 5.2.1.

Within the broad engineering field mainly four course subject areas developed (but in the future not limited to); Industrial automation and machine security in robotics, Machining and Tribology, Negotiation skills in businesses, and advanced FEM (Finite Element Method) and Matlab (multi-paradigm numerical computing). FEM and Matlab are not described below, because they are not further analyzed methodologically.

*Industrial automation* deals primarily with the knowledge of automation of manufacturing, quality control and material handling processes. *Robotics* include

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1 Abbreviation: AU = Industrial Automation, Ma I = Machining, Ma II = Machining and Tribology, Neg = Negotiation skills, FEM = Finite Element Method, MS = Machine Security in Robotics, Mat = Matlab
design of highly flexible and reconfigurable robotic systems as part of a production system. Both automation and robotics include optimization of operations, commissioning of production systems, and include related processes, PLC programming, calibration, reconfiguration and machine safety of robots. 

*Machining* is a traditional cutting process on raw materials, to cut a piece of workpiece material into a desired final shape and size, through guided movement of the cutting tool. It covers several processes, usually by following operations: metal cutting, turning, drilling, milling, CNC operations etc. *Tribology* is interacting surfaces in relative motion, meaning changes in position of an object over time. It includes the study and application of the principles of friction, lubrication and wear. Tribology is a branch of mechanical engineering and materials science.

*Negotiation skills* is social and human skills that engineering practitioners also need to practice. In the project this course module is part of the 7.5 ECTS course Operations management directed towards technical work situations. It includes theory about negotiation techniques and situations based on theory. Especially focus is on training negotiations for industry experts combining their professional expertise, as purchasers, project managers, production engineers, CAD designers etc.
This chapter presents the research design of a collaborative practice research approach interrelated with four case studies and one action design study. It includes the methodological arguments, my interventionist role of an action researcher in combination with the individual studies. Each study is presented including the methodological approach, the conducted analysis and the findings.

The overall objective of this chapter is to explore how mutual construction of production technology knowledge emerge through learning activities between multiple actors in joint industry-university collaborative e-learning practices. The five included studies focus on emerging processes between multiple actors (industry managers, research teachers and industry practitioners) within the two stakeholder institutions, the industry and the university, in which they give implications for an e-learning design process. The reason for such study focus is to further explore knowledge construction that enables and influences interactions between theory and practice for development of scientific and practical knowledge. Hence, the studies are incorporating relations between scientific theory and practical knowledge of two institutional settings. Action research approaches embrace such broad study focus (Chiasson, Germonprez, & Mathiassen, 2008; Mathiassen, 2002; McKay & Marshall, 2001).

The underlying methodological choice of an action research approach was based on the nature of the project; longitudinal, different systemic levels, multiple actors, study of changes over time, exploring, designing, evaluating and making interventions and suggesting change efforts. Hence, I was able to be part of, initializing and actively participating within the project. My dual role as both project member and researcher created a unique opportunity for me to interpret, design and intervene, as part of a changing practice through active participation in both research and practice. Following that, the methodology choice was to be able to actively collaborate through mutual project activities combined with traditional case studies. Given such direction, the thesis apply an overall collaborative practice research approach as a way to organize and conduct research of e-learning activities based on close relationship between researchers and practitioners (Mathiassen, 2002).

The collaborative research approach presented by Mathiassen (2002), is described to be a pluralist research methodology that allows for combining action research (AR) with conventional practice studies, and as such emphasizing research activities that advances science while at the same time inform professional practice
This broad approach aims at finding ways of balancing between practical relevance and academic rigor (Chiasson et al., 2008; Lindgren, Henfridsson, & Schultze, 2004; Mathiassen, 2002; Mathiassen & Nielsen, 2008; Rogerson & Scott, 2014). The collaborative approach and thus the pluralist AR methodology used in this thesis is furthermore applying the dominant approach to AR (Chiasson et al., 2008, p. 42-43; Mathiassen, 2002). This means that in the context of the broader research program in which the thesis is situated, is analyzed with AR from the outset is combined with other research methods. AR is the primary method from the very start, and a key approach for producing explanations.

The research design in this thesis apply the AR on the overall program level mixed with four qualitative case studies and one action design research (ADR) study (Sein et al., 2011), to examine and explain the research questions, see Figure 5. The overall cycle of the whole AR ProdEx project is reported on multiple levels of analysis based on a portfolio of research methods including literature studies, case studies (interview studies and focus group sessions), and other AR interventions such as project meetings, workshops, planning meetings etc. Cycles of Study II-IV are iterated within the overall program level.

In the following, action research in general and collaborative practice research in particular is discussed, followed by the conducted overall action research activities. Thereafter each of the individual studies I-V are reported including the
choice of method approach, analytical tools used, and including a summary of results. The four qualitative case studies, I, II, IV and V, are mainly built on interview data, analyzed from an interpretive perspective (Kohlbacher, 2006; Revsbæk & Tanggaard, 2015; Walsham, 1995, 2006). The course design Study III, apply an iterative action design research (ADR) approach, based on Sein and his colleagues model of four stages; 1) Problem formulation, 2) Building, Intervention and Evaluation, BIE, 3) Reflection and learning, and 4) Formalization of learning (Sein, et al., 2011).

5.1 Action Research

There is no single type of action research and Bryman (2012) defines it as an approach where researcher(s) and the member(s) collaborate in a joint intention of problem solving to improve work practice or to propose a new course of action. The researcher can act in a variety of forms, from employment as a consultant, to act as a more independent action researcher. The data collection process can involve a number of methods, both qualitative and quantitative techniques and it has a time dimension usually over a longer period. Action research is historically based in organizational and social studies, but is more common today within the IS research community, often used in combination with design research (Avison, Baskerville, & Myers, 2001; Baskerville & Myers, 2004; Mumford, 2006; Sein et al., 2011).

Action research favors change, active participation and involvement of the researchers. This means that AR allows for practical problem solving while expanding the scientific field (Baskerville & Myers, 2004; Sein, et al., 2005). Essentials in AR is to achieve changes through actions, to improve through intervention and to involve in everyday and close collaboration with the research “object”. With and in the cyclical processes reflection and learning are defined as explicit goals within a joint research approach.

Drawing the attention to the AR oriented approach applied in this thesis, means that the action researcher’s goal is not only to produce new knowledge but also to cause changes to what is being researched on. One reason behind this approach is to show important underlying correlations, for instance in a production system, that could not be discovered if there was not a certain course of action initiated into the process (Jakobsson, 2012). This can be seen as the conduct of an experiment where the researcher initiates a task, participates in, and in the meantime, do studies within (Gustavsson, 2004). It concludes the interconnection between knowledge and action reasoned by scholars like John Dewey, long before the term action research was introduced.
It has been debated that AR is not a proper research methodology, mainly because of its project-oriented approach and therefore scholars suggest principles and criteria to overcome these problems (Chiasson et al., 2008). R. Baskerville and Myers (2004) suggested four pragmatist premises for conducting AR. First, to establish purpose of action and theoretical assumptions before action is taken. Second, to conduct practical actions in the problem setting, e.g. talking, asking and formulating agreements. Third, practical actions must inform the theory, meaning that theory must be validated by its practical outcome, and fourth, reasoning must be socially constructed, e.g., the action researchers must be participant observers. These four premises apply well to how other scholars have framed AR in IS research (Mathiassen, 1998; Mathiassen & Nielsen, 2008; Sein et al., 2011).

5.2 Collaborative Practice Research

Mathiassen’s (1998) early work introduced the research approach Reflective systems development that appreciated an interpretive understanding of local practice through evaluation of underlying assumptions within practices of design work. The approach favored practitioners’ knowledge and work practice as sources in a knowledgeable design process. Rationality and reflection was two aspects incorporated within the design process of artifacts (Mathiassen, 1998). Furthermore, rationality is culturally contingent within organizational knowledge, meanwhile the process of reflection mostly handles individuals’ cognitive and practical abilities to reflect on their own experiences (Stolterman, 1991). Reflections, though is a process that is valuable to make explicit and share with others, as a socially constructed learning process.

The reflective approach allow for a coherent view of practice and research with two different modes of inquiry, a research mode and a practice mode. When designing and developing new practices and systems, which in this thesis concern the exploration of an inter-organizational e-learning practice, there is a growing complexity that will be questioned from the reflections of the actors included, because they bring in contradictory perspectives from their various disciplines, i.e. organization science, educational science and production science. Hence, the dialectical reflections between theory and practice are then helpful to understand the tensions involved in practicing and improving development (Mathiassen, 1998).

Making experiences is an active process between resources in the setting (physical and social) and between the individual and the collective subject (Gustavsson, 2004). In Argyris & Schön’s (1996) early work, reflective practice takes place when practitioners apply past knowledge into a new situation. It occurs when practitioners reflect upon an incident while it is happening. These types of
processes are therefore hard to grasp. The changes of experiences is argued to be a knowledge constructive process through reflection during, and after actions taken, for instance through problem solving in practice (Argyris, 2000; Argyris & Schön, 1996).

Hence, the type of collaborative practice research approach applied here, allows for integration of both theory and practice by means of problem solving related to working life goals (Mathiassen, 2002). This means that the approach facilitates the production of both theoretical and practical knowledge by emphasizing research activities that advances science while at the same time inform professional practice (Mathiassen, 2002; Mathiassen & Nielsen, 2008; Sein et al., 2011). Furthermore, the approach acknowledge studies of forthcoming activities and interventions in close relationship to the on-going practice embracing practice research with focus on understanding the practice, design research with focus on designing artifacts, e.g. e-learning courses and technologies, and action research focuses on changing work practice (Mathiassen & Nielsen, 2008). Action research focus on changes in practice, for instance changes in collaborative processes, meanwhile design research focus on changes in the artifact. These three dimensions is considered in the Reflective systems development (Mathiassen, 1998), and furthermore the Collaborative practice research approach (Mathiassen, 2002) for professional development intertwined with research actions that emphasized it as an intervention process, or as a continuous learning process that unfolds reflection and learning.

However, it is this broad combination of various research activities that the Information Systems (IS) scholars usually elaborate if combinations and similarities in and between action research and design research is applicable. Scholars have specifically argued the challenges of relevance and lack of rigor (Baskerville & Wood-Harper, 1996) if AR is an applicable research method (Avison et al., 2001; Chiasson et al., 2008; McKay & Marshall, 2001). Risks for the researchers can be lack of objectivity, lack of discipline, mistaken for consulting, and context-dependency, and resulting in problems of generalizing research results (Chiasson, et al., 2008). However, the interventionist approach accept iterations between different roles (understand, support, improve) and thereby researchers can solve practical problems meanwhile develop science iteratively. It suits specifically longitudinal studies over a period of time in which the researcher can follow up and make iterations of interventions and thereby study the consequences of changes from multiple perspectives. Combining AR actions with traditional research methods strengthen the validity of such a collaborative research approach (Bryman, 2012).
5.3 Overview of Research Activities

This section outlines the action research activities combined with the five studies on an overall methodological level during the five years of studies. The aim of the research activities was, over time, to capture the process of how learning activities develops from multiple actors’ perspectives between the two stakeholder institutions, the industry companies and the university.

During 2013-2015, e-learning design and action design research were grounded through the empirical context, particularly in Study I-III. Eventually, the action research approach made incorporation of new concepts possible which became important for the research. In 2015, Engeström’s (2008) concept of knotworking advanced as a possible concept to study tying, untying, and retying together seemingly separate threads of activity. Specifically activities of intertwined expert knowledge and expertise between multiple actors’ collaboration on different levels and from different perspectives in the e-learning design process aiming to facilitate co-construction. The e-learning design process includes diverse learning activities towards new forms, content and perspectives that facilitates and enables co-construction of knowledge. In Study IV and V knotworking is applied to further explore how performances and content of co-construction, e.g. finishing a task and to add value, among coupled actors and activities in the e-learning courses and project meetings over a period of time. Concerning all studies, activities postulate expectations, values, reflections and contradictory views as a reflective process for learning.

The studies were conducted longitudinal from the beginning of 2013 until spring 2016, between the two stakeholder institutions, i.e. between the participating companies in close relationship with the Production Technology West (PTW) research environment at University West. These two institutions represent the two main inter-organizational stakeholder units. The study context is the joint ProdEx project in which the mutual interest is to strengthening industry engineering competences, skills and develop production technology knowledge for workplace transformations.
5.3.1 Project activities, actors and phases

In the overview, see Figure 6, the studies and related papers are illustrated together with the frequencies of activities and occurrences over time.

The activities started with the project initialization in January 2013 (MERIT, 2013-2015) until spring 2017 (ProdEx, 2014-2019). The activities included in the thesis comprise; nine company meetings/seminars, eight internal ICT-seminars, and, iterated with monthly project meetings in which the participating research teachers took part. The different stakeholders and actors participating within the different activities, meetings, seminars and studies include:

Managers: HR managers, Production managers (and/or CEO and/or principal business managers)

Network org: Industrial development Center West and Innovation center for the municipality

Project group: The researcher (author), research teachers (~8), ICT pedagogues (~2), IT technician (1), administrator (1), operating project leader and senior project leader. This group met frequently in different constellations and between company seminars.

Research teachers: Research experts, all with a PhD degree, i.e. lecturers, docents or professors, and also part of the project group,
responsible for designing, implementing and running the courses.

**Practitioners:** Industry practitioners, i.e. operators, technicians, project leaders, purchasers, project leaders, from the manufacturing industry, participating in one or several courses

During the project, mainly two types of data was collected, project data and case study data. Data collection in the project activities were observations (taking notes and/or audio recording), participating in discussions, making suggestions, that is, intervening in forthcoming decisions, giving feedback to the project group from the case studies etc. Data collected within the five studies were mainly interviews, focus group sessions, and course study data (web-conferencing observations, learning material, video material, LMS content, learning instructions and participant questionnaires).

The studies and actors included in this thesis are the following:

**Study I:** Managers I. Manufacturing industry e-learning readiness and learning conditions. Interview case study, spring 2013, six months.

**Study II:** Research teachers. Design plans for e-learning courses. Interview case study, spring 2014, two months.

**Study III:** Course design. ADR in cycles, deriving design principles. Evaluation model including three pilot courses, spring 2014-jan 2015, one year.

**Study IV:** Practitioners. Construction of knowledge and learning from course participation. Case study with focus group sessions, spring 2014-spring 2016, two years.

**Study V:** Managers II. Co-construction and expansive transformation in the workplace. Interview case study, autumn 2015, six months.

The interviews and focus group sessions are systematically transcribed, analyzed and is further described under section 5.4 – 5.11.

The collaborative research design was initiated, managed and built on the practice need of development and guidance driven by an inductive approach (Bryman, 2012). Each of the studies were initiated in a cyclical process over time, due to the founded empirical needs after evaluation of each individual study. Typical three types of stakeholder actors were included in studies; managers, practitioners and
research teachers. The course itself also became a study object. The five studies are studied from three overall perspectives; the industry, the university and the collaborative perspective, see Figure 7.

![Figure 7. Three types of actors combined with the course study, studied from four perspectives](image)

The action research approach was applied on the overall dominant program level (Chiasson, et al., 2008) described in three broad phases, in which each of the individual studies are included (see Figure 5, section 5.1) Problem formulation, 2) Planning and course design, 3) Reflection and formalization.

The following outline describes the interrelations of the five studies and how they correlate to the whole action research program level, meaning the collaborative practice research design (Mathiassen, 2002). Data and knowledge from these interdependent phases was conducted through iterative cycles of reflection and learning to be further formalized for future results. These phases applied well to both the project specific collaborative activities such as company meetings, project seminars etc. and to the individual research Studies I-V.

1. **Problem formulation**

This phase took one year, from January 2013 to spring 2014, and included Study I and company meetings concerning finding companies’ specific knowledge gaps, further on defined as *competence mapping* process of manufacturing companies needs and the university ability to meet such needs. Research approach and question for this initial stage is thoroughly described in Study I. The focus was to establish collaborative relations between the companies and PTC. Study I was continuously followed up by the industry stakeholders’ discussions in collaborative company meetings. Additional two networking industry organizations volunteered to participate in the project. During this initial phase, four ICT-seminars took part with research teachers assisting with their ideas and knowledge of the e-learning course design. Themes during these seminars handled pedagogical approaches in on-line learning, tutoring and communication
on-line, video production, Adobe Connect for web-meetings, lectures and application sharing with Matlab4.

2. **Planning and course design**

This phase initiated early in spring 2014 with the Study II, III and partly IV and was iterated as course design cycles within the overall whole project iterations of phase 1. Study II explored research teachers design plans, and Study III, the ADR process of Building Intervention and Evaluation (BIE) of particularly three pilot courses (Sein et al., 2011). This phase resulted in derived design principles of a generative course model. It meant that design plans, challenges and implementation of the courses both gave implications to reflection and formalization into the phase 3, by receiving suggestions and informing the knowledgeable discussions of the project and company meetings and other project activities on program level.

3. **Reflection and formalization**

This phase concluded the test period of the pilot courses and was ongoing during spring 2015. This phase gave input to the need of further studies of the collaborative activities within the courses when applying and implementing the decided design principles variously. Reflections of the three courses mainly selected from the focus group sessions with the practitioners, Study IV, became a natural continuation of the course Study III. In this phase, it became evident that the practitioners’ learning of production technology, and their evaluation of the course formats, was part of constructive negotiations (knotworking) for forthcoming development. The constructive reflections of knowledge sharing and knowledge learnt with support of the e-learning courses, therefore became two important levels for further studies of forms for co-construction and e-learning design.

The course formalization process had implications for the research teachers continuing design and implementation work. They therefore pursued support from the project group and the university IT-support, stressing the digitalization challenges and the need to learn more about digitizing pedagogical on-line tasks, on-line engineering labs, case examinations, and other production of digital course content.

On an overall level Study V aimed at finding a continuation and formalization of the project activities, and therefore a second manager study was performed during autumn 2015. This study focused on following up on the companies participating in Study I (Managers I), and examine the reflections on their eventual participation in the project meetings and through their eventual course participation (Study IV, practitioners). The project also searched for new partner companies. Of the initial
15 companies, only six companies took part initially. Another eight new companies were interviewed and asked of their thoughts of becoming new partners to ProdEx, a total of 14 companies were interviewed. Besides aiming to explore new the research findings, this study was set out to increase company collaboration and establish partnership before sending in another continuing application for ProdEx II, for a continuation until the end of 2019 (in total seven years).

The collaborative practice research approach allowed me as an AR researcher to continuously make efforts and suggest changes that aimed to give implications on design implementations drawn from the research findings. This opportunity meant that I was able to work and take actions in close collaboration with the study objects, and on the same time conduct case study research. I had different roles; to explore, to intervene, and to reflect. I was also able to suggest improvements based on different types of participation and research data collections (Bryman, 2012; Chiasson et al., 2008; Mathiassen, 2002). Hence, I studied activities on local levels, was part of the actions in use, and was influencing actions forthcoming.

