OULU 2018
A 717

ACTA UNIVERSITATIS OULUENSIS

Pertti Seppänen

BALANCED INITIAL TEAMS IN EARLY-STAGE SOFTWARE STARTUPS

BUILDING A TEAM FITTING TO THE PROBLEMS AND CHALLENGES

UNIVERSITY OF OULU GRADUATE SCHOOL;
UNIVERSITY OF OULU,
FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

ACTA UNIVERSITATIS OULUENSIS
A Scientiae Rerum Naturalium 717

PERTTI SEPPÄNEN

BALANCED INITIAL TEAMS IN EARLY-STAGE SOFTWARE STARTUPS

Building a team fitting to the problems and challenges

Academic dissertation to be presented with the assent of the Doctoral Training Committee of Technology and Natural Sciences of the University of Oulu for public defence in the Wetteri auditorium (IT115), Linnanmaa, on 8 June 2018, at 12 noon

UNIVERSITY OF OULU, OULU 2018

Acta Univ. Oul. A 717, 2018

Supervised by
Professor Markku Oivo
Doctor Kari Liukkunen

Reviewed by
Professor Filippo Lanubile
Docent Arto Ojala

ISBN 978-952-62-1948-6 (Paperback)
ISBN 978-952-62-1949-3 (PDF)

ISSN 0355-3191 (Printed)
ISSN 1796-220X (Online)

Cover Design
Raimo Ahonen

JUVENES PRINT
TAMPERE 2018

Seppänen, Pertti, Balanced initial teams in early-stage software startups. Building a team fitting to the problems and challenges

University of Oulu Graduate School; University of Oulu, Faculty of Information Technology and Electrical Engineering
Acta Univ. Oul. A 717, 2018
University of Oulu, P.O. Box 8000, FI-90014 University of Oulu, Finland

Abstract

The rapid development of digital technology and software in recent years has created great variety of totally new business opportunities. Software startups are commonly considered to be the fastest in exploiting the new opportunities and the most innovative in creating new products and services. At the same time, software startups are often small, immature enterprises with limited resources and inexperienced teams.

The initial team plays a key role in the early stages of a software startup. This research focuses on the initial team from the perspective of human capital – the knowledge, experiences, skills, and other cognitive abilities. It studies the initial team empirically, utilizing the multi-case study and triangulation methods applying the human capital, resource-based view, capability, and the opportunity discovery and creation theories. The empirical data were gathered from thirteen software startups in Italy, Norway and Finland, and from a student experiment.

From the analysis of this data, a generic structure of a software startup's initial team was identified, consisting of three different roles, with each having a specific human capital profile. This team structure sought a balance between the team's human capital and problems and challenges to be solved. The level of the initial human capital of the team and the means to strengthen it varied, and affected the progress of the work in the studied startups.

Though the components of the team's human capital were not rare and inimitable in terms of the resource-based view, building a balanced startup team created a unique and task-specific setup, which is a key capability of a software startup. The balanced startup team structure is proposed to be the generic human capital model of a software startup's initial team.

Keywords: capability, competency, effectuation, entrepreneurship, founder, human capital theory, idea validation, initial team, innovation, lean startup, opportunity creation, opportunity discovery, product development, product development process, resource-based-view theory, software startup

Seppänen, Pertti, Tasapainotettu alkutiimi varhaisen vaiheen ohjelmistostartup-yrityksessä. Tiimin rakentaminen vastaamaan ongelmia ja haasteita
Oulun yliopiston tutkijakoulu; Oulun yliopisto, Tieto- ja sähkötekniikan tiedekunta
Acta Univ. Oul. A 717, 2018
Oulun yliopisto, PL 8000, 90014 Oulun yliopisto

Tiivistelmä

Digitaalitekniikan ja ohjelmistojen nopea kehitys viime vuosina on synnyttänyt suuren joukon kokonaan uusia liiketoimintamahdollisuuksia. Ohjelmistostartup-yrityksiä pidetään yleisesti nopeimpina hyödyntämään uusia mahdollisuuksia ja erityisen innovatiivisina luomaan uusia tuotteita ja palveluita. Kuitenkin samalla, ohjelmistostartup-yritykset ovat usein pieniä, kehityksensä alussa olevia yrityksiä, joilla on pienet resurssit ja kokematon henkilökunta.

Varhaisen vaiheen ohjelmistostartup-yrityksissä alkutiimin merkitys on keskeinen. Tässä tutkimuksessa tarkastellaan alkutiimiä inhimillisen pääoman, osaamisen, kokemuksen ja taitojen, näkökulmasta. Tutkimuksessa tarkastellaan alkutiimiä kokeellisesti, käyttäen monitapaustutkimuksen ja triangulaation menetelmiä ja soveltaen inhimillisen pääoman, resurssipohjaisen näkemyksen, kyvykkyyden ja liiketoimintamahdollisuuksien hyödyntämisen teorioita. Kokeellinen tutkimusaineisto on kerätty kolmestatoista yrityksestä Italiasta, Norjasta ja Suomesta ja yhdestä opiskelijoilla tehdystä kokeellisesta tutkimuksesta.