In the following description, case studies and interpretive interviews are generally described (section 5.4), followed by an outline of qualitative content analysis (section 5.5). Thereafter each of the individual studies will be presented including their specific method approach, analysis, and results. Study IV included mainly qualitative interview data from focus group sessions. The focus group data method and analysis is presented as a part of the summary of Study IV.

5.4 Case studies and Interviews

This section describes the case study methodological approach used for the studies I, II, V (interviews) and IV (focus group sessions). The aim to collect empirical data and to explore practice from a company perspective is in line with Walsham’s (1995) interpretive case study definition meaning to study human actions and interpretations, surrounding the development and use of computer-based information systems. Walsham (2006) further describes four elements when setting up a fieldwork; to tackle the style of involvement, gaining and maintaining access, collecting field data and working in different countries. Walsham (1995; 2006) describes the researcher’s involvement as a spectrum where at the one end there is the ‘outside researcher’ and at the other end an ‘involved researcher’. The most involved researcher is that of an action researcher trying to consciously explicitly to change things in the way they find it most applicable according to the overall project.
In line with Walsham’s (1995; 2006) interpretive stance, I have alternated my role as an action design researcher with the role of a participant observer, avoiding to intervene with my own opinions when performing research in the studies. Within the participative action research activities described in Figure 4, section 5.3.1, my role was an involved researcher and to support change. During the four case studies, I pursued coherence between the studies, performing the interview sessions with the same guidelines, activities and strategies with the professional role of an interested but participant observer in order to identify patterns and progress over the years.

I continuously reflected upon my role in relations to the other stakeholders and actors in order to actively grasp their perspectives without pushing my own opinions and alleged solutions on to their table. Being aware of my own role made me able to both act with a closeness to the respondents and the project, and also to take a distance when needed. In order to perform ethically and not crossing integrity boundaries, I was thoroughly describing my involvement concerning the dual role of being a professional researcher versus being a colleague to some of the respondents. This was especially important when interviewing the research teacher colleagues (Study II) and during the phases of the course design cycles (Study III - Building, Intervention and Evaluation, BIE). The interviews and focus group sessions with the industry company actors (managers and practitioners) in Study I, IV and V, were made in informed consent, especially as they all were audio recorded.

The specific involvement and access to the data sets have been different and in progress during the four studies, described in the forthcoming sections. The data collection of these studies are visualized in Table 2, including time, studies (actors), number of sessions, respondents and number of companies in each study. Throughout the qualitative data collection of all the studies, I have independently been the main interviewer during all sessions and designed the interview guides, (except Study II, in which a master student was the leading interviewer, and I supported). I have verbatim transcribed all the recorded sessions, analyzed and coded the material by using the QDAS system NVivo 10 and later on version 11 (Study I, II and IV).
Table 2. Data collection: time, studies, type of action, and number of sessions, participants, and companies

<table>
<thead>
<tr>
<th>Year</th>
<th>Study and actor</th>
<th>Type</th>
<th>Number of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sess-ions</td>
</tr>
<tr>
<td>2013</td>
<td>Study I – Managers I</td>
<td>Interviews</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Competence mapping</td>
<td></td>
</tr>
<tr>
<td>Spring</td>
<td>Study II – Research</td>
<td>Interviews</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Teachers</td>
<td>Design plans</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>Study III – Courses (3)</td>
<td>ADR</td>
<td>3</td>
</tr>
<tr>
<td>(Apr) -</td>
<td></td>
<td>Course Design</td>
<td></td>
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<tr>
<td>2015</td>
<td>Study IV – Practitioners</td>
<td>Focus groups</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Co-construction and learning</td>
<td></td>
</tr>
<tr>
<td>Autumn</td>
<td>Study V – Managers II</td>
<td>Interviews</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expansive transformations</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>Study IV – Practitioners</td>
<td>Focus groups</td>
<td>1</td>
</tr>
<tr>
<td>Spring</td>
<td></td>
<td>Co-construction and learning</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>47</td>
</tr>
</tbody>
</table>

* In total 20 different companies participated

5.5 Qualitative Content Analysis

The following section describes qualitative analysis, and specifically content analysis. Qualitative content analysis was used to analyze interview data in Study I, II and IV (focus group sessions). The analysis of the studies are presented separately in section 5.6 – 5.10.

Analysis of empirical and qualitative data are in my opinion a particular process of time duration from the start of the interview sessions over a period of time, to listening, to transcribing and then coding (and perhaps re-coding). It is also, about how the researcher is possible to explicate shared experiences from the interviews, usually in the forms of texts. Then there is the individual interpretation that the researcher(s) chooses to unfold from the conversations that really took part.

Revsbæk and Tanggaard (2015) discusses an everyday listening experience they describe as analyzing in the present. By listening many times, they describe that listening becomes about interpreting past situations to understand the present situations, “…a practice of noting evoked recollections and associations situated in the listening present and related to the interview incident.” (Revsbæk & Tanggaard, 2015, p. 377). This approach has not so much to do with how to interpret texts, rather more of
interpreting situations. It handles how to open up the material in a reflexive process where the situation that took place must be recollected instantly. This means the interview session in itself becomes a unit of analysis, hence to understand the way conversations are progressing during the interview. With that in mind, I fully agree upon to re-live interview situations to find its meaning, conducted as a form of intervention in which negotiations around a specific topic, is developing. Hence, I as a researcher therefore need to reflect afterwards, to recollect the whole conversation and its meaning.

As such, I decided to plan, structure and perform all data collection and analysis work independently. This included the design of the interview study guides and to have the direct correspondence with the respondents. I was the main interviewer, made all transcriptions, coded the data, was re-listening and re-coding data to make reflections on the reflective conversations. Both the supervisor team and the project group supported these steps. These steps were made in Study I, II, and IV. Study V has not yet been transcribed and coded in NVivo, but analyzed according to the interview notes. As mentioned before, the teacher Study II, was performed by a master student as main interviewer, and I was supporting the five sessions. She performed transcriptions, however, I read the transcripts, listened to the interviews and re-coded the material.

Content analysis is a general term for a number of different strategies used to analyze text (Powers & Knapp, 2010). Qualitative content analysis (CA) was used in all three studies, to interpret the text data through an inductive approach (Bryman, 2012; Graneheim & Lundman, 2004; Kohlbacher, 2006). The analysis of the studies started from induction, meaning that there was no initial theory or theoretical concepts guiding the coding or the search for patterns. This method is useful in case research when the boundaries between phenomenon and context are not evident (Kohlbacher, 2006). Content analysis is used variously, and is here viewed as a research technique for making replicable and valid inferences from texts to the contexts of their use (Krippendorff, 2004). Hsieh & Shannon (2005) defines content analysis as a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns.” This definition also falls well into the thematic analysis method. Both content analysis and thematic analysis are being used interchangeably and it seems difficult for researchers in general to choose either of them because boundaries between the two have not been clearly specified, meaning there are mostly overlaps but also some differences (Vaismoradi, Turunen, & Bondas, 2013).
In both approaches, the researcher wants to find out about the actual behavior, attitudes, or real motives of the people being studied, or to detect what has happened (Ten Have, 2004). In content analysis, it is possible to analyze data qualitatively and at the same time quantify the data. Content analysis uses a descriptive approach in both coding of the data and its interpretation of quantitative counts of the codes. The main difference against thematic analysis lies in the possibility of quantification of data in content analysis by measuring the frequency of different categories and themes, and not used in thematic analysis (Vasimoradi, et al., 2013).

Another difference is concentrating data as either manifest and or latent. Both manifest (expressed in discourse, patterns of talk, and discursive actions) and latent (unspoken) content deal with interpretation, but the interpretation varies in depth and level of abstraction (Graneheim & Lundman, 2004; Powers & Knapp, 2006). In contrast, thematic analysis incorporates both manifest and latent aspects as an inseparable part of the manifest analysis approach (Braun & Clarke, 2006). Meanwhile in content analysis, one can decide to use either perspective separately (Graneheim & Lundman, 2004). Furthermore, thematic analysis put a stronger emphasize seeking patterns in and across data, and usually the analysis are not theory-guided.

### 5.5.1 Coding process

In Study I, II, and IV, a systematic classification process of coding and identifying concepts, unit of analysis, codes, categories and themes were identified by patterns of behavior and situations viewed as a process rather than outcome in relation to the research questions (Graneheim & Lundman, 2004; Kohlbacher, 2006). Following the notions of Graneheim & Lundman’s (2004) the label of meaning unit is a code and codes are tools to think with, and labels condensed meaning units to think about data in new and different ways. A category answers the question “what” and is identified as a thread throughout the codes. Often it refers to a descriptive level of content, and usually includes a number of sub-categories on various level of abstraction. Themes answers the questions of “how” and is often understood as a thread of meaning through condensed meaning units, codes/sub-categories, on an interpretive level. A theme can be seen as an expression of both manifest and/or latent content of the text. Given this interpretation of a theme, various themes can consequently relate differently according to “the research question(s) and chosen theoretical perspectives” (Graneheim & Lundman, 2004).

I have chosen the above definitions of codes (meaning nodes in NVivo), categories and themes. The first analysis round in all three studies (Study I, II, and IV) was initially inductive and empirical, which Hsieh and Shannon (2005) label...
conventional content analysis, meaning researchers avoid using preconceived categories. Then after finding relevant theories to apply to the data material, a re-analysis was conducted, i.e. a deductive analysis was performed (Elo & Kyngäs, 2008). A conventional analysis process (Bryman, 2012; Elo & Kyngäs, 2008) has been following by these steps;

- **Preparation** - selecting the unit of analysis, deciding on the analysis of manifest content or latent content.
- **Organizing** – systematically open coding and creating codes, sub-codes and categories, collating and grouping codes under higher order categories and themes, analyze the structure and abstracting by a general description.
- **Reporting** – Conceptualizing, modelling and reporting the analyzing process and the results.

In Study I and II, IV and V a thematic interview guide was used including both defined questions and open-ended questions, see Appendix A, B, D and E. These themes were not applied as predefined categories or themes during coding and categorization of the transcripts, rather, the reading and coding of the interview transcripts were open-minded, interpretive and cyclical. Generally, the content was discussed in the supervising team around the initial interpretations and accordingly the relevance of themes and developing categories of the data. Theories was eventually chosen, and applied during the iterative analysis processes. For all transcriptions and coding the computer qualitative data analysis software (SQDAS) NVivo 10 (later on 11th edition) was used.

### 5.6 Study I – Managers I

The first case Study I was designed to explore manufacturing companies’ conditions of competence development work, both internal strategies and external relations (Hattinger, Christiernin-Gustafsson, & Eriksson, 2013; Hattinger, et al., 2014a; Hattinger, et al., 2014b). The research interest concerned the companies learning and knowledge views and their presence or absence of recurring strategies for defining and supporting critical expertise and competences as means for an effective production. The research questions was:

**RQ:** What are the learning conditions and the e-learning readiness in manufacturing companies that will affect the design of work-integrated e-learning?

When the case study was initialized early in 2013, both the research and the project interest was to create relations with the top management of manufacturing companies within the region, i.e. with production technology managers and human resource managers through an interview study. The study was explorative in order to reach an understanding of the companies’ knowledge view and their
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This included their internal competence management work, and their external collaborations and efforts to maintaining a high qualitative production process related to business competitiveness. Hence, the initial interviews, aimed to explore the managements’ perceptions on their strategic competence work and strategy plans, their willingness to join a collaborative competence project, and facts about the employees’ competence level. In summary, the companies described abilities to gain new knowledge in various production technology fields to strengthening their expert knowledge.

In paper I (Hattinger, et al., 2013) we discussed if there were relations between business goals and future use of technology-mediated courses. In paper II, (Hattinger, et al., 2014a), the concept of absorptive capacity was used as a theoretical lens for analyzing managerial rationales for engaging in competence initiatives. An additional conference paper discussed different forms of work-integrated learning and co-creation of knowledge through e-learning initiatives (Hattinger, et al., 2014b).

5.6.1 Interviews

The study comprised 16 interviews in 15 companies (in one company, two interview sessions took part) with 27 respondents, HR managers and Production Managers (senior production manager, and/or CEO) during spring 2013. The interviews lasted about one to one and a half hours in duration. To get access to the manufacturing companies within the Western part of Sweden, we invited a broad sample of known companies selected from the PTW research group network. About 30 industries were invited by e-mail with the request to participate in an interview. The e-mail was directed to the senior Production manager (or alike) and the senior Human Resource manager. The response was over the expectations, and more than 20 companies were interested, but some had to postpone an interview session, due to hard working schedules at the time. A semi-structured interview guide was sent out one week before the meeting, see Appendix A.

To interview production managers’ and HR managers afforded me to do a thorough pre-study of every company and sector. I was aware of the power dynamics in research interviews (Kvale, 2006), especially when I was asking sensitive questions about the companies economic and strategic situation, and their plans to endure competitiveness, with questions such as what they thing will happen if they do not “invest” in the employees competences forthcoming. I was conducted the first interview alone, with a senior HR manager in the largest aerospace company. This respondent made me confident of the importance of the project, the ideas around the initiative and the possibility to research a joint industry-university collaborative competence project. I saw the first two
interviews as a learning process, and an important knowledge production process related to the overall aim of this study. The respondents input according to the topics presented in the interview guide, were open for points making and diverse perspectives. I allowed for including contradictory views and negotiations, viewed as meaning making contributions and constructive production for further collaboration (Tanggard, 2007).

During the interviews, I was neutral but open to discussion (balancing), of their production systems and manufactured products, their customer demands, how they describe their employees, future production plans in relation to staff etc. After my short introducing in the interview, I mainly let the managers lead the conversations, meaning that I was listening carefully, interesting, and guided the conversation and making sure that both professionals (production and HR managers) made their voices and perspectives open. Therefore, many side questions outside the pre-defined themes were raised. The meetings in themselves felt both critical but also enlightening and sometimes innovative, because sometimes issues and ideas were discussed which normally do not bring forward innovative ideas and critical aspects in every day work practice. Before ending the sessions, respondents were also asked to fill in with information or questions not being elaborated on.

A major benefit with the research interviews placed at their factory plant, was the upstarted connections and recruitment of important partners into the company network, beneficial for both the research project and the project group. Throughout the case, I did nine interviews by myself alone, the other six interviews were conducted together with one of the supervisors.

5.6.2 Analysis

The first coding round was grounded in the company basic facts such as number of employees, sector, and employees’ formal education levels etc. these quantitative and qualitative facts was documented in an Excel matrix. Throughout the iterative coding, the searching was of manifest character to find expressions, words or phrases, to find nuances and attitudes around competences, knowledge, learning and technology use related to the overall study aim. The first coding round resulted in 10 nodes; company background, knowledge and markets, competence needs, personal competence development, IT-use and learning, competence evaluation, master thesis and students, knowledge and business development, co-production with university, work-integrated learning.
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These broad nodes were then categorized into five themes:

1. Practitioners competences on advanced level – basic facts
2. Critical production processes requiring expert competences for future company development
3. Industry competence needs now and in the future
4. Forms and modalities for competence development initiatives
5. Learning organization and co-production with higher education (HE)

These themes were further analyzed into sub-nodes. In the early paper I (Hattinger et al., 2013), the main analysis concerned theme four and five. The analysis concerned relations between the competence business goals and use of IT-mediated learning tools. Companies that reach a high level of both aspects were discussed to be a changing and learning organization, and therefore have conditions for joining competence projects supported by technology-mediated courses together with a university partner.

In a second re-analysis of theme five, the analysis focused on work-integrated learning (WIL) and co-creation. These two concepts were analyzed in relation to business strategies and change processes including their perspectives on innovation on management levels. Also management perspectives on the employees’ informal learning were coded and efforts around collaboration with higher education institution. Examples of sub-nodes that developed from this analysis are characterized as follows (Hattinger, et al., 2014b);

<table>
<thead>
<tr>
<th>WIL – Business strategy</th>
<th>“Sometimes we discuss it in the business plan”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“Every production manager can do more”</td>
</tr>
<tr>
<td>WIL – Change processes</td>
<td>“Finding critical process and do a customer value added analysis”</td>
</tr>
<tr>
<td>WIL – Informal learning</td>
<td>“Learning by doing all the time”</td>
</tr>
<tr>
<td>Co-production – student</td>
<td>“This thesis work (bachelor) have raised our turn over with XXX XXX SEK”</td>
</tr>
<tr>
<td>Co-production – HE</td>
<td>“Do not know what academia can provide”</td>
</tr>
<tr>
<td></td>
<td>“Development projects and lectures can be placed here at our production plant”</td>
</tr>
</tbody>
</table>

After discussions within the supervisor group, a suggestion was to use the absorptive capacity (AC) theory (Cohen & Levinthal, 1990), e-learning readiness factors (Schreurs & Al-Huneidi, 2012) to further analyze of all data, i.e. the five themes. This theory-guided approach resulted in another structural and condensed combining of the ten categories, described above, into a re-
conceptualized framework of four new constructs, meaning four new themes, see next section. Each of the constructs was exemplified with excerpts on three levels; low, medium and high level of readiness. Examples of condensed references were: “critical and functional competences is discussed”; “we discuss changes and how to grasp ideas as a process to be innovative”; and “we continually aim to write the competence plan together with academia”. The whole analysis is presented in Paper II (Hattinger, et al., 2014a).

In summary, the first qualitative content analysis was used to interpret the text data as an inductive approach (Bryman, 2012; Kohlbacher, 2006). The analysis started out empirically grounded, went through the process of open coding of manifest meanings and was iterative (Kohlbacher, 2006). Different coding resulted in three publications. The main findings were applying the absorptive capacity theory, meaning to both look into external and internal capacities for learning and innovation. Consequently, codes was re-structured into four new themes and theory-ingrained into constructs. The sorting and re-grouping of excerpts and categories was discussed several times in the supervisor group to ensure reliability. NVivo and an extensive Excel matrix, supported helpful overviews to the analysis and findings.

5.6.3 Results

An initial and overall challenge was that the short-term approval of the project initiative MERIT, was only for two years. Furthermore, the funding agency stressed that the designed courses should be on master level (meaning advanced level). In the interview study we found out that the formal education level are generally low among operators and engineers in the manufacturing industry, with mostly a three-four years technical high school education. This issue was hard to convey during 2013-2014, especially when initiating a broad and joint collaboration between industry-university, ending up without any courses to offer. One way of solving this issue was that the university started to validate practitioners’ skills and experiences so they could register on advanced courses. Study III describes this situation further.

Until the university were having any courses to offer, some companies were vague about the joint collaboration, because they were not fully informed of the project content, neither did they have direct insight into how this in the long-term would benefit them nor what they would be able to contribute to in forms of co-construction. Results from the last analysis of the whole interview study, indicated that companies have a solid internal structural of their competence work, consisting of yearly routines, rules and strategies (Hattinger, et al., 2014a). This is not surprising, giving the continuous demands in the manufacturing industry of meeting high quality standards within the series of the general ISO 9000 family standard, or ISO/TS 16949 Automotive Quality management standard, or the
aerospace standard AS9100 and so forth. However, the results showed a broad variation regarding companies’ practices and routines of defining expert competences, long-term competence strategies, and external organizational networking with research institutes and higher education. Only the two large companies (one in aerospace and the other in automotive sector) showed strategies for supporting innovation and strategic collaboration outside the own company. Basic company facts among the 15 companies illustrated a low degree of employees with an academic diploma, which had implications for meeting the academic course levels when designing curricula for up-coming courses. By applying a combination of the two theoretical concepts of absorptive capacity, AC, (Cohen & Levinthal, 1989; 1990) and an e-learning readiness instrument (Raymond, et al., 2012; Schreurs & Al-Huneidi, 2012) as analytical lenses, the data was comprehended into four constructs in which the companies were evaluated against, see Figure 8. These constructs were; Awareness, E-learning maturity, Dynamic capability and Co-creativity, see paper II (Hattinger, et al., 2014a).

![Figure 8. Interrelations between constructs](image)

- **Awareness** means the capability within the company to identify and describe internal knowledge needs and knowledge content within engineering, in line with absorptive capacity.
- **E-learning maturity** comprised IT and e-learning technology use and maturity.
- **Dynamic capability** refers to the company’s capacity to pertain knowledge creation in order to sustain a competitive advantaged. It includes the ability to adapt to and customize the organization due to changes outside the company, to customize the company needs to external requirements, in order to become a learning organization.
- **Co-creativity** and co-creation, refers to collaboration outside the company, especially with other research institutes, HE, and company networks. Co-creation of knowledge was found meaningful when the companies talked about their ability to contribute to the project, based on their goals.
Summarized results show that;

- seven companies have their own R&D department or run R&D activities
- six companies were rated having a high level of awareness
- four companies have high level of e-learning maturity
- four companies showed a dynamic capability
- half of the companies were rated as highly co-creative

In addition, companies with high education level also had high level of absorptive capacities and a higher e-learning maturity. In summary, high e-learning readiness was discussed as a concept that comprise the capabilities that organizations’ need in order to capitalize on e-learning initiatives. For a company to have e-learning readiness within the whole organization, all four of the constructs should be on high level. A high level of both absorptive capacity and e-learning readiness is assumed to constitute a solid foundation for developing e-learning courses that aim to strengthen employees’ skills and theoretical competences.

Even if the companies collaborative activities with academic institutions was marginal at the time of the study, the managers optimistically discussed a rich variation of possible active collaboration with external institutions and were open to new forms of co-construction and work-integrated learning. However, their broad-minded work for company innovations was limited. The findings also implied a dual and intertwined approach for research and project actions to continue. Another aim was to create a long-term close relationship and tighter connections to the company stakeholders. One main argument for the companies to join, was the universities willingness to open up the production technology research environment, PTW, and the machining hall at the Production Technology Center. Boundary crossing activities between industry and university was initiated concerning competence mapping of industry target knowledge needs, including content, time and practical workplace cases. The study generated diverse arguments for a continuation, which gave further engine to new project activities and studies capturing the research teachers design plans, and to speed up the design work towards course implementation.

Given these findings, we **were strengthened in continuing with a well-planned design of implementing richer collaborative activities between university and industry companies as a general joint collaboration and to further investigate forms and facilitation for co-production.**
5.7 Study II – Research Teachers

Study II (Hattinger, Spante, & Ruijan, 2014c; Hattinger & Spante, 2017) took place in spring 2014 performed with the five research teachers assigned to develop the three initial courses. In this study we explored how research teachers perceived design challenges, how they identified and framed earlier experiences of e-learning and/or distance education, or maybe a lack of experiences. This was defined as their conceptions on design plans for blended e-learning courses targeting industry practitioners’ knowledge needs. The study also included the researchers’ ideas on how to incorporate practitioners’ knowledge as contributors in the learning sessions. The research question asked was:

RQ: How do expert research teachers approach a new e-learning situation with experienced engineering practitioners in the manufacturing industry?

During the second year of the project in 2014, the course design plans were delayed, and no courses had yet been implemented. During this rather stressful time, it was decided to perform a teacher study together with a master student in information systems. We were interested in finding out how the research teachers perceived the teacher role for upcoming blended e-learning courses. The challenges included learning technologies, content production of engineering material and pedagogical strategies and case methods. Especially, the focus was on their ideas of work-integrated learning, meaning how to include the practitioners every day practice into the course situation integrating learning and work practices.

5.7.1 Interviews

At the time for this study, five researchers (included all available teachers planning the three upcoming courses), were interviewed. The five researchers included one professor in Machining, one assistant professor in Industrial automation, one senior lecturer in Industrial automation, and two in Mechanical engineering. All senior lecturers held a PhD degree. The respondents were in total four men and one woman. The interviews lasted about one to one and a half hours in duration guided by a semi-structured interview guide, see Appendix B.

A female international Chinese master student and I conducted the interviews. She was leading the interviews with me as support, and I took notes. This was an applicable set up, due to that the respondents are my everyday colleagues, and she needed to practice interviewing. To interview teachers that on a daily basis supervise both master student and PhD students, made the conversations both informative and relaxed. Even if the English language could have been an obstacle, this was not the case here, due to the respondents’ broad experience.
with international students. The reciprocity and trust within the conversations were running smooth and therefore in a dialogic manner. Kvale (2006) discusses common conceptions of interviews as dialogues and describe diverse power dynamics that he claims always is in-built and are driving research interviews variously. One of his conceptions is the “interview is an instrumental dialogue” which was the approach most applicable here. It meant that the conversations were instrumentalized to provide both the student and me with the respondents’ descriptions and narratives. In that sense, we were having the power to rule the conversations even if the respondents’ reflections were not interrupted and not even rearranged if they did not follow the thematic interview guide. Consequently, the conversations aimed to explicate teachers’ future hindrances, novelties and other issues they delineated around educational design (Lippke & Tanggaard, 2014; Tanggaard, 2007; Turner, 2010).

5.7.2 Analysis

Study II went through two different analysis over two years (Hattinger, et al., 2014c; Hattinger & Spante, 2017). The first analysis was a collaborative process between the master student, the Informatics supervisor and me. The analysis process was similar to the steps in Study I, i.e. we conducted a systematically open coding. The first round of analysis targeted the research teachers’ subjective experiences as fundamental insights on how to address e-learning design challenges to inform future e-learning design. After the first coding process, and finding excerpts that supported the overall aim, the TPCK (Technology Pedagogical Content Knowledge) framework was suggested to be applied to the coded data (Mishra & Koehler, 2006). This theory remodeled the analysis into new nodes and categories. The first published conference paper was presenting the results related to TPCK (Hattinger, et al., 2014c). Comprised themes discerned were; view on e-learning approaches, media technology, assessment, and work-integrated learning. The TPCK-analysis showed that teachers are novel e-learning designers, however they are eager to experiment with media technology. They did have vivid ideas on how to design work-integrated learning cases, but found such ideas hard to implement into digital courses.

A year later, a re-analysis was made on the transcripts and initial coding. The first round of the re-analysis focused the research teachers conceived transformation of campus-based teaching into meditated courses. This first analytical dimension focused manifested challenges. The second coding round was focusing the meanings of the teachers’ perceptions and identities viewed as a transformation process of the professional identity (Graneheim & Lundman, 2004). This analysis was then theory-guided by boundary crossing theories and learning mechanisms at the boundary inspired by Akkerman & Bakker (2011a). Their theoretical approach follows the line of the cultural-historical activity theory (Engeström,
5.7.3 Results

In paper III (Hattinger & Spante, 2017), results were focusing on research teachers’ earlier perceptions of teaching and their forthcoming plans. Hence, their perceptions (ideas and experiences) were related to their pedagogical and technical concepts, such as strategies and plans for meeting the practitioners expectations of both practical and theoretical knowledge related to their work practice. This meant to find strategies to include practitioners’ experiences and engineering expertise. It also meant to digitize engineering learning content such as labs, programming, drilling and milling cases that align with workplace needs. The research questions in this paper are:

RQ 1: How do research experts approach a new e-learning situation with experienced engineering practitioners in manufacturing industries?

RQ 2: What implications will the approach have on the engineering research experts’ professional identity?

The approach to understand the expert research teacher role was viewed as a sideways social learning process, rather than viewing the learning situation as teacher-student situation. This view was applying learning at the boundary through boundary crossing (Akkerman & Bakker, 2011a) as an overall theoretical approach to be able to explore the space and the relational meaning making (Edwards, 2005a) between the researchers and the practitioners, viewed as “sideways learning” (Engeström, 2001, p. 154-155) rather than learning as acquisition from teacher to learner.

We identified research teachers shifting identities when they phase challenges in their professional role while encountering a new structured learning situation, especially which and how learning mechanisms occur when shifting identities (Akkerman & Bakker, 2011a). One learning mechanism was analyzed when teachers are shifting their identities between campus courses and e-learning courses, which had implications on their coordination of planned learning activities. Hence, the learning mechanisms identification and coordination (Akkerman & Bakker, 2011a) were useful analytical tools to unfold the research teachers’ diverse roles when crossing boundaries between practitioners’ versus campus students, and between campus education and blended e-learning.

Results show that crossing boundaries between industry and university was one main challenge. This challenge was two-folded. The first was to find an applicable
learning design of useful engineering learning materials and a pedagogy that apply to industry relevance, for instance using practical case tasks aligned to problem solving and applying research-based problem solutions. The second part, was to find ways of including the practitioners as active learners and legitimizing them as co-producers, meaning mutual knowledge construction, emphasizing knowledge sharing within the learner group.

With the learning mechanism *othering* (one form of identification), one practice can be identified and redefined in light of another. The researchers found themselves in various forms of identification processes making design plans to include practitioners knowledge as active learners. *Legitimizing the practitioners in co-existence* with other practitioners as well as with the researchers on equal grounds is part of the process of co-construction of knowledge. With the learning mechanism legitimating coexistence, results show that these two mechanisms are important features of what the concept co-construction of knowledge should entail. We defined the research teachers’ upcoming learning situation as both situated challenging (the design work towards industry target groups) and challenging to mediate (the e-learning design work). The use of the two learning mechanisms identification and coordination (Akkerman & Bakker, 2011a), revealed that the researchers consequently face a dialogical teaching situation when making design plans for this type of structured learning occasions targeting a new group of learners that aim to co-construct knowledge that will have implications for work-integrated learning.

**5.8 Study III – Course Design**

Study III was conducted with an action design research (ADR) approach (Sein, et al., 2011) specifically target the course design process (Hattinger & Eriksson, 2015). It summarized the project’s ADR method in halftime, see Appendix C, including project and research activities from spring 2013 until early 2015. The ADR approach was influenced by the results from the initial research teachers plans (Study II) which had implications on the building, evaluation and learning, BIE of the initial three courses. The focus was on planned and implemented course design activities and the actions taken by the diverse actors, i.e., managers, research teachers and practitioners. This study specifically apply Sein et al.’s (2011) ADR method, which emphasize both organizational change efforts in combination with development of technological artifacts as an ensemble. The research question was:

*RQ*: How can e-learning courses be designed to support competence development and work-integrated learning?
Next section describes limitations and possibilities with action research (AR), design research (DR) and action design research (ADR). Then the chosen ADR model by Sein et al., (2011) is used for designing the competence activities.

The main argument to choose this method was put forward by the early work of Lindgren et al. (2004). They were stating that there is no prior research on the role of IT in supporting the management of organizational competence when including test and development of design principles in a cyclical process of CMS (competence management systems). Their ADR approach was emphasizing that IT artifacts are ensembles shaped by the building of an IT artifact, intervening in the organization and evaluating it concurrently. This work was further developed and published in MIS quarterly (Sein et al., 2011).

5.8.1 Limitations and possibilities with AR, DR and ADR

Recent IS scholars approach ADR by combining action research (AR) and design science research (DR), seeking for both practical relevance and academic rigor (Lindgren et al., 2004; Rogerson & Scott, 2014; Sein et al., 2011). They mean that the combination of research studies of technological design together with studies of social processes within organizational contexts will facilitate the production of both theoretical and practical knowledge. ADR, developed by Sein et al. (2011, p. 40) “is a research method for generating prescriptive design knowledge through building and evaluating ensemble IT artifacts in an organizational setting.” The approach is a synthesis of DR and AR to build innovative IT artifacts offering a solution and learning from organizational intervention while solving a problematic situation. The method integrates the three approaches understand, design and change, (Mathiassen & Nielsen, 2008), into a combined action and design research method viewed as an ensemble (Sein, et al., 2011).

ADR offer a combination of action research with design research, even if this combination have been debated among IS scholars for years (Cross & Sproull, 2004; Hevner, 2007). The ongoing debate concerns whether to understand AR and DR as a similar approaches or not (Cole et al., 2005; Järvinen, 2007; Lee, 2007). Järvinen (2007) argues in particular it is a similar view and signify that the main variation between them concerns the research intent. Other argue for a combined approach to seek for both practical relevance and academic rigor (Lindgren et al., 2004; Sein et al., 2011). Meanwhile some design science research (DSR) scholars argues that they are incompatible if the differences are not thoroughly addressed, e.g., how results are analyzed and generalized (Iivari & Venable, 2009; McKay & Marshall, 2001).
Within the dominant DR or DSR field, focus is primarily on the research and design of various forms of artifacts (Hevner, 2007; Iivari & Venable, 2009). However, DSR is by some scholars said to be too technologically deterministic, and its lack of concerns of organizational contextual influences on the artifact design, the evaluation and the use in practice (Mathiassen, 2002; Mumford, 2006). Some criticize the strong focus of artifacts performance, the goal-orientation regarding the technology itself, to not paying enough attention to contextual consequences and effects, such as usefulness, economic turnover, peoples work conditions etc. to the same degree as AR perspectives in organizational studies focuses.

Iivari and Venable (2009) mean that DR is largely utility-centric, as opposed to being explanation-centric, and therefore AR and DSR are incompatible if we do not address these differences thoroughly. In comparison with AR, an essential difference is that DSR assumes neither any specific client nor joint collaboration between researchers and the client. Iivari and Venable (2009) refer to the client as a class of generalized problem. However, the benefit with such stance is that this type of research makes possible to unpack the black box of IT details properly. Furthermore, they recommend an ethical framework to be agreed upon at the beginning of a joint AR and DSR project, due to the untried nature of the technology.

To overcome the critiques of AR’s inability to generalize results Iivari and Venable (2009) propose an instantiation of a class of problem being generalized into a higher class of problem, and to generate generalized outcome, researchers should follow the suggested principles in their ADR method. To address the DR benefits they emphasize the IT artifact in center of the study, in line with Orlikowski and Iacono (2001, p. 130) request to “increase attention and explicit consideration of IT artifacts in all (IS) studies.” To be noted is that this method requires design contributions as a separation to other forms of action research within social sciences (Mathiassen, 2008).

Given the debate of AR, DR and ADR in various combination, in which research traditions overlap, or merge into various applicable methodologies intertwining design of technology and practice research, can be confusing. However, when studying complex empirical contexts of intertwined technology use, design and learning, such as the study aim of this thesis, ADR allow a rich view, and also to intervene and to get close to the study subjects and technology artifacts. The researcher need to have awareness of the choices that the different approaches have during research. Either putting technology or design in the center, or the subjects using and thereby informing technology, as the focus of the study center. Either locus of focus will give different results on how collect data and how to conduct analysis. I argue that the intertwining of theory and practice, meaning,
both the theory-ingrained and design-ingrained principles, including a thorough
and a step-wise in-built method such as the ADR approach designed by Sein et
al. (2011), is applicable in combination with AR on an overall program level.

5.8.2 Designing competence activities

Study III (Hattinger & Eriksson, 2015) summarize learning activities in the three
initial courses and activities of the company meetings during 2014-2015, see
Appendix C. Sein et al.’s (2011) ADR method was used within this study and
addresses a problem situation encountered in a specific organizational setting by
two contrasting challenges: 1) addressing a problem situation by intervening and
evaluation, and 2) constructing and evaluating an IT artifact that addresses the
type of problems typified by the encountered situation. The project activities and
studies applied to the four stages of the ADR method are here presented
chronologically (Sein, et al., 2011). The method consists of four stages; 1) problem
formulation; 2) building, intervention and evaluation - BIE; 3) reflection and
learning, and 4) formalization of learning.

The first problem formulation stage, concerned the competence mapping stage
presented in the beginning of chapter 5. The second step BIE, is the core that
construct and evaluate the IT artifact into a realized design. Theoretical
foundations and intent of the researchers and the influence of users and ongoing
use in context is intervening in the design. This stage also clarifies the locus of
innovation, which may come from the artifact design or the organizational
intervention. This difference represents the key choice influencing the research
design followed by the ADR team (project group).

Building Intervention and Evaluation – BIE of the course design

After the problem formulation stage of competence mapping reported in Study
I, the second stage, BIE reached for design principles of a generative course
model. The first pilot course in Industrial Automation I, of 2.0 ECTS, initiated in
spring 2014, was implemented with ten industry practitioners and lasted for ten
weeks. Activities in relation to this course were; design and tests of new LMS
platform and video production of course material. The evaluation phase had
implications for the design of the next two courses Negotiation skills I, and
Machining I. Two design cycles of the three courses starting with the teachers’
studies design challenges is illustrated in Figure 9.
Figure 9. Two cyclical iterations in the course design process including design principles

The three courses from spring 2014 to January 2015 and related project activities comprised 36 participants in the three courses and about 80 members (project group and company stakeholders). The ADR process and the results were published in paper III (Hattinger & Eriksson, 2015).

Reflection and Learning

This stage summarized lessons learned for the three courses, after two design cycles. Design principles for upcoming courses were mainly set. This stage focused on evaluation of the applied Design Principles (version one) and was evaluated from a course participant perspective. These principles were presented and discussed at a company seminar in February 2015. DP version 2 were suggested and negotiated within the project group.

Formalization of Learning

This stage concluded the test period and was ongoing during spring 2015. A formalized process for course design including course administration from lessons learned in former cycles was built into DP version 2 and resulted in a future defined e-WIL course design that was guiding further courses.
5.8.3 Course evaluation model in practice

A research approach for data collection and analysis for each of the implemented courses as part of the BIE, aimed at collecting data of practitioners e-learning maturity, former knowledge level and learning experiences. The model included these steps:

1) initial questionnaire (course day one) to all participants;

2) observations and evaluation of learning content, files and video material including selected LMS (mainly DisCo),

3) observations within web-conference meetings (in Adobe Connect and Skype for business), recording discussions, negotiations and lectures between teachers and participants, and

4) a concluding focus group session (end of the last course day) with a semi-structured interview guide, guided the participants view on knowledge content, IT tools, digital instructions, video material, digital communication, WIL projects (cases), examinations and virtual labs, see Appendix D. This stage is further described in Study IV.