Tutkimuksessa löydettiin alkutiimin yleinen malli. Mallissa on kolme roolia, kullakin oma inhimillisen pääoman profiili. Mallissa on tiimin inhimillisen pääoman ja ratkaistavien ongelmien tasapaino. Tiimien inhimillisen pääoman määrä ja sen kehitystavat vaihtelivat, ja vaikuttivat tutkittavien yritysten edistymiseen.

Vaikka alkutiimien inhimillisen pääoman komponentit eivät olleet ainutkertaisia resurssipohjaisen näkemyksen kannalta, tasapainossa olevan alkutiimin rakentaminen synnytti ainutkertaisen, tehtävänmukaisen tiimirakenteen, jota voidaan pitää yrityksen keskeisenä kyvykkyytenä. Havaittu tiimirakenne esitetään yrityksen alkutiimin inhimillisen pääoman yleiseksi malliksi.

Asiasanat: alkutiimi, effektuaatio, idean validointi, inhimillisen pääoman teoria, innovaatio, kompetenssi, kyvykkyys, lean startup, liiketoimintamahdollisuuden havainnointi ja luonti, ohjelmistostartup-yritys, perustaja, resurssipohjainen näkemys, tuotekehitys, tuotekehitysprosessi, yrittäjyys

To my small beloved granddaughters, Lotta, Hilda and Liina

Acknowledgements

This thesis summarizes the research conducted in 2014 – 2018 at the M3S research group of the Faculty of Information Technology and Electrical Engineering of the University of Oulu.

First, I want to thank my superiors, Professor Markku Oivo and Doctor Kari Liukkunen for their contribution to this research. Markku and Kari hired me to the research group, guided me into the academic world, and provided me with the environment necessary for my research. They supported me by reviewing my work, by giving guidance and feedback, and, especially at the beginning, by encouraging me in this research. At the same time, Markku and Kari trusted me and gave me the personal freedom to find my own way and focus on the phenomena that interested me. I very much enjoyed that freedom.

Besides my superiors, I wish to thank Professor Pekka Abrahamsson for his support. Pekka invited me to the global network of software startup researchers and thereby helped kick starting my research. The network provided me with a research agenda that gave me guidelines on how to direct this research. Pekka is also excellent in giving short but apt comments. With such comments, he happened to help me over a couple of difficulties, in which I was stuck.

I wish to thank the three academics who volunteered in helping me to finalize my doctoral research, the pre-reviewers Professor Filippo Lanubile and Docent Arto Ojala for their contribution to the final form and content of my thesis, and Professor Jürgen Münch for carrying out the demanding task of the opponent in its public defense.

Adjunct professor Raija Halonen and Docent Xiofeng Wang were the members of the follow-up group of my research. I was extremely late with the follow-up group and without Raija's and Xaio's engagement I would have been in problems with the formalities of my doctoral studies. My warmest thanks to Raija and Xaio.

Nirnaya Tripathi, who started his doctoral studies at the same time, has been an excellent co-author, manuscript reviewer and discussion partner throughout the years of my research. His very systematic research orientation has helped me to do research right. Many thanks to him. Thanks as well to other early roommates, Iflaah, Hanna-Leena, and Rahul. Our Finnish-Pakistani-Indian team has given me a lot, both professionally and personally.

My twin brother Veikko, a seasoned author and evaluator of doctoral theses, crystallized privately that a thesis should consist of three components: the problem, the viewpoint and the context. Many thanks to him, though in my research the nice

order of those components were many times more or less upside down. The simplest guidelines are sometimes the most difficult to follow.

The interviewees of the case startups and all my friends and colleagues who supported and encouraged me in this research in many and various ways earn thanks as well.

The academic roads towards a doctoral decree are long, taking years. For me wandering on them, the road maps were visible and understandable. For those who were just waiting that the wanderer reaches the final goal the route tends to be fuzzy and cumbersome, requiring lots of patience. Therefore, the warmest thanks to my family, to my children Mikko, Annariikka and Laura and especially to my wife Anneli.

In Kempele 29.4. 2018 Pertti Seppänen

Abbreviations

ESSSDM	Early Stage Software Startup Development Model
ICT	Information and Communications Technology
SSRN	Software Startup Research Network
SWEBOK	Software Engineering Body of Knowledge

List of original publications

This thesis is based on the following publications, which are referred to throughout the text by their Roman numerals:

I Seppänen P., Oivo M., Liukkunen K. (2016). The initial team of a software startup, Narrow-shouldered innovation and broad-shouldered implementation. In press.

II Seppänen P., Tripathi N., Oivo M., Liukkunen K. (2017). How Are Product Ideas Validated? The Process from Innovation to Requirement Engineering in Software Startups. International Conference of Software Business (2017). doi:10.1007/978-3-319-69191-6_1.

III Seppänen P., Oivo M., Liukkunen K. (2017). Little Big Team: Acquiring Human Capital in Software Startups. 18th International Conference on Product-Focused Software Process Improvement (2017). doi:10.1007/978-3-319-69926-4_20.