The three first steps included documented and recorded data, besides the main data collection in the focus group sessions. The initial questionnaires was collected from about 200 participants. These are not coded statistically. Questions regarded practitioners’ education level, and year of engineering practice work, level of former e-learning knowledge, social media experience, view on work-integrated learning, and expectations on the forthcoming course content related to their work-practice and professional formal function. I only read these questionnaires. Generally, it showed that the social media and e-learning experiences were low, the academic level were low, but the expectations on forthcoming course was high. The web-conferencing meetings were also valuable due to novel experiences both by the research teachers and by the practitioners. Due to time limitations these audio-recorded sessions are not transcribed.

Table 3 shows the analyzed courses and related follow up focus group sessions. Also number of different companies from various industry sectors each semester is included. A total of 18 courses with about 200 industry practitioners in 15 different companies participated from spring 2014 until spring 2016. Between four to 13 practitioners, and one to five companies participated in each session. About 20 industry practitioners, joined three courses or more, i.e., they participated in more than one course. The participants mainly came from two large companies, one in the aerospace sector and the other an automotive company. The total of 18 courses includes six different course types of 2.5 ECTS, which conclude 15 ECTS.
The table shows the 12 courses analyzed within this thesis. The courses FEM I (running two times), FEM II, Matlab I and Matlab II (five courses) were not included due to too few participants taking part in focus group sessions. According to Bryman (2012, p. 501) there should be at least four participants in a focus group to make it a meaningful data unit. Industrial Automation I, in spring 2016 was also excluded because a fourth follow up session was not needed due to saturation of evaluation. In sum, six courses were not analyzed. In addition, three research teachers took part in four sessions, i.e., Negotiation skills (same researcher participated the two first times), Machining I, and Machine security in Robotics. About 95 percent of starting participants were examined and completed the courses. This is an interesting low drop-out rate of participants. The drop-outs occurring, occurred mostly on the course day one, and was due to work- and/or private time issues. Only within the FEM and Matlab courses examination rates were about 50 percent.

5.8.4 Results

The overall question during this study was how to design e-learning courses that support competence development and work-integrated learning. The emphasis was empirical-methodological driven emphasizing challenges concerning the intertwining of learning-technology. The BIE-activities were driven by the design
challenges and intertwined with the ADR design activities and was reflected back and integrated into the practice with implications for further design. In Figure 10, the left square show the BIE-stages of the practical course design activities implemented by the research teachers supported by the project group and IT technicians and media designers. The square on the right, research activities, shows the research design model, with four activities, interacting with the practical actions. I was responsible for developing and running all the research activities with support from supervisors and research teachers.

<table>
<thead>
<tr>
<th>Course design activities</th>
<th>Research activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study guide</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Digitize engineering material and problem solving tasks, video instructions, lectures etc</td>
<td>Observations and evaluation in Web-conferences and in LMS</td>
</tr>
<tr>
<td>Case methodology</td>
<td>Focus group sessions</td>
</tr>
<tr>
<td>Examination</td>
<td>Follow-up sessions to project group</td>
</tr>
</tbody>
</table>

2. Building, Intervention and Evaluation - BIE

Iterative design and implementation
Learn to use e-learning
Formative and summative evaluation

Figure 10. BIE including course design activities and research activities

The possibilities with a researcher intervening before and during the course supported the researchers’ design and implementation work, especially regarding a more objective evaluation of the reflections of the course experiences. Knowledge from the focus group sessions conducted in Study IV, was evaluated and feedback was given back in short reports to both project group and individual teachers. This summarized knowledge was accordingly discussed orally and hence thereby created valuable resources for reflection and learning. This continual activity was a formative intervention where the practitioners raised their experiences concerning both lessons learned, contradictory knowledge views about both e-learning design, learning content, technical and practical issues of conducting cases etc. In Study III, results from these three initial courses included two design cycles derived into design principles version 2, DP 2 (Hattinger & Eriksson, 2015).
A general ProdEX course of 2.5 ECTS (European Credits) is designed by:

**Schedule:** 5-6 weeks with maximum 2-4 lecture days at PTC (including final examination day), and additional web-conferences between the lectures on-line seminars, lab- and assignment presentations etc.)

**Course material and tasks:** instructional videos, authentic industry cases mixed with academic assignments, virtual and physical labs, written instructions, Power points, books, articles. Materials published on the university LMS (learning management system) DisCo.

**Communication and interactions** through DisCo, chat and web-conferencing.

**Examination:** through home assignments and case-based labs (both digital and physical). No written (traditional) final exams.

**Pedagogical philosophy,** pedagogical strategies that activate participants making and contributing, by bringing in their authentic and proven experiences closely related to personal skills and the companies’ production processes. This is labelled work-integrated learning as pedagogical philosophy.

The general design principle 2 resulted in instantiations of the three courses with variously practical results. This meant that the implementation of the factual technology, the digitalization of course material and the case design of the practical cases and tasks were applied variously. Some courses were more or less digitalized and interactive. Industrial automation (AU), machining (Ma) and negotiation skills (Neg-skills) are three knowledge subject fields of engineering knowledge and hence include different research teacher groups. The applied design was guided by the research teachers’ design plans, meaning their individual identity, e-learning conceptions and e-learning skills when finalizing the design. Consequently, these three first applied variants also set the agenda for further courses, which in turn asked for continuous BIE of repeated courses.

AU includes the most digitalized video material and virtual labs. Neg-skills uses a pedagogy with the most interactivity and group work, including and synchronous case-role-play in web-conferencing. The Machining course uses real cases at the home-factory, but did not implement any video-material, see appendix F for a full applied course description. Even if the early course cycles solved some problematic issues in the design and implementation stages, there was still challenges to be resolved.

**Summarized challenges that needs to be addressed in the e-WIL courses forthcoming:**
## RESEARCH DESIGN AND FINDINGS

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Validation</td>
<td>95 percent of the participants must be validated and the university need to find new rules and routines for enrolling participants. It is time-consuming for the university which have consequences for recruiting new participants.</td>
</tr>
<tr>
<td>Interaction in LMS</td>
<td>Participants stressed the lack of a common digital discussion forum assigned by the university.</td>
</tr>
<tr>
<td>Web-conferencing</td>
<td>Some companies have high security rules and do not allow cameras. Sound problems and drop-outs were still on-going in Adobe Connect. Low user-maturity of web-conferencing, including both researchers’ and practitioners. However, a positive attitude towards the technology and a high failure tolerance of e-learning problems.</td>
</tr>
<tr>
<td>Digitized material</td>
<td>Only the AU course contained new video material and virtual labs. IT system, e.g. Camtasia or alike, for producing and structuring digital learning material, such as instructional videos, takes time to learn and require new digital skills and ICT support, both technical and pedagogical.</td>
</tr>
<tr>
<td>Company support</td>
<td>A large variation of a required management support towards practitioners interest to participate in the courses and to gathering their new learning.</td>
</tr>
</tbody>
</table>

Study III, was conducted midway through the thesis. It specifically targeted the essentials of the competence activities of the course design process and was influenced by the constructive company manager - project group meetings. However, I was still interested in exploring the practitioners’ perspectives on the designed and implemented course efforts, from a broader perspective, besides the three initial courses.
5.9 Study IV – Practitioners

Study IV (Hattinger, et al., manuscript) explores practitioners’ perspectives on knowledge construction through the learning activities within the courses and through the focus group sessions. Mainly their reflections, knowledge views and learning trajectory are studied in order to delineate forms and content of mutual knowledge construction. This also includes the relations between the practitioners and the research teachers. Main data source was the focus group sessions organized as formative interventions, taking part at the last course day in each course. These sessions were part of the last design phase of the Building, Intervention and Evaluation (BIE), conducted in Study III (Hattinger & Eriksson, 2015). It included the initial pilot course started in 2014 and ended with the courses in spring 2016. In total it comprised 18 courses of which 12 focus group sessions are analyzed in this study and reported in paper V (Hattinger, et al., manuscript). From a holistic perspective the study seeks to understand how practitioners contribute to the scholarly knowledge, the industry company knowledge and the end-user knowledge, see Figure 9, in section 5.8.2. Data from the focus group sessions are analyzed through the practitioners’ and the research teachers’ collaborative negotiations of production technology knowledge and e-learning design issues related to the course implementation and their performance, hence the learning activities. This study asks:

RQ: How is knowledge mutually constructed between expert research teachers and practitioners into expansive learning?

I wanted to reach an understanding of the processes between subjects (the practitioners), tools (e-learning content and technologies), and their shared objective towards an increased understanding of co-construction of knowledge. Knowledge construction concerned the practitioner’s mutual discussions of how they experienced advanced educational tasks and cases related to their professional functions including their use and acceptance of e-learning technologies. Their use of technology tools, were two-folded; both production technology systems and the e-learning technologies. This study was made longitudinal, and I could follow the trajectory of knowledge development between practitioners, and practitioners and researchers related to the tool-mediated actions and the intertwined learning activities over two years.

Midways, during 2015 I was in particular inspired by the Cultural-Historical Activity Theory, CHAT, and the concept of knotworking became important to understand the negotiations among the practitioners within the learning activities. Knotworking, and specifically negotiated knotworking, can be used to understand the social processes in inter-organizational collaboration of the learning activities (Engeström, 2008; Kerosuo et al., 2015). The knot of collaborative work is not
RESEARCH DESIGN AND FINDINGS

reducible to any specific individual or organizational entity as the center of control because the *locus of initiative changes* from moment to moment within a knotworking sequence. This means that knotworking cannot be adequately analyzed by an assumed center of coordination (not a fixed object), rather the unstable *knot itself needs to be made the focus of analysis*.

Knotworking was studied within the focus group sessions that connect temporary groups of practitioners, tasks, and tools across organizational boundaries, to improve learning and knowledge development within production technology. The tying and untying of problems and suggested solutions were knotworking that took part during the course activities and hence described during the sessions. Knotworking that is negotiated in conversations and communicated, meaning they are discursive manifested, can be studied from various perspectives (industry, collaborative and university) and in different time scales. Consequently, grasping such expressed knowledge, was used to give implications for the overall e-learning design process to explore in what way and what type of knowledge that is mutually co-constructed during the learning activities.

5.9.1 Focus group sessions

The focus group method is a form of a group interview within a specific topic in which the interviewees are selected because they are known to have been involved in a particular situation and can therefore give experiences about the involvement (Bryman, 2012). This method builds on the theory of group dynamics in human interaction in familiar constellations, humans therefor tend to be more readily to talk about their experiences and provide deeper insights by interacting with each other, than a person-to-person interview probably would have led to (Stewart & Shamdasani, 2014). This method was applied to the focus group sessions, formed as interventions that creates a meaning unit, where participants' together can verbalize their meanings, knowledge views and negotiate through group interactions.

My role was to lead, moderate and guide the discussions with the background of a semi-structured interview guide. About half of the sessions took part in collaboration with one of my supervisors, and she mainly took notes and only interrupted when necessary, e.g. when clarifying a specific topic. The interview guide was directing the open-ended dialogues containing broad themes of e-learning technologies, communication, course format/modality, teacher support, examination, competence areas, work-integrated learning and future competence needs, see Appendix D. The main reason of a thematic guide was to relate the discussions around topics to guide the participants’ negotiations built on their reflections of the e-learning practice related to work experiences. I used the same interview guide in all sessions over the two years, which made me able to collect
the same type of data and to analyze occurring courses in cycles. Hence, to analyze similarities and differences between the sessions regarding the content and dialogues. To be noted is that these occasions did not replace the researcher teachers summative course assessments they perform continuously (Hassan, 2011; Pachler, et al., 2010).

The sessions were audio recorded and participants were taking part in informed consent. Each session took from one hour - one hour and 15 minutes’, recorded and verbatim transcribed into text. I conducted all transcriptions, and later on the analysis and coding. In conclusion: 12 sessions with four to 13 participants joining each session, comprising 119 participants from 15 different companies was included, see paper V (Hattinger, et al., manuscript).

5.9.2 Focus group analysis

The transcriptions and analysis was ongoing over two years and resulting in three analysis processes. Initial and first content analysis was inductive and grounded in the data material related to the overall aim to explore industry practitioners’ technology and learning activities and how they together express and negotiate in forms of co-construction of knowledge. For this matter, the content analysis approach with concepts, unit of analysis, codes, categories and themes was used (Graneheim & Lundman, 2004). The analysis focused individuals’ expression of their knowledge experiences and the ongoing collective social interaction.

In the first open coding round, texts were coded, categorized and labelled according to various functionalities, and resulted in eight categories with four-six sub-codes of each category. The function-oriented categorization were labelled e.g. learning technologies, pedagogical strategies and learning, competences and knowledge and so forth with corresponding sub-codes such as, login problems, web meeting problems, Disco and tasks, and communication and interaction, see Figure 11 coded node tree in NVivo.
Through re-reading the transcriptions over time, a second analysis with new codes proceeded. Insights, traces and new patterns were depicted concerning participants negotiations of not only e-learning technology use and course material, i.e. the tool-mediated course design, but also their contradictory views and motives for knowledge development and new learning. Practitioners’ different standpoints for competence development, the fragile university support and the various company support fostered initial tensions and contradictions which was manifested in their arguments. These issues sometimes ended up in various solutions driven by themselves ones they were brought up to discussion. Hence, in this second analysis I re-coded the transcripts into sub-codes to the themes contradictions and co-construction. This categorization was not theory-inspired, rather data-driven. In practice, this meant that both first and second analysis were inductive and delineated manifested data. The analysis focused the immediate negotiations within the sessions and how the mutual objective “to learn and build new knowledge within various engineering fields”, was manifested into potential co-construction and transformations in the workplace. Meaning to further develop their industry experiences combined with new theoretical science and problem solutions into new learning insights.

The following third analysis was theory-guided with CHAT through a formative intervention methodology (Engeström & Sannino, 2011; Engeström, et al., 2014; Sannino, et al., 2016). This method offer a particular analysis of manifestations of
Contradictions for capturing change efforts (Engeström & Sannino, 2011), and hence the analysis resulted into a new conceptual framing. Contradictions can serve as power for learning and change through their discursive manifestations and thereby become a power for expansive transformation. Contradictions are best manifested through the faces of dilemma, conflict, critical conflict and double bind (Engeström & Sannino, 2011, p. 34). Dilemmas are easier to resolve than double bind. Double binds are situations that are facing equally unacceptable alternatives in an activity system and therefore need a collective effort to resolve such situation, if possible.

During the contradiction analysis, I observed transitions from contradictory tensions into possible solutions, meaning that the tensions were resolved during the sessions, through practitioners’ ongoing negotiated knotworking. After the exhaustive contradiction analysis the analysis therefore was divided into another two analysis phases and resulted into actionable (possible) solutions, and expansive transformations. The criteria for analyzing actionable solutions are defined by the expressions that practitioners manifest through their new ideas of how to resolve a problematic situation in the workplace. Expansive transformations concern expressions of how to use and actively engage in new work practices that can be integrated in the workplace, hence in everyday practices (Hattinger, et al., manuscript). The three-phase analysis with transitional phases is forming a trajectory of learning by knotworking and hence facilitates mutual co-construction of knowledge and expertise in a continuing process.

5.9.3 Results

The data analysis of manifested contradictions and actionable solutions were categorized into A. Company objectives, B. Practitioners competence development and C. Course objectives and design, see Table 4. Relations between A and B concern intra-organizational issues, i.e. company objectives (e.g. management support) versus practitioners’ personal competence development motives for studies. Relations between B and C relates to emerging inter-organizational tensions between the industry practitioners and the university throughout the course activities and the negotiations about their experiences. The analysis of contradictions resulted in manifestations of; e-learning technology failures, late course instructions, hard case-tasks to solve, low communication response, blurry instructions, web-conferencing sound problems, low management support, time for studies versus work responsibility, etc.
Table 4. Categorization of manifested contradictions and actionable solutions

<table>
<thead>
<tr>
<th>Category A. Company Objectives</th>
<th>Category B. Practitioners Competence Development (CD)</th>
<th>Category C. Course objectives and design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company management, stressing effectiveness objectives and how they manage to support CD for their personnel to reach such objectives.</td>
<td>Practitioners’ personal motives for CD. Choosing a working career versus private life and family responsibilities. Working versus time for studies.</td>
<td>New blended e-learning course design with user-oriented e-learning technologies and learning strategies aiming to motivate learning towards the course objectives and practitioners earlier experiences.</td>
</tr>
</tbody>
</table>

A systematic re-reading of clusters of narratives and rhetorical questions of the data material within the three knowledge subjects; Industrial automation and Machine security in Robotics (IA-MS), Negotiations skills (Neg-S) and Machining and Tribology, Ma-Tri, resulted into a total of 94 contradictions. Dilemmas and double binds, related to category A and B were mainly negotiated in the initial course cycles (specifically in IA-MS) and concerned the value of academic studies versus working towards a carrier. This handled also the importance of having both practical experiences and academic expertise, meaning how to balance such requirement and what type of support the practitioners felt could be expected from the company management.

Practitioners’ experiences of the course implementation and learning content versus the course objectives (category B-C) also included research teachers’ identities and concepts of how to design and teach together with experienced practitioners and the acquired support from the university. Dilemmas and conflicts related to the course implementation were found in all three themes. These contradictions regarded technology problems with audio and voice functionality within web-conferencing (more frequent within Adobe Connect than Skype) causing communication disturbance. There was also a lack of interactivity between course occasions, and a low use of chat-functions in DisCo or in other social media-channels. Most communication between scheduled course meetings was organized by the practitioners themselves and not guided from the research teachers’. Other critical issues were the lack of practical support of real labs from the research teachers’, especially in theme Ma-Tri.
However, dilemmas and conflicts regarding the material artifacts behavior (the technology), and the course formats, did not violate the individuals’ personal inner, and therefore did not interfere personal feelings. Contradictions related to the materiality could thereby more easily progress into actionable solutions. The more troublesome contradictions rather concerned *intra-organizational tensions between manager effectiveness objectives and practitioners’ motives of participation in competence development initiatives to achieve such goals* (interface A-B). These types of contradictions did not actually reach to a specific and actionable solution. Rather, practitioners emphasized the value of taking part in the ProdEx-courses as injections for further learning and development.

The negotiated knotworking within each specific course and throughout the themes (the focus group sessions for each course) were shaped through their manifestations of contradictions. The knotworking were untying problems from various perspectives and solutions started to develop. The traditional nature of engineering problem solving was triggered (Itabashi-Campbell, et al., 2011) and a fluent process with loose boundaries between the phases of manifestations of dilemmas, conflicts, critical conflicts and double binds was pushing towards actionable possible solutions. This was made possible once the negotiated knotworking was evolving within the formative sessions, and conducted outside the particular course situation, making reflection and knowledge sharing possible. When practitioners mutually reflected and confronted each other ideas, experiences, and perspectives of the course-work within one specific session, new ideas of change started to appear. Hence, transitions from manifested contradictions into actionable solutions, were in many cases developed by the practitioners themselves. Practitioners’ tensions were eased by bringing problems aloud, discussing annoying failures, and communicating and sharing experiences with others.

New *actionable solutions* started to mutually be co-constructed out of manifested contradictions, which was possible through the negotiated knotworking. Many excerpts in the study show examples of actionable solutions such as; practitioners reached a better understanding of both theoretical and practical knowledge, and were modeling a new solution to the problematic situation of time for studies and academic degrees. Other practical solutions concerned how to overcome troublesome course formats and modalities, hard examination tasks and case-based problems. Also new learning insights was brought forward as creative feedback.

The second transition of the sessions, was developing into forms of *expansive transformations*, especially within the course sessions, IA II, and Tribology, probably because these courses are more content thicker. In the IA II course, all participants had brought their own automation tools to perform labs on, reaching
way beyond course objectives. New learning and networking between the companies was initiated. Practitioners learning of new ways to perform problem solving, and analysis (Tribology) will increase the use of already invested machines at the home company. In the Neg-S, awareness of cultural differences (soft skills) were brought up as a key knowledge to make future new businesses.

The learning by negotiated knotworking through the phases of manifestation of contradictions, actionable (possible) solutions into expansive transformations, developed into an incredible valuable trajectory for exploring mutual co-construction of knowledge and learning for the whole projects concern.

The deep analysis of manifestations of contradictions, depicted the specific variations and problematic issues at the kernel of the project. One common assumption in blended e-learning initiatives in inter-organizational efforts are that the learning technologies and the digitalized learning material are the most troublesome obstacle for success. However, this study show that this was not the case. The still most critical issue is to make industry organization mature enough to understand that they need to support, give time, and creating career paths for their employees, as one important trigger for future expansive workplace transformation. Contradictions around course formats and learning technologies were mostly regulated on a lower system level, that is, the industry practitioners independently made solutions on such practical problems, and therefore these dilemmas and conflicts were more easily to overcome.

This study has shown that transformations of individual’s knowledge trough socio-cultural learning activities can be made collective through negotiated knotworking from manifestations of contradictions into transformations. When experienced insights are contradicted and negotiated with colleagues, in a network of other industry partners and by support of a university, new knowledge construction can start to emerge. The focus group sessions, supporting the sideways trajectory of learning by knotworking, therefore turned out to be a valuable resource for exploring learning and knowledge development.

5.10 Study V – Managers II

This study was conducted during autumn 2015 and was focusing the industry management’s perspectives, meaning their conceptions and efforts regarding competence work towards knowledge transformation and work-integrated learning. Given the results from the focus group study there was a need to further explore the diversity of the companies’ management actions to support their employees’ participation and knowledge transformation in ProdEx courses and also their own (management) efforts around competence initiatives. The research question was:
RQ: How is industry management supporting practitioners’ new knowledge from e-learning interventions into expansive transformation of the workplace?

We set up the interview study as both a follow up on Study I and also invited new companies to participate. Among those who participated in Study I, there had been a drop out during 2013-2015 and we wanted to understand the lack of participation in the project company meetings, and sometimes low course participation. Besides, at the time for the study the project was searching for a continuation of the project (ProdEx II project until 2019), and we were eager to establish a closer relationship with “old” industry partners and also broaden the joint collaboration with new industry companies.

Hence, the general interest concerned managers’ conceptions on internal and external competence work, for both “old” and “new” companies. For the “old” ones the interest was to capture reasons for the various engagement in the project up to now, why some initial companies only participated in occasional meetings and did not have employees in the courses. For the new companies, the interest was to explore learning conditions and their view of forthcoming membership to become strong partners in the project. The more specific interest of this study was to capture engaged companies ideas and experiences of activities and models for work-integrated collaborations and workplace transformation.

5.10.1 Interviews

A project colleague and I conducted 14 interviews with 14 companies of which eight had already participated in Study 1, and six companies were new. Between two to five senior managers took part in each interview session that lasted about one to one to two hours in duration. We asked for top management of production technology and HR function similar to Study I. Hence, the companies picked out their own responsible personnel applicable to our request of the interview meeting.

I was the main interviewer, and my colleague took notes during the sessions. I was keen to not let the interviews turn into a recruitment and selling meeting for the upcoming project application and therefore I started with the interviews first. After finishing the audio recorded interview sessions, my colleague described the continuation of the project. During the interviews she supported and filled in with answers, specifically related to knowledge within the engineering field. For the new companies I used a slightly revised version of the interview guide from Study I. For the “old ones” I used a new version containing additional questions regarding work-integrated learning and transformation, see appendix E. New questions were phrased as;
How do you think the project activities have supported your company’s competence work? What new activities and new knowledge subjects would you like to co-produce with us? What knowledge and which learning have been used or is useful after your employees participated? Do you have models for follow-up, and/or knowledge sharing after your employees participated? How do you view knowledge and work transformations for the future? Etc.

The transcriptions of the interviews is not fully conducted at the time this thesis is written. However, I have performed a data analysis of the notes from the interviews, comparing answers and knowledge views to find patterns and comparisons between the companies. I have also listened through the audio records. Through this light analysis I found three main themes that are of special interest in relation to the research question, these are; internal competence plans, project participation and collaboration with HE, and co-production and company support towards transformations.

5.10.2 Results

Two of the 14 companies, are large industry consultant companies (businesses in the whole Sweden), with an overall high education level and no own manufacturing. Their knowledge needs relates to more advanced courses such as Matlab and FEM (Finite Element Method). Two other two companies are manufacturing of products in which components of the thermoplastic part is included. The latter two companies were having trouble to take a broader advantage of the e-learning initiative due the course content focused on other types of materials (i.e. various types of steels, aluminum and nickel-based super alloys) and related production processes. The following results are categorized due to the three themes that relates to the research question of industry managements support of practitioners’ new knowledge from e-learning interventions into expansive transformation of the workplace.

Internal competence plans

One manager describes that they historically worked with gap analysis, but experienced that it is a time-consuming work. Today they work more with personal competence plans. They perform mostly internal and specialized educational efforts. When buying a new machine, the supplier support an initial short education, operating the specific equipment.

The six new companies had about the same e-learning readiness as in Study I. This meant that they have structured routines and follow-ups for internal competence work, however to consider academic courses for competence development of employees was in many cases a new thought.
**Project participation and collaboration with higher education (HE)**

The companies’ stress that their participation must be related to their own competence requirement. Some companies meant their low participation was because they fear and lack former and enough former competences among their employees. They were not fully aware of the opportunities to validate earlier work experiences for the course application. Other “old” companies did not participate in courses, due to lack of time, even if the courses were for free and flexible in space and time. General collaboration with universities and other external research institutes are most common among the consultant companies and within the large aerospace company. The manufacturing companies with mainly operators and low level of service clerks mostly collaborate with specialized high school educations and other vocational schools, and not particularly with HE.

In alignment with Study I, this study show that even if they are literally not collaborating with HE due to various reasons, they welcome a joint continuation in the project (old companies). All of the six new companies wanted to actively join in the forthcoming initiative. They saw it as great opportunity to become co-partners and being able to demand their own competence content and flexible forms for running the courses, meaning to have impact on the e-learning design process in forms of mutual co-construction.

**Co-production and company support towards transformations**

We asked questions of the management’s ideas and activities of competence feedback methods from employees’ participation in the e-learning courses, see Appendix E. The following list, show examples of activities they perform:

- Production technicians have a meeting where they draw from others what they learned. It is important that what you learned can be used directly [international diversified manufacturer of motion and control technologies].
- Should be employee-driven, and not managerial. Here our managers are often technical experts, however most of them men and only 23 percent women (in the control lab) which we strive to change [international manufacturer in petrochemicals].
- There are documents and routines to be used after courses and we emphasize that all courses we participate in are directly related to our competence development requirement [local family business, assembly manufacturer in aerospace, gas turbines and parts].
- We have limited follow-up on completed courses. Currently discussing how to go further with the quality department on the effect of certificate courses [international manufacturer powertrain, chassis and interior, including own R&D].
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- Our company requires that everyone after a course should do at least one thing differently. They also have an assistant next to the production manager and works with documented work procedures [local manufacturer in precision engineered components for automotive and aerospace sectors].

- Creating own groups knowing communicating what they participated in. Regular development talks. Mainly checking what type of courses that are internally available. Higher credits are nothing missing, however we have a co-op student [international manufacturer in turbomachines].

- No highly structured working methods, however there is a routine for reporting courses [international manufacturer in truck equipment, couplings].

- No structured model to take care of acquired knowledge however uses persons who work well as a mentors. Pair persons so they can learn from each other and there is a statement of strategy that older people should learn younger. Would like to see more skills transfer activities, breakfast seminars and small events [consultant company within aerospace and automotive sector].

- When someone has been on a course, you should inform the other team members of a short variant. We have our own small library [the other consultant company within aerospace and automotive sector].

There is a broad variation on the companies’ efforts of planning for transformative actions and to find method for qualitative and effective knowledge transformation after organized competence initiatives. Only two-three companies (both old and new ones) presented a routinized system or methods/models for following up on such participation and how to further spread their knowledge learnt. The efforts tends to be short-term and not strategic and rather directly related to knowledge needs here and now. Strengths for knowledge transfer are low, and person-dependent. These results align with the results in Study IV, when practitioners discuss dilemmas of working versus studying. Hence, support to develop strategic models for knowledge development towards workplace transformations, meaning how work integrated with new learning can impose new transformative actions through formalized learning activities, therefore need to be further developed.

Ideas on how to co-construct knowledge before, during and after the e-learning design, were exemplified in the interview data. When discussing knowledge learnt and possible methods for knowledge transfer after formalized initiatives, they saw a great interest in co-participation in the courses through own learning instructors. Other creative ideas of co-construction discussed were ways of sharing learning material from the factory plant and by conducting cases in-house throughout course implementations. Hence, the interview sessions in themselves turned out to be a new starting point engaging both the “old” and the “new” companies.
5.11 Summarized Results

This chapter gives a short summary of the results from the five studies.

Study I – Managers I

The aim was to explore the learning conditions in the manufacturing companies and the organizations abilities to gain new knowledge to sustain a competitive and innovative advantage.

RQ: What are the learning conditions and the e-learning readiness in manufacturing companies that will affect the design of work-integrated e-learning?

The study resulted in four new constructs; Awareness, e-learning maturity, dynamic capability, and co-creativity. The e-learning readiness comprised the capabilities that organizations’ need in order to capitalize on e-learning initiatives. Theories of absorptive capacity (Cohen & Levinthal, 1990), and e-learning readiness (Schreurs & Al-Huneidi, 2012) was applied. In order to have strong e-learning readiness within the whole organization, all four of the constructs should be on high level. Generally, the 15 companies were in the middle of a scale from immature to highly mature of e-learning readiness. All companies have high awareness of internal competence work, but most of them need to work more on their dynamic and co-creative capacities, meaning actively co-produce knowledge with external partners. This Study is reported in paper II (Hattinger, et al., 2014a), in paper I (Hattinger, et al., 2013) and (Hattinger, et al., 2014b).

Study II - Research Teachers

The aim was to explore research teachers’ design plans of digital e-learning courses, meaning their perceived design challenges and how they identified and framed earlier experiences of e-learning and/or distance education, or maybe a lack of experiences. The study also included the researchers’ ideas on how to incorporate practitioners’ knowledge as contributors in the learning sessions.

RQ: How do expert research teachers approach a new e-learning situation with experienced engineering practitioners in the manufacturing industry?

Results show that researchers’ identity is challenged when designing for e-WIL. By their boundary crossing perceptions (Akkerman & Bakker, 2011a), meaning their ability to identify different practices knowledge needs and diverse motives for learning, their insight into design and plans for coordination of e-learning, meaning both engineering content design and how to design case tasks including practitioners’ co-constructive participation. Four of the five researchers had never
before conducted e-learning courses, however showed maturity in implementation of the first initial courses. This Study is mainly reported in paper III (Hattinger & Spante, 2017) and in the conference paper (Hattinger, et al., 2014c).

**Study III – Course design**

The aim was to analyze the ADR-process and design principles drawing on three initial courses. The study was conducted about half-time into the project in 2015.

RQ: _How can e-learning courses be designed to support competence development and work-integrated learning?_

In this study the three initial courses were evaluated through the design cycles of Building, Intervention and Evaluation, BIE (Sein et al., 2011), as an integrated part of the overall action research activities, see Appendix C. The design cycles was also iterated through the reflection on learning (follow up sessions in Focus groups) and formalization of learning into new course design, meaning a de-constructed artifact. Hence, results were generated through derived design principles of the e-WIL courses through the applied ADR-method (Sein, et al., 2011). A model that hereafter became the “role model” for upcoming courses regarding the course modality and content design, see Study IV (Hattinger & Eriksson, 2015).

**Study IV - Practitioners**

The aim was to explore employee-driven knowledge development on micro-level through an activity theoretical lens within e-learning production technology activities. We examined industry practitioners and university research teachers’ joint negotiated knotworking (Engeström, 2008), and mutual construction of knowledge within formal e-learning courses targeting industry knowledge needs for a competitive manufacturing. Knowledge discussions in inter-organizational e-learning practices tend to be temporal, problem oriented, and possibly actionable.

RQ: _How is knowledge mutually constructed between expert research teachers and practitioners into expansive learning?_

This study analyze professionals’ negotiations viewed as both tensions and power for change through their manifestation of contradictions, suggested actionable possible solutions and as potentials for future expansive transformations integrated in the workplace. Results show that negotiated knotworking stimulated a sideways learning trajectory and was facilitating forms and content for co-
construction of knowledge. This Study is reported in paper V (Hattinger, et al., manuscript).

Study V – Managers II

The aim was to explore industry managers’ perspectives and conceptions regarding competence work towards knowledge transformation and work-integrated learning. This included how to manage and further support practitioners’ new knowledge after an effective competence initiative.

RQ: How is industry management supporting practitioners’ new knowledge from e-learning interventions into expansive transformation of the workplace?

Comprised results show that of the 14 companies only two-three companies have routines, ideas, methods, and models for supporting practitioners’ transformative actions after formal competence initiatives. All of the companies were interested to learn more and develop actions for stimulating knowledge transformation integrated in the workplace for future expansive learning. Co-construction with higher education was further discussed as a mutual interest before, during and after implementation of e-learning courses.
6 Analysis and Discussion

This chapter analyzes and discusses the overall results of the thesis in four sub-sections.

This thesis was initiated by two dominant challenges and on-going societal changes. One major change is the manufacturing industry emergent need of high-qualified engineers and practitioners due to the increased digitalization, automation and robotization that impact the engineering work practices. As such, new competences, new professional engineering skills and expert knowledge in production technology emerge. Another change is the digitalization of education as a promising affair, however challenging for the university that needs to open up to external collaboration and to meet needs of blended and digitized education. Such challenges stresses the university into readiness of handling new learning strategies and to be able to design work-integrated learning situations, that will meet new types of industry expert knowledge needs through target-oriented and blended e-learning education. Given these pressures on both the industry and the university organization, a new type of collaborative education was developed. The ProdEx course concept was developed as a joint collaborative competence project between industry and university to meet such changes. This thesis has studied such initiative from four perspectives, the industry managers, the practitioners, the research teachers, and also on the specific course unit.

The overall thesis question was:

How are production technology knowledge mutually constructed among multiple actors in a joint e-learning design process between industry and university?

Initial research question in Study I concerned the industry conditions and readiness for work-integrated e-learning. Then I asked about research teachers concepts for approaching a new e-learning situation with experienced practitioners, in Study II. Study III, conducted in 2015, asked how e-learning courses can be designed to support competence development. In Study IV, the question was inspired by activity theory, and asked how knowledge mutually is constructed among research teachers and practitioners into expansive learning. The final question in Study V targeted how industry managers’ are supporting practitioners’ new knowledge gained from e-learning interventions into expansive transformations that can be integrated in the workplace. The research interest in Study I-III, was mainly driven by e-learning design, and applied a socio-cultural theoretical perspective. About halftime into the research in 2015, activity theory became the overarching applied theory for Study IV, V and for understanding results of the holistic project. The thesis focus
on mutual construction of learning activities by using three main concepts; e-learning activities, knotworking and co-construction. These concepts embrace the knowledge field production technology, the learning design knowledge and the intertwining process of teaching and learning, throughout a design process of e-learning courses in the context of the longitudinal ProdEx project. Work-integrated learning, has been both a philosophy and a support for developing inter-organizational collaborations and for designing courses. As such WIL embraces the whole thesis approach.

The following analysis and discussion is structured as follows:

**In section 6.1**, summarized results are analyzed from a holistic perspective of the whole thesis during the four and half year trajectory (Jan 2013-Jun 2016) through a cultural-historical activity theoretical approach.

**In section 6.2**, negotiated knotworking and co-construction of knowledge are discussed from the industry perspective, the university perspective and the collaborative perspective.

**In section 6.3**, forms and content of co-construction of knowledge related to results are explicated. A model for the overall e-learning educational project is illustrated as a zone of proximal development for expansive learning.

**In section 6.4**, co-constructing expertise and work-integrated transformations are presented as overall thesis results.

### 6.1 Challenges in an e-Learning Practice

The centre of the five studies was learning and knowledge creation activities, including the process of performing actions, constructing, shaping and negotiating mutual object-oriented activities in forms of knotworking and in response to tool-mediated actions (Engeström, 2008; 2015). This thesis has not specifically tried to identify individuals certain skills or competences as a separation from work, nor defined attributes of work tasks (Sandberg & Tsoukas, 2011), rather the studies have deviated multiple actors’ perspectives and goal-oriented actions towards meaningful objects of activities applied to cultural-historical activity theory (Engeström, 2001; 2015). CHAT is historically linked to Vygotsky (1978), who attempted to describe learning and development as mediated processes, meaning that the individual could no longer be understood without his/her use or production of artifacts. Today CHAT both theorizes and provides methodological tools for investigating processes by which social, cultural, and historical factors shape human functioning. Engeström and colleagues (Engeström, 2015; Engeström & Sannino, 2011), emphasize the analysis of the activity system (the industry-university organizations) concerning
contradictions and tensions as engines for change and therefore stresses the importance of developing the collective object of activity. In the following, results from the five studies together are analyzed and discussed through a CHAT-perspective related to actions, activities, knotworking and co-construction (Engeström, 2001; 2008; 2015).