IV Seppänen P., Oivo M., Liukkunen K. (2018). Opportunity Exploitation in Software Startups. A Human Capital View. In press.

V Tripathi N., Seppänen P., Oivo M., Liukkunen K. (2017). The Effect of Competitor Interaction on Startup's Product Development. 43rd Euromicro Conference on Software Engineering and Advanced Applications (2017). doi:10.1109/SEAA.2017.34.

In publications I–IV the author of this thesis was in charge of planning the research, gathering the research data, analyzing the data, and drawing the conclusions. In publication V, the author contributed by providing the experiment with a justified reference, to which the experiment teams were compared, and by analyzing the data, developing the statistical reporting, and drawing the conclusions together with the first author. In all publications the supervisors, Prof Markku Oivo and Dr. Kari Liukkunen, contributed with scientific reviewing, guidance and feedback.

Table of Contents

1 Introduction

1.1 Background

Recent technological developments have enabled changing of society and human life, known as digitalization. Digitalization, the integration of digital technologies and computer-based solutions into all aspects of everyday life, has induced changes both to technology and to customer preferences (Gray & Rumpe, 2015). The changes create new business opportunities and promote new innovations (Alvarez & Barney, 2007; Ojala, 2016a; Parviainen, Tihinen, Kääriäinen, & Teppola, 2017). Software startups are considered to be especially fast in exploiting the new opportunities and to deploy the new technology (Kon et al., 2014; Paternoster, Giardino, Unterkalmsteiner, Gorschek, & Abrahamsson, 2014), and the number and economic significance of software startups have increased rapidly (Cukier, Kon, & Lyons, 2016; Kon et al., 2014).

As a growing trend in the ICT industry, software startups have increasingly become the focus of research interest in academia. The recent research topics vary from business-oriented process models (Blank, 2013; Bosch, Olsson Holmström, Björk, & Ljungblad, 2013; Ries, 2011), to work models (Giardino, Paternoster, Unterkalmsteiner, Gorschek, & Abrahamsson, 2016; Giardino, Wang, & Abrahamsson, 2014), and characteristics and characteristic challenges (Giardino, Sohaib Bajwa, Wang, & Abrahamsson, 2015; Paternoster et al., 2014; Wang, Edison, Bajwa, Giardino, & Abrahamsson, 2016). In spite of that, dedicated research on software startups and the software development work in startups is still at a relatively under-explored level.

In 2014, the level of research on software startups triggered the creation of an international network of researchers, Software Startup Research Network (SSRN). It was founded as a relatively informal forum of researchers focusing on research into software startups. As one of the first common activities, SSRN explored different possible research paths and published a proposal for a software startup research agenda (Unterkalmsteiner et al., 2016). The purpose of this was to gather research directions that need additional contributions. Research into human aspects of early-stage software startups was identified as one such direction.

Software startups are considered as innovative entities, and lots of public interest has been dedicated to innovations and creativity. Inventiveness as a characteristic of software startups has also been confirmed scientifically in recent

literature (Paternoster et al., 2014). While innovation and product ideas are the starting points of new enterprises (Ries, 2011), transforming the ideas into products, services and business cases is one of the most crucial tasks during the early stages of startups. However, the recent research into software startups reveals their extremely limited resources (Paternoster et al., 2014). From the viewpoint of the human resources needed to transfer ideas to products, such challenges as small and inexperienced teams and little work history have been identified (Paternoster et al., 2014). In spite of the challenges software startups tend to aim at rapid evolution and scaling (Paternoster et al., 2014).

On the other hand, earlier research into entrepreneurship and firms have confirmed the value of the human capital to the performance of firms (Barney, 1991; Becker, 1993; Bosma, Van Praag, Thurik, & De Wit, 2004; Crook, Todd, Combs, Woehr, & Ketchen Jr, 2011). The apparent conflict between software startups' limited resources and the aimed evolution and scaling, and the scarce prior literature on the human aspects in software startups (Unterkalmsteiner et al., 2016) provide the reasoning of this research, exploring software startups from the viewpoint of the human capital.

Research into human aspects of entrepreneurship and enterprises without a specific focus on software startups has, however, been conducted over several decades. It has created several recognized theories that provide this research with a solid theoretical basis, such as human capital theory (Becker, 1993), resource-based view (Barney, 1991), capability theory (Del Canto & González, 1999), and opportunity exploitation theories (Alvarez & Barney, 2007). Human capital theory addresses cognitive abilities in different contexts, including enterprises (Becker, 1993; Bosma et al., 2004; Hatch & Dyer, 2004; Lazear, 2004; Marvel & Lumpkin, 2007). Resource-based view and its derivative, capability theory, address the relationships between enterprises' resources and capabilities and their business success (Barney, 1991; Del Canto & González, 1999). Opportunity exploitation theories study the innovation processes of entrepreneurs and their dependence the knowledge and skills (Alvarez & Barney, 2007; Ardichvili, Cardozo, & Ray, 2003; Mainela & Puhakka, 2009; Sarasvathy, 2001).