**Challenge I: Matching industry competence needs with university knowledge fields**

In Study I, the initial companies’ ability and awareness to define expert knowledge and competences varied and earlier collaboration with higher education or research institutes were scarce (Hattinger, et al., 2014a). This challenge was made visible during the industry-university company meetings when industry managers’ and project group participants (including the research teachers’) negotiated knowledge needs on long-term basis. Actions were turned into goal-oriented activities with a long-term continuation when there was a match of related knowledge subjects (or domains of knowledge subjects) between the research teacher’s particular subject knowledge, and the managers abilities to describe their knowledge needs related production processes, systems and related manufacturing goods and materials. This was defined as *competence mapping* of knowledge needs which became a shared object of activity, continuously negotiated during the project, and mainly by inter-organizational activities between the stakeholders (Hattinger & Eriksson, 2015). Negotiated knotworking in the company meetings, was explicated as a hard work, especially when and how to appoint a certain knowledge subject that could match more than one company’s knowledge needs. Level of depth and direction of learning material, available teachers and other instructors (research engineers), and time to match competence needs, was, and is, an ongoing challenge to constantly work with.

This initial phase, in the expansive learning cycle, in the thesis analysis could according to Engeström (2008, p. 132) be defined as actions of *questioning* (step 1) in which both stakeholders needed to further negotiate and expand towards shared motives in joint collaboration, to grant a continuation and further existence of the project. The management’s acceptance of the project was a boundary crossing activity (Akkerman & Bakker, 2011a) which was supported by the joint company meetings, in order to engage the managements’ insight into aligning their practitioners to join the courses.
Challenge II: Combining practice-related experiences with theoretical knowledge

Another continuing problem turn was for the university to find enough active engaging companies and management members, and for the companies, to receive ready designed targeting courses from the university in time. Lack of time to define competence needs to make course design plans until implementation stressed the university project group and the research teachers, described in Study II (Hattinger et al., 2014c; Hattinger & Spante, 2017) Given this problem, the university started to limit, and target specific knowledge subjects offered as courses for speeding up the design. Another obstacle in the design process was the dual aim of both digitizing relevant engineering content and to find the right level of knowledge content. The university tradition of course design is built on declarative and general knowledge in strict course syllabus, meanwhile most companies requested procedural knowledge to be applicable and ready to set to use as soon as possible (Corbett & Anderson, 1994). This was still the situation in Study V, especially within the new company partners. Hence, designing courses on “right” levels created clashes between industry and university cultures about what knowledge is most important. Hence, such difference may hinder the possibilities to develop a mutual object of activity.

In Study II (Hattinger & Spante, 2017) and Study III (Hattinger & Eriksson, 2015), the university was struggling with no former models for designing engineering courses in short blended e-learning modules combined with the research teachers with novel, and low former experiences of designing and implementing e-learning course target industry knowledge needs. These issues were negotiated with the industry companies during company meetings. Furthermore, industry companies often lack insight into the university traditions with pedagogical and technical ways of educational practice. However, through the mutual collaborative activities, meaning the negotiated knotworking, knots were untied between the university and the companies, when realizing that their knowledge needs in subjects they regularly purchase by consultants, could be offered in co-construction with the university expertise. Also, tensions of how to blend the courses were overcome. The three designed courses in industrial automation, negotiation skills for businesses and machining (basic level) showed to be good initial examples, see Study III (Hattinger & Eriksson, 2015).

Challenges described, are actions of analyzing (step 2) the situations and modeling (step 3) the new situation in iterative cycles (Engeström, 2008). Challenges between industry and university of defining knowledge levels and content when planning for new courses, expanded during the research. Hence, this was a result of transitional processes from actions currently performed by individuals to a new
collective activity. A transcending from the socio-spatial short-lived actions into a longer perspective of mutual commitment (Engeström, 1999).

**Challenge III: Contradictions as power for modeling new courses**

During the three first courses in Study III (Hattinger & Eriksson, 2015) and in Study IV (Hattinger et al., manuscript), the practitioners became actively engaged in the course design through their participation and evaluation in the focus group sessions. IT challenges regarded use of e-learning technologies (learning management systems and web-conferencing), and e-learning content (videos, digital instructions, virtual labs). A number of IT tools were tested for various purposes where the high IT security of some companies needed to be addressed. To incorporate and strengthening the practitioners as part of the mutual knowledge construction within the courses, three different case design models were developed that variously aimed to activate co-construction of knowledge as situated learning (Lave & Wenger, 1991).

1) **Virtual digital case:** A pre-designed digital lab on the computer, aiming for learning PLC programming at an individual level. It included PLC logics, and practitioners and researchers met in Skype-conferencing discussing various questions and solutions. The learning strategy stimulated a high tech e-learning environment, but with low collaboration with peers.

2) **Online collaborative negotiations:** A formalized role-play case with prepared instructions and then performed in group of six collaborators and assigned with various roles. The session is conducted in a three hour web-conference meeting (Adobe Connect). The learning strategy stimulated online web-conferencing and high interactive collaboration.

3) **Real workplace case:** A turning and milling case, performed at the home company. Written and oral instructions from the professor. The performance meant to be able to breaking the daily manufacturing processes at the home factory, to be able to do the lab. However, even if problems occurred to perform the lab, the task showed results that were deviating far from traditional campus solutions and new innovative solutions occurred. The learning strategy stimulated low e-learning, but high work-integrated learning and expansion.

The various case methods within the courses, aimed to bring in practitioners experiences and practice-based procedural knowledge interrelated with theory and problem-based learning. They were designed to activate practitioners’ to collaborate in a formal learning situation by stimulating them to share experiences with each other. The knowledge sharing was a type of knotworking designed by the research teachers to stimulate their ideas and experience based knowledge, by triggering them to contribute with own experiences and actionable possible solutions. The cases and its performances were negotiated in Study IV (Hattinger, et al., manuscript). Tensions and gaps between course objects (curriculum) and
their own performances (personal motives and expectations), were manifested as contradictions between this intertwined situation of theory and practice. However, as shown in Study IV, when the manifestation of contradictions were negotiated in the focus group sessions, they became sources to explicate personal reflections and expectations of problem sharing (questioning manufacturing solutions) and/or clashes towards learning material, learning technologies, case methodology, course instructions and teacher interactivity. As mentioned before, the iterations of the focus group sessions after each conducted course made it possible to grasp its dynamics, potentials and limitations through both modeling the new course solution (step 3) and examining the course model (step 4) in the expansive learning cycle (Engeström, 2008).

Challenge IV: Creating course modalities applicable to workplace demands

This challenge concerned the flexibility and blend of the course design described as the course modality (course schedule, number of physical meetings, web-conferencing versus physical meetings), forms (e-learning technologies and pedagogical strategies), and the trajectory of course design and implementation over the years. The flexibility of the course design was negotiated through knotworking in both the company meetings and in the focus group sessions (Study IV). Practitioners in companies established close to the university, wanted more physical meetings, meanwhile, practitioners’ from companies more than 100 km away, suggested more on-line collaboration (Servage, 2005). In Study IV, the analysis of manifestations of contradictions, showed that in the beginning of the project (in 2014-2015), it was tough to define course modalities, learning strategies, interactivity, and communication forms integrated as part of everyday work practice. However, through negotiated knotworking of the dilemmas and conflicts, meaning the problematic contradictions negotiated in the courses and on the management level, were diminished once explicated (Kunda, 2009), and transitions into actionable possible solutions were developing (Hattinger, et al., manuscript). For instance, dilemmas such as lacking time to practicing programming labs in a real setting, were mutually solved among the practitioners, through their suggestions to increase and schedule web-conferencing sessions.

The iterations of course modalities and other design-related issues concerned actions of examining the course model (step 4) in order to implementing the new model (step 5) (Engeström, 2008), which started to be formalized during 2015-2016.

Challenge V: Establishing a company-network and implementing the courses permanently to stimulate workplace transformations

This challenge concern the formalization of the joint university-industry collaboration and establishing a solid course format (the blend) including course modalities, choices of e-learning technologies and pedagogical learning strategies. Stimulating workplace transformations were mostly discussed in Study V.
Interestingly is, that some companies are aware of support for knowledge transformations after employees finishing formalized course initiatives, however many companies lack methods. The university are also novel in the sense that they do not have defined tools or insights into companies’ different cultures to push knowledge transformation. Consequently, during 2016-2017 the university has invited managers and course participants to joint co-construction dialogues to support development of best practice and methods for expansive transformations integrated in the workplace.

Study V and the efforts recently performed show that the project are in step 6, reflecting on the process and striving towards step 7, consolidating the new practice (Engeström, 2008). However, the framework of implementing a full expansive learning cycles requires concentrated efforts and deliberate interventions, to reach for step 7, meaning to generalize the new e-learning practice in relation to the everyday work practice, both at the university and in the industry companies.

The five studies show that learning activities of production technology knowledge and e-learning design were negotiated in cycles over time among the actors in which all parties contributed to implications for further design of the new e-learning practices. There are still challenges to encounter, however the activities should be understood as negotiated knotworking of evolving contradictions for constructing and re-constructing solutions as power for change, towards facilitation of co-construction of knowledge.

### 6.2 Negotiated Knotworking towards Co-construction of Knowledge

The learning and knowledge approach throughout this thesis has been focused on activities taking place in the space between various actors and on the boundary between the industry companies and the university. The use of negotiated knotworking became a valuable concept to study different actors’ development in a new e-learning practice towards collective object of activities. Knotworking is connected to the object, not the practitioners, because the practitioners and the initiators of knots can change in co-construction work (Engeström, 2008; 2015). Knotworking poses challenges to work communities because they lack mutual standard procedures, however loosely coupled actors, such as course teams, can bring new types of thinking, theories, problem solving, and thereby initiating expansion into learning what is not yet there (Engeström, 2008; 2015). Knowledge and learning can be viewed as an intertwined learning process of academic knowledge and industry experiences on equal terms in such settings (Tynjälä, 2008).

In Study III and IV, analysis show that novel course meetings created tensions on both organisational and individual levels. The courses were not built on the
mainstream of university campus courses neither structured as effective training courses within the industry, rather they developed throughout a process of multi-professional participation within a design-process on mutual interest through shared objectives. Industry managers, practitioners and research teachers engaged through actions towards shared objective of activities in joint collaboration (Engeström, 2015). Study IV and V, was mainly driven by their manifested contradictions and shared motives in which skills and expert knowledge expanded in a process of collective object-oriented activity, towards expansive transformation (Engeström & Sannino, 2011; Sannino et al., 2016).

**Overall perspective**

In Study I, II, III and IV, intentionality and visibility among the actors were seen through the design cycles and through evaluation of the e-learning courses. Hence, managers, practitioners and researchers were studied framed by their different cultural-historical experiences and on their actions taken. This included exploring and grasping learning mechanisms at the boundary between the industry organizations’ and the university organization, see Figure 12. Furthermore, boundary crossing activities in and between their organizations and the course situation versus work practice, were positioning stakeholders identity, coordination activities and reflective practice specifically within the project contour (Akkerman & Bakker, 2011a).

![Figure 12. Boundary crossing and co-construction from three perspectives](image)

In Study II (Hattinger et al., 2017), researchers’ boundary crossing led to learning mechanisms of othering, meaning they could identify themselves both as researchers and understand practitioners’ broad practical skills and plan for learning sessions of including them as active learners. This was later made visible in Study III (Hattinger & Eriksson, 2015) and Study IV (Hattinger et al., manuscript), as processes of co-construction in practice that was shaped through manifestations of contradiction as power for change. *Co-construction was negotiated as shared meanings among the practitioners, concerning both subject specific course content and how to handle machine-oriented tasks.*
However, to give away problem-solving solutions, and negotiate different types of effective knowledge-intensive practices, showed to be challenging, see Study IV. Sometimes this was due to the consequence of the culture of engineering with classified company solutions and the “silence” of implicit knowledge among the practitioners (Kunda, 2009). I realized that it is not sufficient to only connect people with special expertise and think interaction and knowledge sharing will happen. If relational agency will occur practitioners also need relational expertise for knowledge building (Edwards, 2010), which needs to be designed as a built-in feature, fostering collaborations and discussions during the tasks in the e-learning courses. Furthermore, during building, intervention and evaluation (BIE) this was processed in the three initial courses in Study III, and in the focus group sessions in Study IV.

Industry perspective

During the focus groups in Study IV it was highlighted the constant interaction and tensions between the ‘general’, cross-situational nature of artefacts and the local, situated actions. The relationships are were also vital for understanding changes in actions of inter-professional exchanges (between industry and university) within the specific course situation and for the practitioners intra-professional situation in their respective company (Kinti, 2008). Practitioners’ manifested problems of the various support from their own management in their companies, regarding support and personal development after they finished the courses, see Study IV. Boundary crossing and negotiated knotworking were lacking in respect to intra-organizational efforts (Akkerman & Bakker, 2011a; Engeström, 2008). Learning mechanisms were not triggered internally within the company, directly after a specific learning participation.

Knowledge transformation into the workplace supported by management within the companies showed absence of effective routines to support such efforts, see Study V. A probable explanation is that most managers’ lack models for continuously support employees ones they are back from a formal competence initiative, even if the courses are designed in blended forms and support work-integrated learning. In study I (Hattinger, et al., 2014a) and furthermore in Study V, many managers confirmed a lack of effective business models supporting knowledge transformations. Managers’ available business methods and workplace routines for transformative actions, were negotiated within the project meetings seeking for support within the company network and through the university, see Study I and Study V. Some managers could describe their routines to perform knowledge transfer, and they were giving role models for others to comply with. Companies were, however, eager to collaborate with the university to learn more of how to take time, and find effective methods for knowledge transformation in forms of work-integrated learning. Managers were therefore supporting a
continuation of ProdEx as a very important effort in which networks and knowledge sharing over organizational boundaries should be included, to overcome these problems. *Managers’ ability to inter-organizational boundary crossing actions is one key activity for co-construction of knowledge in collaborative competence initiatives.*

**University perspective**

In Study II, research teachers initially were struggling to digitize engineering knowledge material. Such work requires special digital adaptations through VPN solutions, software distribution, and digitizing machine labs (Hattinger, et al., 2014c; Hattinger & Spante, 2017). Enough time, earlier experiences and former learning strategies of high qualitative e-learning models were scarce. Study II shows that the research teachers identification and coordination mechanisms stressed new learning through encountering both new technology and a new target group of experienced practitioners (Akkerman & Bakker, 2011a). Another challenging situation for the research teachers show were to encountering experienced and knowledgeable practitioners are stressing university research teachers, even if they are experts within their own knowledge subject. Even if the researchers were novel e-learning designers, they adapted quickly to a new teaching situation (Buchanan, Sainter, & Saunders, 2013; Curtis et al., 2010; Raymond et al., 2012). They had an incredible high technology failure tolerance. In addition, the engineering culture of problem solving made them become quick and analytical e-learning designers. *To be problem oriented and curious of e-learning technology [researchers and practitioners] is another key activity for co-construction of knowledge.*

The university organization were also tested when implementing courses that are temporary, not advertised through ordinary recruitment channels, or planned for economically, and do not apply traditional application merits (instead, validation of practitioners work experiences). These issues were specifically discussed during the action research activities in the project group. Consequences of such “fragile” university organization were brought up by the practitioners’ during the focus group sessions as dilemmas for working plans versus studies. However, these issues were mostly solved during 2015-2016. The e-learning technology problems addressed in Study IV, were also solved along the way. The industry practitioners seem to have a much more technology failure tolerance that could be expected. *To have insight into another organizations rules and culture, i.e. abilities for crossing organizational boundaries supports mutual collaborations. This can be considered as a “tacit” failure tolerance which benefits co-construction of knowledge.*
Collaborative perspective

Study III and IV became two important iterative building, intervention and evaluation phases (Sein, et al, 2011) and for studying social learning processes through mutual activities towards expansive learning (Engeström, 2008; 2015), and for training and grasping various forms of co-construction of expert knowledge (Jasanoff, 2004; Fenwick, 2007). Even if the learning activities were unstable, and not fully developed and robust, practitioners generally discussed how they generated new production technology knowledge by meta-cognitive reflections through mutual insights between the research teachers and the practitioners (Akkerman & Bakker, 2011a; 2011b). They argued how they during the examining cases learned new problem solving on old solutions, for instance within the industrial automation I and II courses. The labs they performed were in many cases easy for those with earlier PLC (Program Logic Control) experiences, however, the new programming taxonomy, and the new way of logical made solutions, informed the practitioners. These practitioner-oriented designed cases aimed to departure from practice to theory emphasizing active participation and sometimes with no fixed answers. However, such insecurity within a formal course, was for some practitioners frustrating but later, through negotiated knotworking, a source for active engagement and learning (Belski et al., 2016).

The real case in machining was challenging but knowledgeable and rendered a lot of contradictions of the lack of instructions in time, possibilities to perform it at the home company, and for some practitioner, weak earlier experiences. For those practitioners that completed the cutting and milling lab, reached different answers, which were frustrating for some (Hattinger, et al., manuscript). However, negotiated knotworking proceeded into a resolution and transitions towards actionable solution, and an expansive learning phase started to emerge (Engeström & Sannino, 2010). In sum, the cases became a source for negotiated knotworking, when reflecting on contradictory course situations, see Study IV.

Real cases support theory-practical intertwining of mutually learning, through co-construction.

Even if most practitioners lacked an earlier academic degree, they were able to practice advanced applied problem solving without former academic degrees in mathematics and mechanics. Especially on course level I and II, it was not required. However, that became more problematic to handle within the advanced Matlab and FEM courses. Therefore these courses were hard to recruit employees to, and also resulted in high dropouts. Also, many failed first exams even if the research teachers gave longer time and more support outside the original time schedule. Finding actionable possibility solutions, such as validating practitioners, were in this case not applicable and the best solution (Sannino & Engeström, 2017).
Another interesting and also beneficial result were the many practitioners taking part in more than three courses. About 30 practitioner, became active and was eager to become co-constructive practitioners, wanted to learn and was suggesting new course subjects etc. I established a contact with many of the practitioners more than once during the focus group sessions in Study IV. One could define them as “habituated” during their learning trajectory and important stakeholders for other newcomers. They also created a tighter relationship with the research teachers in the various research groups (automation, machining, and advanced mathematical statistics). These practitioners demonstrated a high interactivity before (e-mail), during the courses, and in negotiated knotworking during the focus group interventions. *Practitioners’ aiming for personal continuous competence development on university level creates both critical and high-qualitative performances and valuable engagement in the process of co-construction towards new knowledge development.*

### 6.3 Co-construction of Knowledge and the Zone of Proximal Development

Learning often expects to be manifested as changes in the individual (subject), that is, in the behavior and cognition of the learners. In line with the origin of CHAT, the object-oriented activities were motivated by practitioners and foremost the researchers, and analyzed as manifestations of contradictions in discourse and negotiated through knotworking (Engeström & Sannino, 2011; Sannino et al., 2016). The contradiction analysis made open discussions of troublesome engineering solutions, built on historical practices and problems were compared with new findings, resolved into actionable solutions, and as such, they brought in new types of constructive learning as an important process for co-construction of knowledge and expert development (Hattinger, et al., manuscript).