This thesis addresses the gap in the research into human aspects in software startups empirically. It aims at exploring what the effects of the founders' and the initial team's cognitive human abilities, experiences, knowledge, and skills, are in early-stage software startups. The research has been conducted using the recent studies of software startups as the empirical background, and the theories created for human aspects of entrepreneurship and enterprises as the theoretical framework.

1.2 Research objective and scope

To address the research gap presented above, this project focuses on the knowledge, experiences, skills, and other cognitive human abilities in the initial teams of software startups, referred in this thesis by the term *human capital*.

There are many definitions of a startup (Blank, 2013; Giardino, Unterkalmsteiner, Paternoster, Gorschek, & Abrahamsson, 2014; Paternoster et al., 2014; Ries, 2011) highlighting different aspects of the startup phenomenon. This research has been conducted on companies fitting to the definition of a startup proposed by Giardino et al. (2014). It states that a startup is a small company exploiting under high uncertainty a new business opportunity with solutions that are not well known. The case companies were classified as *software startups* because they developed products and services with the main functionality implemented in software.

The *initial team* of a software startup has no established definitions in the prior literature. It was defined in the context of this research as the personnel who participated to the development of the first product of the case companies: to innovating, creating the business cases, developing minimum viable products (Ries, 2011) or prototypes, conducting feasibility studies, and developing the first versions of the products, including the founders and both employed personnel and subcontractors.

Due to human capital in the initial teams of software startups being a relatively uncharted research area, a *broad focus* and *triangulation* were opted as the basis of this research. These methods have enabled the gathering of knowledge from several viewpoints.

As there were no available theoretical frameworks that directly fit the objectives of this research, a union of established theories on human aspects of enterprises was used. This consisted of the human capital theory, the resource-based view theory, the capability theory (Barney, 1991; Becker, 1993; Teece, Pisano, & Shuen, 1997; Väyrynen, 2009; Winter, 2003), and the opportunity discovery and creation theories (Alvarez & Barney, 2007; Alvarez, Barney, & Anderson, 2012; Sarasvathy, 2001). The recent studies provided this research with the key characteristics of the software startups, their evolution phases, processes, strengths, and challenges (Blank, 2013; Bosch et al., 2013; Giardino et al., 2016, 2015; Giardino, Wang, et al., 2014; Paternoster et al., 2014; Ries, 2011; Wang et al., 2016).

The principle of the theory triangulation deployed in this research is presented in figure 1.

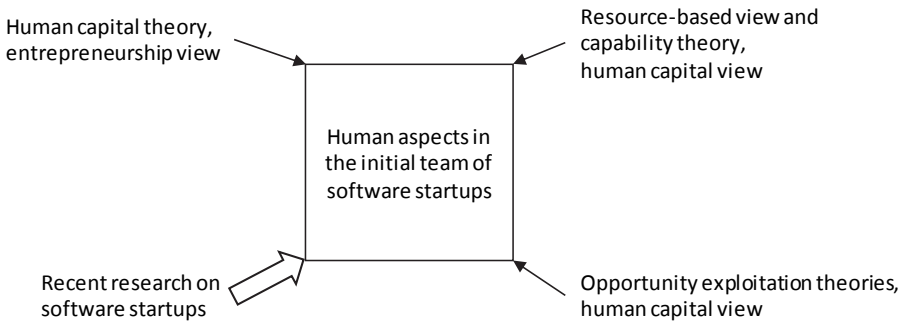

Fig. 1. Theory triangulation principle.

As mentioned above, there has been earlier research into entrepreneurship and human capital, without a specific focus on software startups. That research has addressed different topics, especially from the viewpoint of the entrepreneur. Such areas as human capital's effect on success and business performance (Bosma et al., 2004; Unger, Rauch, Frese, & Rosenbusch, 2011), on innovation (Marvel & Lumpkin, 2007), and on the means to increase human capital (Hatch & Dyer, 2004; Martin, McNally, & Kay, 2013), were explored. Research focusing on the whole team of a startup has addressed the team's human capital and the means to increase it (Hatch & Dyer, 2004; Unger et al., 2011).

A derivative of the resource-based view, the capability theory, addresses human capital by defining capabilities as core competencies in product development, gained by collective learning within the organization (Del Canto & González, 1999), and as a company's ability to build, reconfigure and integrate internal and external competencies in order to address rapidly changing environments (Teece et al., 1997).

This research has studied human capital in software startups, from both the founders' and the teams' perspectives. It has sought answers to the following research problem: *What are the characteristics of the human capital in early-stage software startups and how does it affect a startup's initial team and work processes?* To explore the research problem, answers to following three research questions were sought:

> *RQ1: How are the human capital areas structured in the initial team of early-stage software startups?*

RQ2: How does the founders' human capital affect the idea-related processes in early-stage software startups?

RQ3: How is the human capital acquired in early-stage software startups?

The focus of the exploration was on technical and engineering-related human capital. Business topics were included only to the extent needed to understand the engineering-related phenomena.

The first step was to explore the types and structures of the initial team's human capital. The research was continued by exploring the relationships of the identified human capital on the actual tasks conducted in the initial team. It was complemented by studies on how the initial team's human capital was gathered. The stepwise broadening of the viewpoints was supported by the theory triangulation, as explained above.

1.3 Research design overview

This section gives an overview of the research design presented in more detail in section 3. The research was conducted as a series of four interlinked studies S1, S2, S3, and S4, and its results were presented in five original publications P I, P II, P III, P IV, and P V. Studies S1, S2, and S3 were empirical studies conducted as multiple-case studies on software startups in four geographically separate European locations. Study S4 was an experiment conducted on a group of students at the University of Oulu simulating software startups. The results of study S1 were reported in two original publications, P I and P II, the results of study S2 in P III, the results of study S3 in P IV, and the results of study S4 in P V.

The main research method was qualitative and explorative, seeking phenomena, structures and relationships related to human capital in the initial team of early-stage software startups. The research data from the case startups were collected by using semi-structured interviews, while the experimentation data were collected by using relevant tools and free-format reflections from the participants. The research data were analyzed mainly with qualitative analysis methods.

This research consists of several studies addressing the same phenomena from different viewpoints. Triangulation tied the studies to each other, created congruence over the viewpoints, and provided the research with a knowledge basis for summarizing results and conclusions. Triangulation "*means taking different angles towards the studied object and thus providing a broader picture"* (Runeson & Höst, 2009). Two types of triangulation were deployed, theory triangulation over

all studies and methodological triangulation over the experiment. Theory triangulation means using alternative theories or viewpoints, while methodological triangulation means using different data collection and analysis methods (Runeson & Höst, 2009).

In this thesis, the studies and their results are summarized into a set of conclusive findings providing answers to the research questions and a basis for the models describing the types, structures, and evolution of human capital in software startups.

1.4 Key findings

A triangulation-type research generated a set of results, each from slightly different perspectives. By combining the results, conclusive findings concerning the initial teams emerged. These fell into two categories; findings on human capital structures and findings on processes.

Though the case startups varied in several ways, the initial team's human capital followed a common structure. The structure of the initial team, consisting of three different roles, was identified in all case startups. The identified roles were *the founder*, *the expert*, and *the implementation team member*.

The identified role and human capital structure were not necessarily the personnel structure. Several founders were also playing the roles of experts and implementation team members. The *role plurality* was identified only in top-down direction, from the founder to the expert and the implementation team member. The determining factor of the founders' role plurality was their personal capabilities—the broader and deeper the founders' capabilities were, the more they also played the roles of the expert and the implementation team member.

Similarly, the identified role and human capital structure was not necessarily an organizational and managerial structure. Earlier research has identified in software startups a loose organizational structure without traditional management hierarchies (Giardino, Unterkalmsteiner, et al., 2014). The three-layered structure identified in this research represents the structure of the initial team's human capital, not its organization. Notable, however, is the founders' roles as leading persons within the startups.

The teams were built to broaden the human capital of the founder in order to cover the problem areas and tasks of the startups. Following the terminology of lean startup (Ries, 2011), the initial teams were built to achieve a *problem–human capital fit*. The initial teams with a problem–human capital fit were in balance both

externally—concerning the problem, and internally—concerning the tasks to be carried out in the startup. The similarity of the initial team structures in different case startups gives reasoning to propose the identified common structure as a generic human capital model of a software startup's initial team: a *balanced startup team*.

Building a balanced startup team was a process where three key means were identified to acquire the human capital forming a problem–human capital fit: *the founders' prior human capital*, *the team growth*, and *learning*. The weights and deployment of the means varied between the case companies along with several other factors: *the problem and the product idea*, *the founder's prior human capital*, *the customer* segment and customer *contacts*, *the availability of existing human capital*, and *the startup's financial situation*.

Though the components of the human capital in the case startups were not rare and inimitable, as defined in the resource-based view (Barney, 1991), building a balanced startup team combines them to a unique and task-specific setup that can be ranked as a *key capability* of a startup (Väyrynen, 2009).

The human capital available in the initial team strongly affected the progress of the early-stage development in the case startups. Recent literature by Ries (2011) and Bosch et al. (2013) propose iterative processes during the early stages of the evolution paths. Iteration is a means to validate the business value and to create solid customer cases for the ideas under consideration. Though the outcomes of the iterative validation rounds are unknown per se, the models present guidelines on how to progress in case of a 'failed' validation round. The iteration rounds of the models can be described as *semi-controlled*, and their purpose is to decrease the uncertainty and risk-level characteristic for early-stage startups (Paternoster et al., 2014).

Both linear and iterative processes were identified in the case startups of this research. The iterations did not, however, follow the recommendations of Ries (2011) and Bosch et al. (2013), but were unforeseen events. Most of the iterations were due to technical problems, but problems in team building were also identified. In both cases, the root cause of the iterations was human capital shortages of the founders or the initial teams.

Interestingly, the identified *uncontrolled* iterations due to human capital shortages provided the initial teams with learning in the same way as semi-controlled iterations proposed by the prior literature (Bosch et al., 2013; Ries, 2011). Thus, besides hampering the progress of the development, they contributed positively to the creation of balanced startup teams.