There is an important shift from understanding defined organizational goals into negotiating their meanings into shared and mutual object of collective activities in which subjects need to internalize, and then externalize their insights mutually (Engeström, 2015; Miettinen & Virkkunen, 2005). When practitioners in the courses, were using external artifacts such as mediational tools (e.g. learning technologies, and machines), they started to evaluate themselves and questioning their old practice and hence enriching them with new significant meaning. Such changes was thereby manifested in signs. Signs are used by individuals as stimuli to gain control of his or her actions and constructs a new understanding of the initial problem (Engeström et al., 2014).
In Study IV, discussions on the new course material, concerning old problems versus new solutions, illustrated signs to stimulate actions into meaningful production. The case-based approaches within the courses were loaded with signs to stimulate practitioners’ intentionality and for them to feel comfortable to bring forward, and contribute to new actionable solutions built on their historical and experience-based knowledge combined with new learning. The case-based approach in the courses therefore became a structured learning activity, that emphasized collaboration and knowledge sharing through co-construction including knowledge content and forms. This pedagogical strategy was stimulating co-construction of expert knowledge into mutual expertise. The courses became a joint collaborative adventure, and a respected activity for co-construction of expert knowledge.

The courses fostered knowledge sharing and networks activities between practitioners, and practitioners and research teachers, as the kernel of the project. Study II, aiming for course design plans, was mainly analyzed through researchers identity shifts and coordination activities (Akkerman & Bakker, 2011a). In Study IV, the analysis of practitioners’ manifestation of contradictions and negotiated knotworking were forming a trajectory of sideways learning from contradiction, resolving into actionable solutions which created cycles of possible expansive transformations integrated in practice (Engeström, 2001; 2015). The trajectory from contradictions into transformations illustrates a process of co-construction of knowledge.

Intra-organizational boundaries between managers and practitioners were analyzed in Study I, IV and V. The management motives, actions, and engagement for supporting the project and their employees’ course participation varied over time. Hence, the project and the specific courses created a glue between the managers and the participants, even if these two actors met in different constellations. The inter-organizational (industry-university) project meetings became the overall boundary crossing activities that were fostering co-construction regarding practitioner support, future competence mapping, knowledge sharing within production technology, and discussing methods for transformative actions within the workplace. The systemic stakeholder level of joint industry-university collaboration, created an important level for knowledge sharing over organizational boundaries for a long-term relationship. Sustainable and joint industry-university collaborations are important for co-construction.
Relations between negotiated knotworking and co-construction

The two interrelated concepts have guided the analysis of the holistic thesis results, i.e. negotiated knotworking and co-construction of knowledge. The analysis within the five studies and on the holistic project, explored a broad variation to further understand the e-learning practices in joint organizational collaborations. Given this, the concepts of negotiated knotworking and co-construction are interlinked, but they also differ. I argue that:

- **Knotworking** arise temporarily in immediate actions of shared objects of interest. Negotiated knotworking is short-term actions on temporarily activities.
- **Co-construction** constitutes forms over time and necessitates negotiated knotworking. The object of activity is a more sustainable process, and entails greater efforts from actors and organizations.

The two concepts are interrelated but they differ concerning the *timescales* involved and in which *direction* the object of activity is emerging. Given this, the argument follows that:

- **Knotworking** at a specific level depends on *direct uptake* in short cycles of activities. This was the situation with the short cycles of course design, building, implementation and evaluation.
- **Co-construction** concern generalization of longer cycles of activities between the industries and the university. This is facilitated through both the e-learning activities in the courses, and by the project-specific activities.

Knotworking stimulates *direct uptake* on short-term responses to changing objects of activity through tying, untying, and retying together seemingly separate threads of activity meanwhile, co-construction implicates *generalization* on longer-term systemic changes which becomes visible in various forms, content, and habits of co-construction. Studies of co-construction over time begins with individual subjects questioning the accepted practice into cycles, and steps of construction of new knowledge and practices. Co-construction can thereby be studied through a large-scale expansive learning cycle (Engeström, 2008, p. 132), see also the analysis in section 6.1.

Co-construction of knowledge perceived from the analysis of the studies and the holistic thesis results show a broad interpretation of forms, actions, activities, and objects of the concept. The following activities are conditional for co-construction over a period of time:
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- Organizing for negotiated knotworking in temporarily teams (direct uptake), in order to stimulate shared motives, and sharing knowledge and learning insights outside traditional organizational boundaries
- Decision making and engagement in new learning practices require stakeholders’ (industry-university) abilities of inter-organizational boundary crossing activities
- Industry managers facilitation of practitioners competence development trajectory, from course participation into knowledge transformation
- Actors’ (managers, practitioners, research teachers) willingness to problem-orientation and curiosity of new technology and knowledge sharing
- Universities openness to new learning strategies of theory-practical intertwining, stimulating mutual learning through innovative pedagogy, e.g. case-based and work-integrated cases and tasks.
- Process-orientation of temporarily knotworking of course development cycles over time, developing into sustainable and inter-organizational activities (generalization)

The illustrated analysis show that knotworking, and specifically negotiated knotworking (see Study IV) as part of co-construction of knowledge, is prerequisite inter-organizational collaborative activities towards new modes of expanded object of activities. In the thesis it meant to find new forms, content, and constructions for strengthening expert knowledge between theory and practice, in order to open up respective expert knowledge area for co-construction of new knowledge. This type of a new collaborative learning practice, was studied over a longitudinal period of time in small-scale ADR-cycles of courses (Study III) and furthermore through all the mutual learning activities within the whole project as a large-scale expansive cycle (see section 6.1). As such, this trajectory opened up the zone of proximal development in a joint collaborative work-integrated e-learning practice towards expansive learning, see Figure 13.
Figure 13. The zone of proximal development in the ProdEx project

Figure 13 illustrates the ProdEx Education classified as a new type of learning practice that in relation to other educational models for professional development (nr. 1-3), is designed to reach for expansive learning. Based on the analysis of the various studies in the thesis I argue that the organized courses and the inter-organizational collaboration between industry and university in the ProdEx project, encapsulate a new educational phenomenon. ProdEx courses and learning activities are constructed with forms, content and actions derived from the other three educational models shown in Figure 13, however interrelated and conducted outside traditional educational contexts and therefore generating a new type of e-learning practice aiming to add new values. The intertwining for learning concern a new context, new roles and new knowledge within the processes of knotworking and co-construction. The new collaborative context intertwine research-based practice with the engineering practice through the courses case-based learning methods, and the experimental hands-on and problem-oriented design. Integration of theory-based knowledge and experience-based knowledge and practice (Collin & Tynjälä, 2003; Feldman & Orlikowski, 2011), is performed when academic expertise and practice expertise are enforced into new learning and knowledge building relations. Practitioners and researchers roles are equally important when they exchange experiences, elaborate on problem solving and
knowledge building, i.e. when they co-construct knowledge in situated learning towards the object to expand expert knowledge and expertise as a potential for new forms of established and long-term practices.

6.4 Co-constructing Expertise and Work-Integrated Transformations

Given the discussion of the relations between knotworking and co-construction in section 6.1-6.3, I will in the following further discuss how these concepts are intertwined with expertise. Expertise involves working at the edge of one’s competence and surpassing oneself (Tynjälä & Gijbels, 2012). Experts constantly meet new challenges and solve problems that are more complex than those they have already solved and constant learning is thereby prerequisite developing expertise. Professional expertise involves working in multiple interacting collaborations, rather than being an individual attribute (Engeström, 2004). Engeström (2004) defines expertise as a collaborative and transformative nature of expertise, meaning that experts do not only face up to change, they also work as agents of change.

The proposed concept in this thesis, co-constructing expertise, builds on Edwards (2005a) notion of relational expertise that includes working with others to expand the object of activity. Relational expertise involves gaining sufficient insight into the purposes and practices of others in order to enable collaboration. Edwards and Kinti (2010) further discuss distributed expertise by extending the relational aspects one step and reason that expertise also needs to include the capacity of interactions between individuals and material artifacts. Cultural tools, and material artifacts such as learning technologies, production systems, as well as conceptual knowledge of specialists is loaded with intelligence, that power distribution of knowledge. For example, recognizing each other’s competences includes both domain specific knowledge such as distributed expertise and relational expertise (Edwards, 2005a; Edwards & Kinti, 2010; Engeström, 2015). The capacity to transform the problems of practice and build common knowledge is further included. Practitioners need to both recognize the specialist expertise that is distributed across practices and settings, and their own core knowledge in relation to purposes and practices of others, hence both their relational and distributed expertise. Tynjälä (2012) also underline the need of a conception of professional expertise by acknowledging that expertise is tightly integrated components of theoretical, practical, regulative, and sociocultural knowledge. He also point to the nature of progressive problem solving characteristic of true experts and that expert work is highly collaborative and transformative in nature.
Both relational and distributed expertise (Edwards, 2005a; Edwards & Kinti, 2010) are concepts aligned to the proposed concept of co-constructing expertise. In line with them, human-relational communications, and tool-mediated interactions form a base for developing expertise. In addition to their insights, I also suggest a further way of mapping expertise that is built on the results from this thesis. Figure 14 outlines the thesis overall process of co-construction of knowledge towards co-constructing expertise for work-integrated transformations.

![Figure 14. A process of co-construction of knowledge towards co-constructing expertise for work-integrated transformations](image)

The process of co-construction of knowledge includes the cyclical trajectory of mutual knowledge construction through negotiated knotworking of e-learning activities. Negotiated knotworking are stimulating the collaborative performance between otherwise loosely connected actors and activity systems, and hopefully increase the process of collective object of activity into a systemic and generalized level of co-construction. It means that new capacities and knowledge are learned in the knots through knotworking (Fenwick, 2007). To be noticed is that negotiated knotworking is prerequisite within the process of co-construction of knowledge towards expansive learning, however, all knowledge development will not lead to expansive learning (Rantavuori, Engeström, & Lipponen, 2016). It is argued that negotiated knotworking will determine such eventual expansion.

Built on the discussed findings in this thesis applied to activity theory (Engeström, 2008; 2015), and modeled in Figure 14, I argue that the concept of co-constructing expertise advances relational and distributed expertise built on Edwards and Kinti (2010). For this reason, this new concept also needs to include manifestations of contradictions depicted through negotiated activities aiming for expansive transformations integrated in work, i.e. towards work-integrated transformations, as a form of a higher level of expertise. Hence, the concept entail three levels of
activities among actors; to have insight into the purposes and practices of others (relational expertise), the capacity to transform the problems of a practice and together build common knowledge (distributed expertise), and finally the capacity of mutually co-construct knowledge acted upon in practice towards work-integrated transformations (co-constructing expertise).

The reasoning above is built on my interventions and mirroring within the action research and the five studies over time, in which I constantly shifted focus of the constructive actions and activities between the organizational and the individual. This means that I was able to view co-construction through the different perspectives (industry, university, collaborative) and from the different actors’ interactions. Through the iterative data analysis I was able to explore different levels of history (old versus new activity), and could therefore understand the transformations of the object of activity and build new insights that forms co-constructing expertise. Through the exploration of short-time knotworking in the interface between different actors, it was possible to achieve an increased understanding of the evolving process of co-construction into a systemic and generalizable level towards increased expert knowledge and co-constructing expertise that will have impact on future work-integrated transformations.

6.5 Methodological and Theoretical considerations

The findings in this thesis are empirically explored through an action-oriented approach which may cause some methodological considerations. The approach aimed to gain results from the reflective understanding of the actions taken in an on-going collaborative context. This was an interactive inquiry allowing to balance actions of problem-solving and data-driven analysis. An action research approach in combination with the four case studies and one ADR-study was found to be a relevant methodological approach for exploring the broad thesis approach and the following research activities over a four year period. To mix an action research approach with a case study approach may cause some problems, however the mixed approach was used to only collect qualitative data and not to seek quantified generalizations. By applying the collaborative practice research approach (Mathiassen, 2002), that allow for combination of action research and other methods, I was confident in using such mixed approach to make close explorations of the empirical setting. I was carefully eager to not pitfall findings from initial findings that may seem convincing enough to be released prematurely as conclusions. The longitudinal study within the same project made repeating and procedural analysis applicable.
During the thesis I have independently collected all possible data and participated actively within the ProdEx project from January 2013 until spring 2016, when I decided to end the active participation within the project meetings, to make a distance from and gain time for reflection related to project activities and data from the five studies. The research role throughout the thesis project activities was of an interventionist character in which I aimed to understand different actions taken by the various stakeholders’ actions and reactions, their reflected practice, and how I as a researcher could reflect back learning. The closeness to the empirical setting may have influenced my understanding and analysis of the findings, however I have tried to use the same research procedure for all respondents to reach trustworthiness (Lincoln & Guba, 1985).

The collected project data such as field notes from project meetings, web-conference observations, audio recording of company and network meetings, documents, analysis of material in the learning management systems DisCo etc. are those kind of useful resources that the action research approach made possible of getting in-depth knowledge of diverse phenomenon around the shared objective of knowledge development. These activities were boundary crossing and gave an opportunity to get the inside engineering cultural understanding and how to interpret actions taken. It also strengthened me to design and perform the qualitative data collection of the case studies, meaning how to interact with industry practitioners in diverse engineering subject matters and constellations. Action-oriented data through active participation in meetings have informed me to make decisions on how progress further in the studies and to understand certain actions built on cultural differences, technology mistakes etc. To go in and out of the project and studies, to intervene in actively, gave me a kind of meta-level reflection process, and continuously on-going during the whole project. The different interventions meant to grasp and trying to understand actors value adding and meaning making built on their shared actions on activities, i.e., their practice within both the e-learning courses and work-related issues. Credibility as part of reliability within the data analysis, dealt with how well categories and themes were covering the research questions. Through a thorough content analysis in iterations I was seeking to achieve credibility by discussing the findings with other colleagues (Graneheim & Lundman, 2004).

In the beginning of the project there was not a set theoretical approach to apply or guiding the thesis project. To theoretically capture the broad scope of this thesis, and due to the inter-disciplinary nature of the knowledge field of information systems research and educational research, choices of applicable theories became a struggling process, also ending up in huge literature studies. Furthermore, the empirical context of engineering education and production technology, and not within social sciences, added on readings to make me get
insights. Hence, the drive for me during the whole thesis has been grounded in a user-centered and design-oriented practice approach between technology and humans. Through discussions in the supervisor team it was decided to initially use the concept of absorptive capacity (Cohen & Levinthal, 1990) to delineate the manufacturing companies and managements readiness, which at the time turned out to be appropriate for analysis because it is assumed to be directed toward facilitating organizational change (Cavalieri & Pezzotta, 2012). However, this theory did not capture the forthcoming studies that aimed at exploration of e-learning design. During the forthcoming studies perspectives of socio-cultural and situated learning was an entrance that guided me. The classical top-down or bottom-up approach of studies did not appeal to me, rather I wanted to find an approach taking a sideways learning view. Another decision was to stay on to different actors perspectives. During 2015, the cultural-historical activity theory (Engeström, 2001; 2015), became the kernel theory to embrace the whole study, because it premise insights to sideways learning, and focuses on shared activities. Other theoretical considerations during the thesis work were Actor-Network Theory (Latour, 2005), socio-materiality (Leonardi et al., 2012; Orlikowski & Scott, 2008), Computer-supported Cooperative Work (Bjørn & Christensen, 2011), practice-based studies (Corradi, et al., 2010), and the large amount of instructional design and technology enhanced learning literature (Kirkwood & Price, 2014).
7 Conclusions

This chapter concludes the thesis contributions to practice, theory and methodology, at the end future work is shortly presented.

With the background of the increased digitalization pressuring manufacturing industry professionals into continuous competence development, this thesis was set out to study mutual knowledge construction between actors in the industry and the university and their potentials for joint learning and development towards transformations. The overall objective was to explore how mutual construction of knowledge emerge through learning activities between multiple actors in a joint industry-university collaborative e-learning practice. The overall research question was; How is production technology knowledge mutually constructed among multiple actors in a joint e-learning design process between industry and university?

The five studies focused on the emerging knowledge construction processes between the actors; industry managers, research teachers and industry practitioners, within the two stakeholder organizations, the industry and the university. The course was also a unit of analysis. The five studies show that learning activities of production technology knowledge and e-learning design were negotiated in cycles over time among the actors in which all parties contributed to implications for further design in the new e-learning practice. Section 6.1 and 6.2 analysed findings of challenges found to further encounter:

1. Continuous competence mapping of industry competence needs with university knowledge fields
2. Combining practice-related experiences with theoretical knowledge
3. Unresolved contradictions around the course, however manifested as change power for modeling forthcoming courses
4. Creating even more flexible course modalities applicable to workplace demands, especially for companies in a wider region
5. Establishing a company-network and implementing the courses permanently to stimulate workplace transformations

Challenge number three concern the analysis of manifestations of contradictions within the courses. Interestingly is that e-learning technology failures and pedagogical mistakes during the project was easier to overcome, than issues concerning company support for practitioners course participation. Hence, inter-organizational contradictions between practitioners and research teachers regarding e-learning technology failures, late case-instructions etc. were resolved
into actionable possible solutions by the practitioners. However, the intra-organizational manifested contradictions between the industry companies’ management and the practitioners, regarding company objects versus the practitioners own motives for competence development, were harder to resolve. There seem to be a lack of rooted, collective motives and established practices for the companies to find actionable solutions in order to reach for expansive transformations in the workplace. However, the activities should be understood as negotiated knotworking of evolving contradictions for constructing and reconstructing solutions as power for change, towards facilitation of co-construction of knowledge.

Theoretical contributions

The main contribution is that co-production of knowledge and furthermore, co-constructing expertise can serve as both explanatory and working concepts for guiding development of mutual expert knowledge in inter-organizational joint collaborative practices. Two established concepts were guiding this contribution, knotworking (Engeström, 2008) and co-production (Jasanoff, 2004). The concept of knotworking became a working tool to examine and understand how practitioners and research teachers were negotiating 1) knowledge of designing blended e-learning courses targeting specific knowledge needs, and 2) the knowledge of production technology towards future workplace transformations.