1.5 Structure of the thesis

This thesis is structured as follows: Section 1, 'Introduction', takes a look at the background of the research, identifying the research gap. Further, it presents the research objective and scope, including the research problem and research questions, and the overview of the research design. Finally, section 1 presents the key findings of the research.

Section 2, 'Background and related work', presents the relevant prior literature that forms the theoretical framework of this research. Each triangulation dimension is presented in separate sub-sections. Due to the broad nature of the deployed theories, the presentation focuses on such publications that address the theories in the context of entrepreneurship.

Section 3, 'Research methods and process', presents the utilized research methods and process. First, an overview on the utilized methods is presented, followed by presentation of the methods and processes of individual studies.

Section 4, 'Original publication contributions', presents the summaries of the original publications. The research objectives, research questions, and key findings of each publication are presented on a publication-by-publication basis. The contributions of the findings of individual publications to this thesis is the key content of section 4.

Section 5, 'Results', draws conclusions based on the original studies and publications, and presents the summative results addressing the research problem of this thesis. First, the answers to each research question are presented separately, then the results are summarized by presenting models describing the structure and evolution process of the human capital within software startups.

Section 6, 'Discussion', provides viewpoints on the results and findings presented in section 5, in the context of the utilized theories. The discussion on the results and findings is structured into two sub-sections; the first addressing the human capital structures, and the second discussing how the human capital affects the work processes in software startups. At the end of this section, the limitations and threats to the validity of this research are discussed.

Section 7, 'Conclusions and future research', summarizes this research, presents its contributions to the science and to practitioners, and figures out possible future research directions based on the findings and results of this research.

2 Background and related work

This research combines a set of inter-linked viewpoints on software startups in order to create a broad view on phenomena related to the human capital and its role in the structures and processes of early-stage software startups. Results of the recent research on the characteristics and processes of software startups built the anchor point, to which the other viewpoints are reflected (Bosch et al., 2013; Giardino et al., 2016; Paternoster et al., 2014; Ries, 2011). That research has a practical focus, exploring phenomena in software startups without deeper theoretical insights.

This research addresses the lack of theoretical insights from the viewpoints of the human capital. The viewpoints are derived from established theories applied to research on enterprises and entrepreneurship: the resource-based view, the human capital theory and the opportunity exploitation theories.

The utilized theories are inter-related and provide this research with a knowledge base that enables the creation of a targeted comprehensive view. The deployed theories are presented to the extent relevant to this research in sections 2.1, 2.2, and 2.3, and the related research on software startups is detailed in section 2.4. Finally, in section 2.5, a summary of prior literature, in the context of this research, is presented.

2.1 Resource-based view theory

The resource-based view is an established business theory proposing that a firm's sustainable competitive advantage is gained when a company has access to valuable resources to which competitors do not have access. Such resources are *rare*, *difficult to imitate*, or *difficult to substitute* (Barney, 1991).

In his original definition of the resource-based view Barney defined three categories of resources within a firm: *physical capital*, *human capital*, and *organizational capital* (Barney, 1991). The human capital was further divided into such areas as *training*, *experience*, and *personal characteristics of an individual*. Companies have been studied from the perspective of the resource-based view by many researchers, broadening and refining the original theory. Examples of broadened definitions of resources are: strategic resources (Combs & Ketchen Jr., 1999), and managerial resources (Peteraf & Bergen, 2003). Del Canto and González (1999), in a study of 100 Spanish companies, divided resources into tangible and intangible. Examples of tangible resources are financial and physical

assets, while intangible refers to such resources as *personnel's knowledge and skills*, and *internal procedures*.

One research path within the resource-based view is the capability approach, which defines so-called capabilities as a category of resources. Väyrynen (2009), has presented a thorough summary of the definitions and research paths of the capability approach. Most relevant definitions of capabilities in the context of this research are the definition of capabilities as company-internal processes and routines (Amit & Schoemaker, 1993; Wagner, Weitzel, & Koenig, 2005; Winter, 2003), and the definition of capabilities as core competencies in product development, gained by '*collective learning in the organization'* (Del Canto & González, 1999).

Continuous changes in business and technology have led to a definition of so-called dynamic capabilities as *'a firm's ability to build, reconfigure and integrate internal and external competencies to address rapidly changing environments'* (Teece et al., 1997). Eisenhardt and Martin (2000) made a reconceptualization of dynamic capabilities in the context of high-velocity markets. They proposed that in rapidly changing environments dynamic capabilities are '*specific organizational and strategic processes'* that follow *'best practices'* instead of being strictly company specific, and have predictable and unpredictable outcomes, depending on the market dynamics. They also claim that unique capabilities are shaped by learnings, such as *'practice, codification, mistakes, and pacing'*.

2.2 Human capital theory

The human capital theory, originally presented by Becker (1993), addresses human abilities and talents as a driver of human activity. The theory can be applied to human activities at multiple levels, from individuals to the whole of mankind. In the context of businesses, companies, and entrepreneurship, the human capital is defined as an individual's *cognitive abilities*, *experiences*, *knowledge*, and *skills*, broadened to cover the teams built up by those individuals. In a meta-analysis of 66 studies on human capital and business performance, Crook et al. (2011) found that human capital is strongly related to performance. In the context of this research, human capital is explored as a key resource of software startups.

Human capital's significant effects on several dimensions of startups' business performance were also identified by Bosma (2004). The founder's human capital was found to be especially important: '*To be more specific, former experience of the business founder in the industry in which he starts his business appears to*

improve all performance measures' (Bosma et al., 2004). Shrader and Seigel (2007), in a study on high-technology startups, identified only a weak direct link between teams' experience and startups' performance. However, a strong dependency of the long-term performance on the fit between strategy and team's technical experience was identified: '*Although there is a weak direct link between team experience and venture performance, the findings strongly suggest that the fit between strategy and team experience is a key determinant of the long-term performance of high-tech entrepreneurial ventures. For small, technology-based new ventures, the team's technological experience appears to be the most important determinant of the success of a differentiation strategy*' (Shrader & Siegel, 2007).

During the early stages of a software startup's evolution path, the human capital resources are very focused within the initial team, especially in the founder. The relationship between the founders' human capital and innovativeness was studied by Marvel and Lumpkin (2007). The founders' experience was divided into experience depth and experience breadth, and the findings indicated that experience depth affected more positively to radical innovations than experience breadth: '*Taken together, the evidence suggests that individuals with greater depth of experience and higher levels of education are better suited for recognizing opportunities with highly desired innovation outcomes*'(Marvel & Lumpkin, 2007). Marvel and Lumpkin's results differed from the findings of Lazear's study, which indicated that entrepreneurs were not necessarily experts in any specific skill area, but instead generalists with broad human capital (Lazear, 2004).

In the context of this research, the question of the sources of human capital is essential. Earlier research on the resource-based view focuses on internal sources, such as *learning* and *company-internal building of capabilities*, as described in section 2.1. Unger et al. (2011) studied the relationships between human capital and success. The authors identified a stronger relationship between success and existing human capital (prior skills and knowledge) than between success and investments on human capital (education). The value of task-specific human capital compared to general human capital was also identified. Partly contrary results were identified in a study by Martin (2013) on the formation of human capital in enterprises. The study found out that entrepreneurship-specific education and training was positively associated with both entrepreneurship-related knowledge and skills and entrepreneurship outcomes.

Negative effects of utilizing external existing human capital on the formation of company-internal human capital were reported by Hatch and Dyer (2004).

Hiring experts with prior experience from outside of a company were found to reduce internal learning, and thus internal human capital formation.

2.3 Opportunity exploiting theories

The lean startup model (Ries, 2011) focuses on the processes conducted in software startups when developing a customer case and a product from an idea. The human capital theory and the resource-based view focus on describing human capital as a resource for the running of those processes. They do not, however, address the questions of where the idea comes from and how that idea affects the future progress in software startups. This viewpoint complements the background of this research. The exploration is based on the theory of opportunity discovery and creation, presented by Alvarez and Barney (2007), Alvarez et al. (2012), and Sarasvathy (2001).

The theory of opportunity discovery and creation presents two opposite types of processes for opportunity exploiting. The opportunity discovery theory focuses on cases where business opportunities exist as objective phenomena, generated by changes in the business environment, such as technology development, changing customer preferences, or changes in national and global economics. They create autonomously competitive imperfections that are the basis of new opportunities. This theory assumes that such opportunities are just waiting to be discovered by alert individuals or teams.

In the context of this research, the key attribute of discovered opportunities is that they enable startups' founders and initial teams to figure out which kind of product or service would be a feasible implementation of the opportunity (Alvarez & Barney, 2007; Alvarez et al., 2012). The *predictability* of the product or service is the key difference, compared to the opportunity creation.

The opportunity creation theory proposes that opportunities can also be developed (Alvarez & Barney, 2007; Alvarez et al., 2012). Created opportunities do not exist autonomously, but are built by an individual's or a team's own actions (Ardichvili et al., 2003). Such opportunities may create new markets that did not previously exist. In the case of opportunity creation, the targeted product or service cannot be defined in advance, but is a result of the creation process (Mainela & Puhakka, 2009). The *uncertainty* concerning the outcome of the opportunity creation is the key difference, compared to the opportunity discovery (Alvarez & Barney, 2007; Alvarez et al., 2012; Mainela & Puhakka, 2009).

Sarasvathy (2001) defines an effectuation approach of human reasoning as a means to address the uncertainty related to the creation of new businesses. Effectuation is an actor-driven process, aimed at tackling uncertainty and contingences, instead of working towards pre-defined targets. The opposite of effectuation is causation, which is a reasoning process aimed at a pre-defined target.

The theories of opportunity discovery and creation have been used as theoretical frameworks in studies exploring opportunity exploitation as a part of entrepreneurship and creating new businesses. Wood and McKinley (2010) present a model of entrepreneurial opportunity production, pointing out the phased nature of the process: '*The model assumes that opportunity production proceeds through several stages, including conceptualization of an opportunity idea by an entrepreneur, objectification of that idea, and enactment of the opportunity into a new venture'*.