Negotiated knotworking was prerequisite processes of co-construction, because knotworking is not a fixed object to be analyzed, rather the unstable knot itself needs to be made the focus of analysis (for instance how to solve a specific engineering problem within a course, labs, or cases). Through negotiated knotworking, knots can be untied and resolved into new actionable solutions. Knotworking that are negotiated stimulates direct uptake on short-term responses to changing objects of activity through tying, untying, and retrying together seemingly separate threads of activity meanwhile, co-construction implicates generalization on longer-term systemic changes which becomes visible in various forms, content, and habits of co-construction. Studies of co-construction over time begins with individual subjects questioning the accepted practice into cycles, and steps of construction of new knowledge and practices. Co-construction can thereby be studied through a large-scale expansive learning cycle, which this thesis project aimed to proceed.
Co-construction of knowledge

Negotiated knotworking was the concept that shed light on the actors’ immediate actions, and how they together worked towards a collective objects of activities built on their production technology experiences and the new theories of learning the encountered during the courses. This concept was therefore used to further understand how co-construction of knowledge was developing over time into a richer concept. In line with Jasanoff (2004) interactional approach to co-production, meaning gaining knowledge about less what is and more of how we know about it, and concerning the process-oriented view in which we seek meaning and learning in a social context. From such conception, the thesis analyzed three perspectives of co-construction of knowledge as follows:

Industry perspective

- Real cases support theory-practical intertwining of mutually learning, through co-construction.
- Practitioners’ aiming for personal continuous competence development on university level creates analytical skills and high-qualitative performances and valuable engagement in the process of co-construction towards new knowledge development.

University perspective

- To be problem oriented and curious of e-learning technology [researchers and practitioners] is another key activity for co-construction of knowledge.
- To have insight into another organizations rules and culture, i.e. abilities for crossing organizational boundaries supports mutual collaborations. This can be considered as a “tacit” failure tolerance beneficial for co-construction of knowledge.

Collaborative perspective

- The courses is a key joint collaborative adventure, and a respected activity for co-construction of knowledge.
- Stakeholders’ abilities to inter-organizational boundary crossing actions is one key activity for co-construction of knowledge in collaborative competence initiatives.
- Sustainable and joint industry-university collaborations are important for co-construction.
CONCLUSIONS

The trajectory from contradictions into transformations is illustrated as a process of co-construction of knowledge, see Figure 14 (6.4). This evolving context was demonstrated by giving and taking as an open and not insecure environment to discuss industry secret business knowledge, built on mutual trust and common intentionality. Different layers of co-construction, became open, in the company meetings and during the courses. Hence, co-construction of knowledge entail tight communication, negotiations around knowledge sharing, questioning, arguing, and making, around knowledge interrelated with both practice and theory. Co-construction is an active action making that is a blend of people and technology. Co-construction includes problem solving, sharing best practice, discussing pedagogical approaches, learning technologies etc.

Co-constructing expertise

Co-constructed expertise is the knowledge that is shared among experts in a process of co-construction of knowledge. It is their common knowledge that is negotiated (however it does not always mean mutual agreements on topics), meanwhile co-construction is more related to the actions and activities that are made through shared objective of activities.

Built on the discussed findings in this thesis applied to activity theory (Engeström, 2008; 2015), and modeled in Figure 14, I conclude that the concept of co-constructing expertise advances relational expertise (Edwards, 2005a) and distributed expertise (Edwards and Kinti, 2010). For this reason, this concept also needs to include manifestations of contradictions depicted through negotiated activities aiming for expansive transformations integrated in work, i.e. towards work-integrated transformations, as a form of a higher level of expertise. Hence, the concept entail three levels of activities among actors; to have insight into the purposes and practices of others (relational expertise), the capacity to transform the problems of a practice and together build common knowledge (distributed expertise), and finally the capacity of mutually co-construct knowledge acted upon in practice towards work-integrated transformations (co-constructing expertise).

Methodological and practical contributions

Through the interventions and the action research approach (Mathiassen, 2002) to systematically study design in action and as a forthcoming process, the project itself became a particular study object that contributed to lessons learned considering how to systematically organizing a joint collaborative learning practice across organizational boundaries. The research activities contributed to an understanding on how particular design and implementation of e-learning courses target industry needs can be designed, structured, implemented and evaluated. A general course model and design principles were developed through action design
research (Hattinger & Eriksson, 2015). The collaborative practice research approach (Mathiassen, 2002) was used during the longitudinal thesis project and allowed for a mixed method approach with five additional studies besides action-oriented interventions. During the action design research cycles (Sein, et al., 2011) this thesis contributed to lessons learned for developing new types of educational practice, i.e. the ProdEx courses. This is illustrated by the zone of proximal development in Figure 13 (6.3). To be able to design a whole educational practice, built on advanced e-learning technologies with content production of advance engineering knowledge, is stressful for the research teachers and for the participating practitioners. Challenges that was found in the studies are the address the following:

Research teachers. Continue with content production of course material, create real cases, digitize and virtualize them. Have insight into practitioners work practice. Motivating team building and have power to negotiate advanced knowledge and stimulate distributed common expertise. Finding balance between industry practitioners’ expert role and their own expert research role.

Practitioners. Need to recognize each other’s competences including both domain specific knowledge such as distributed expertise and relational expertise and to be prepared for transformative activities forthcoming. They need to be problem oriented and curios of the technology, through active engagement, co-creative and technology driven.

Course design. The course occasions are the kernel activity for guiding co-construction of knowledge activities and co-constructing expertise. Real cases are the glue for negotiated knotworking and co- construction of new innovative knowledge.

Companies. Finding working structures to overcome knowledge breaks between practitioners and managers. Prioritize future competence demands, by making time for themselves and the practitioners.

University. To not standardize the courses too much, continue supporting validation of practitioners’ experiences, and to continuously create spaces for negotiated knotworking and design cycles of new courses.

Even if there still are challenges to encounter, the project is a success with a very low rate of drop-outs because of the skilled practitioners, and the highly professional research teachers’ interest to digitize learning material, to develop new types of e-learning pedagogies and for being professional towards the experienced practitioners’ know-how. Analyzed results show that doing, knowing and learning were stimulated within the designed course activities that integrated
pedagogical forms, content and learning technologies, in which collaborative and reciprocal knowledge sharing were co-constructed among the actors, i.e. the industry managers, practitioners and research teachers.

I have researched learning activities of intertwined expert knowledge and e-learning implications in a joint e-learning practice. I studied negotiated knotworking on different levels and through different stakeholders’ perspectives in an e-learning design process that aimed to facilitate co-construction into co-constructing expertise towards work-integrated transformations.

7.1 Future Work

The research studies in ProdEx generated an extensive data collection that I am interested in to further analyze together with some follow-up studies. As highlighted in the discussion there are still challenges to overcome for future innovative collaborative e-learning initiative that needs to further be explored. The manager data in Study V are particularly important to shed light on concerning managers’ perceptions for future participation. Also, to follow up on research activities among the first industry practitioners engaged early in 2013 are especially relevant to further explore. Interesting topics to research are how knowledge transformation in practice are implemented and how co-construction of knowledge and expertise are concepts tightly connected to doings in practice. I also intend to further use the methodology of a formative change laboratory intervention (Engeström et al., 2014).

At the time that this thesis is finalized I have been accepted for a two-year post-doc scholarship through the Knowledge foundation program Prospekt. In my granted application INDIGO (Industrial Digitalization and Organization), I intend to further address and study the effects of the increased digitalization and automation in the manufacturing environment, in specifically two manufacturing companies. This problem domain is part of the UW new research field Industrial-Work-Integrated Learning (I-WIL). I-WIL targets the understanding of processes of learning, knowledge exchange and professional transformation within industrial areas such as production systems. The INDIGO-project will support my future interest to further studying manufacturing work through on-site participation in factories. In the factory plants I will be able to study routines and processes that need to be developed to utilize knowledge embedded in digital systems in a production process, and thereby analyze forthcoming competences developed in an increasingly digitized and automated production process. I will also be able to investigate strategic competence plans in cooperation with a HR department at one factory.
8 References


REFERENCES


REFERENCES


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REFERENCES


REFERENCES


REFERENCES


APPENDIX A. Interview guide Study I – Managers I

1. **Background data**
   - Number of engineers with an academic bachelor or master’s degree?
   - Describe shortly the company’s competence work supporting employees?

2. **Competence areas and content**
   - What type of knowledge subject areas within the manufacturing demands expert competences?
   - Which are the critical production processes?
   - Which educations are related to these knowledge areas?

3. **Course forms and IT use within the course design and implementation**
   - In what forms do you implement and organize education today?
   - Web-conferencing, distance education and use of competence networks?
   - Simulations- and visualization programs, equipment, other?

4. **Knowledge/learning/education as engine for effectiveness and innovation**
   - Do you on the macro management level discuss relations between individual competence development – effectiveness –innovations?
   - Learning organisation?

5. **Organizing/organization and co-production**
   - How do you view collaboration with the university around a possible co-production of a master education built on your knowledge needs?
   - How would you like to organize and realize a joint master education?
APPENDIX B. Interview guide Study II – Research Teachers

1. **Background**
   What knowledge area/courses do you teach in, can you describe it?
   - What is your general teaching model/pedagogical approach for campus courses?
   - What experience do you have within this area?
   - How can you use the experience in your former learning/teaching for guiding the work in the project?

2. **Challenges with e-learning technology and courses**
   - What are the challenges for using information technology/software when developing your campus course into online learning?
   - What effect/function do you expect of the digital technique to be realized in your course?

   **Course content (resource) development online**
   - How will you design the course content?
   - How will you digitize your course content and digitize laboratory sessions/virtual labs?
   - What media will you use to make the course content?

3. **Communication**
   - How do you prefer to communicate with the participants in the online course?
   - Do you prefer participants have free discussions or more focus on specific topic discussions?
   - What ICT would you like to support in the online discussions?

4. **Examination/Assessment**
   - How would you like to examine and assess the participants in the online education?
   - What advantages/perspectives in your examination principles do you like to illustrate or clarify?

5. **Work-Integrated Learning aspects**
   Given the target group of engineering practitioners from the manufacturing companies and the courses aim to improve their work ability:
   - What preparation work/new skills do you think you will need to gain?
   - What differences would you prefer to explain in detail as the course is differing from traditional campus courses?

6. **Other difficulties**
   - Are there other difficulties for you when designing the course?
   - Are there any difficulties that you worry about in an online education system?
## APPENDIX C. Overview stakeholders, activities, and studies

<table>
<thead>
<tr>
<th>Time</th>
<th>Stakeholders</th>
<th>Studies</th>
<th>Project activities</th>
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<tbody>
<tr>
<td>2013</td>
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<tr>
<td>Jan-Jun</td>
<td>Managers, Networks</td>
<td>Study I</td>
<td>One company seminar; seven companies, two networks companies</td>
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<tr>
<td>Aug-Dec</td>
<td>Proj. group</td>
<td></td>
<td>Four ICT-seminars, 10-15 participants in each session</td>
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<tr>
<td></td>
<td></td>
<td>Study I</td>
<td>Meetings about web platform design/LMS, course marketing and participant applications</td>
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<td></td>
<td></td>
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<td>Meetings about iterative design and implementation of pilot courses</td>
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<td></td>
<td></td>
<td>Initialization of informatics master thesis</td>
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<tr>
<td>2014</td>
<td>Proj. group</td>
<td>Study II –</td>
<td></td>
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<tr>
<td>Jan-Mar</td>
<td></td>
<td>Five interviews</td>
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<tr>
<td>Apr-Aug</td>
<td>Participants</td>
<td>Study IIIa - Focus groups¹</td>
<td>Pilot course Industrial automation I</td>
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<td></td>
<td>Proj. group</td>
<td></td>
<td>Continual formative evaluation²</td>
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<td></td>
<td>Managers, Networks</td>
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<td></td>
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<td>Internal meetings, deriving design principles in relation to lessons learned</td>
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<td>Research teachers</td>
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<td>Sep-Dec</td>
<td>Proj. group</td>
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<td></td>
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<td>Two ICT-seminars, 10-15 participants in each session</td>
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<td>Managers, Networks</td>
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<td>One company seminar; 20 companies two networks</td>
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<td></td>
<td>Research teachers</td>
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<tr>
<td>Nov-Jan</td>
<td>Participants</td>
<td>Study IV - Focus groups¹</td>
<td>Pilot course Machining I and Negotiation I</td>
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<td>(-15)</td>
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<td>Continual formative evaluation²</td>
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<td>Two observations in Adobe Connect</td>
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<tr>
<td>2015</td>
<td>Managers, Networks</td>
<td>Study IV – Focus groups¹</td>
<td>Three courses (including one new)</td>
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<td>Jan-Jun</td>
<td>Proj. group</td>
<td></td>
<td>Continual formative evaluation²</td>
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<tr>
<td>Aug-Dec</td>
<td>Manager Networks</td>
<td>Study V – 14 interviews</td>
<td>Two company seminars with new additional companies, networks and project members</td>
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<td></td>
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<td>Study V – Focus groups¹</td>
<td>Eight courses (including five new)</td>
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<td>Participants</td>
<td></td>
<td>Web-conference observations, four courses</td>
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<td>Continual formative evaluation²</td>
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<tr>
<td>2016</td>
<td>Proj. group</td>
<td>Study IV – Focus groups¹</td>
<td>Four courses (including one new)</td>
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<td>Feb-Dec</td>
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<td>Continual formative evaluation²</td>
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<td>Manager Networks</td>
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<td>Internal project meeting ProdEx II</td>
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<td></td>
<td>Participants</td>
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<td></td>
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<td>Two company meetings, upstart ProdEx II and co-production further courses</td>
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¹ Focus groups: 1) 2)
APPENDIX D. Focus group session Study IV - Practitioners

Distance education technology
1. How did the login to the university web work?
   a. How did DisCo work as learning management system?
2. Skype/Adobe Connect, following these issues:
   a. Technology and functionality, e.g. to enter and use these systems?
   b. Presence?
   c. To perform seminars, present and discuss?
   d. Meeting length?
   e. Good for lecturing? Side points?
3. The virtual lab?

Communication
1. Have you used social media for communicating with each other during the course?
2. Teacher interaction, how did you experience that? E-mail, or other media forms?
3. Other web-based/net-based systems? In what forms and which/what tool?

Course forms and teacher support
1. Was the course mode/tempo of 2.5 ECTS during five weeks applicable?
2. Seminars and lectures at PTC?
   a. Long or short physical meetings.
3. Other course modality issues?

Examination
1. Were the examination tasks at right level?
2. Appropriate forms for examination? How?

Competence areas
1. Is the subject you participated in relevant for your work function?
2. Has the included subject fields met your expectation?
3. Are you interested in further university studies towards a degree (exam)?

Work-Integrated Learning, WIL
1. How are you able to use the knowledge learnt related to your work? Which knowledge was mostly essential?
2. Business and management support, meaning was your new knowledge requested by your company afterward? Company follow up?
3. How was your experiences captured by the teachers during the course?
4. Did you learn anything from the other course participants at other companies?

Future
1. More courses within MERIT/ProdEx?
2. What knowledge subject and when?
APPENDIX E. Interview guide Study V – Managers II

This study is performed autumn 2015 and targeting managers participating in Study I.

1. Present and internal competence work
   • Competence work with the personnel?
   • What educational efforts are prioritized and for whom?
   • IT support at the company?

2. Information diffusion and participation (in MERIT/ProdEx)
   • How have you payed attention to offers and information from the MERIT project?
   • How have you discussed your participation and collaboration?
   • If you did not participate, what was the reason?

3. MERIT courses and present collaboration (for those respondents with on-going collaboration)
   • Which courses did your employees participate in?
   • How do you experience the course content, pedagogy and quality?
   • Web-conferencing technology and IT availability for the studies?

4. Collaboration with PTC/University West
   • How pleased are you with the collaborative MERIT meetings at PTC?
   • Did you get proper information and did UW meet your expectations of collaborating around targeting your knowledge needs?

5. Work-integrated learning and co-production
   • Individual focus: How do you acknowledge the employees competence level and academic degree?
   • Company support: If you have employees participating in the courses, how did you catch and made efforts around their new knowledge and competences? If you did not participate, can you give examples on competence feedback methods, models?
   • Do the courses trigger integration of theory and practice into new work practices?

6. Future knowledge needs and course offers
   • What knowledge subject areas are actual and working?
   • On what level, academic or other?

7. Co-production
   • How do you want to collaborate with UW/PTC more actively together and around competence mapping target your needs?
   • In relation to the upcoming project application, are you interested to participate in company network for co-producing courses collaboratively?
APPENDIX F. Course description – Three knowledge subjects

AU I – Industrial Automation
Neg-skills – Negotiation skills
Ma – Machining

The AU I course included four meetings at PTC and no web-conferences (however, in the second cycle, Skype for business was used between the three meetings at PTC), examination included four home assignments, one virtual PLC lab, and two physical labs at PTC. The course material included six videos, four power points and exercises distributed in DisCo. There was no communication in chat forums between the sessions, only e-mail communication.

The Neg-skills I course included two course days at PTC (first and last day), one test web-conference with Adobe Connect and one sharp meeting with a case-based task, a Harvard-case, this role play included six participants in each session. The whole examination included three tasks, the Harvard case, a participant created own video film about negotiations (at least two persons collaborate), and a final oral presentation. Literature and exercises were distributed in DisCo. No discussions on-line, but some student-driven communication through Skype.

The Ma I course, included three days at PTC, one test web-conference of Adobe Connect and one sharp meeting where participants demonstrated their solutions on a lab. Examination included making their own turning and mill-lab at their own home company and a final written examination last course day (this exam was later on exchanged with a hand-in task and oral presentation). Power-points and lectures was distributed on e-mail. No discussions on-line.
Tidigare avhandlingar – Arbetsintegrerat lärande

1. THOMAS WINMAN Transforming information into practical actions A study of professional knowledge in the use of electronic patient records, 2012.

8. ANNIKA ANDERSSON In case of emergency Collaboration exercises at the boundaries between emergency service organizations, 2016.

9. MARIE WESTERLIND Knowing at work A study of professional knowledge in integration work directed to newly arrived immigrants, 2016.

Co-constructing Expertise

Increased digitalization, automation and robotization affect manufacturing industrial work, hence practitioners constantly need competence development for a future-oriented effective production. Digitalization also challenges universities to open up to external collaboration, and to be able to design blended e-learning targeting industry knowledge needs. This thesis proceed from such challenges. The objective was to explore how mutual construction of knowledge emerge through learning activities between multiple actors in a joint industry-university collaborative e-learning practice. The empirical setting was a longitudinal e-learning project which was explored through action research integrated with five studies. The studies investigate four perspectives: industry managers, practitioners, research teachers and the course unit. Results from the studies contributes to a wider understanding of co-construction of knowledge in an e-learning design practice.

The main contribution suggested in the thesis is that co-constructing expertise entail three levels of activities among actors; to have insight into other practices, to build common knowledge, and to reach the capacity of active and mutual co-construction of knowledge.

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ISBN 978-91-87531-75-0 (Print)
ISBN 978-91-87531-76-7 (PDF)