An empirical study of Ojala (2016b) explores the opportunity discovery and creation and propose two alternative pathways of the exploitation, one for opportunity discovery and another for opportunity creation. Another empirical study of Ojala (2016a) applies opportunity creation theory on a business model creation and proposes an iterative process that covers both the initial creation of the business model and its evolution over time.

2.4 Related research on early-stage software startups

Research focusing specifically on software startups has only emerged in recent years, while research on technology startups with a broader view has deeper roots. In this section, earlier research on software startups is presented from the viewpoints of startup models and processes, software startup characteristics, and software startup challenges.

Until now, research on startups has presented a variation of models describing the early stages of the new company. Compared to established companies, a startup faces bigger and faster changes in business, technology, personnel, and operations. Thus, typical software startup models are phased, e.g. the progress of a startup is divided into stages with different characteristics. Early startup models were proposed by Crowne (2002) and Blank (2013), who both identified four phases in the evolution of a startup, following each other in a *linear* manner.

Linear startup models were later developed further by addressing the fact that startups do not necessarily follow a linear progress path. The lean startup model (Ries, 2011) defines an *iterative* process model where the progress in software

contains modifications, steps back, and restarts. Lean startup covers the evolution path of a startup from idea to growth, but the biggest interest has been in the early phases, focusing on creating a validated customer case in order to avoid the waste of developing products without market potential. Creating a customer case is performed by measuring the business value of an idea together with the targeted customers. Lean startup defines concepts of its own for describing the evolution and processes of the early-stage startup: *the problem-solution fit*, the *product-market fit*, *the build-measure-learn loop*, *the minimum viable product*, and *pivoting* (Ries, 2011).

Instead of developing the final product all at once, a startup following the lean startup model develops minimum viable products. These are then used to collect customer feedback that provides the startup with validated learning. Based on this information, a decision is made, whether to continue from the minimum viable product to the final product, or to modify the idea and build a new minimum viable product. The steps are repeated until the problem-solution fit and the product market fit have been achieved, or a decision to abandon the product idea is made.

Iteration in the lean startup model is based on the assumption that unsuccessful product ideas are so probable that the possibility of failure should be taken into account from the very beginning. The negative consequences of a failed idea are minimized by the development of minimum viable products, instead of the final product, by learning from each failure, and by keeping the next steps after a failure under control. Though in the beginning the outcome of each validation round is unknown, the process itself is under control, and the iterations can be defined as *semi-controlled* iterations.

The early stage software startup development model (ESSSDM) (Bosch et al., 2013) puts even more focus on the possibility of unsuccessful product ideas. It presents a funneling-type process, applying lean startup principles to a set of alternative ides. It proposes that a startup should have, from the beginning, several product ideas, among which the process refines the best one(s) to be continued into the product development phase.

Wang et al. (2016) divided the evolution of software startups into six phases, *concept*, *in development*, *working prototype*, *functional product with limited users*, *functional product with high growth*, and *mature product*. The authors studied the challenges of software startups across the lifecycle phases. *Building the product* was the biggest challenge, followed by *customer acquisition*, *funding*, and *building the team*. In the early phases, such challenges as *acquiring initial funding*, *building*

a minimum viable product, creating a business model, acquiring first paying customers, and *mastering technological uncertainty* were identified.

A different view on software startups is taken in a thorough literature study by Paternoster et al. (2014), summarizing fifteen characteristics typical for early stage software startups. Several characteristics identified in the study represent challenges for the progress of a software startup, as shown in table 1.

Table 1. Characteristics of software startups (Paternoster et al., 2014).

Characteristic	Description
Lack of resources	Economical, human, and physical resources are extremely limited
Highly reactive	Startups are able to quickly react to changes of the underlying market, technologies, and products (compared to more established companies)
Innovation	Given the highly competitive ecosystem, startups need to focus on innovative segments of the market
Uncertainty	Startups deal with highly uncertain ecosystems from many perspectives: market, product, competition, people, and finance
Rapidly evolving	Successful startups aim to grow rapidly
Time pressure	The environment often forces startups to release fast and to work under constant pressure (terms sheets, demo days, investors' requests)
Third-party dependency	Due to lack of resources, to build their product, startups rely heavily on external solutions: External APIs, open source software, outsourcing, commercial off-the-shelf solutions, etc.
Small team	Startups start with a small number of individuals
One product	A company's activities gravitate around one product/service only
Low-experienced team	A good part of the development team is formed by people with less than five years of experience and often recent graduates
New company	The company has been recently created
Flat organization	Startups are usually founder-centric and everyone in the company has big organizational responsibilities, with no need of high-management
Highly risky	The failure rate of startups is extremely high
Not self-sustaining	Especially in the early stages, startups need external funding to sustain their activities (venture capitalist, angel investments, personal funds, etc.)
Little work history	The basis of an organizational culture is not present initially

Giardino et al. (2016) presented the Greenfield Startup Model, covering several key characteristics of the early-stage software startups. This model proposes that the need to speed up the work is the key driver in software startups' product development. Together with a severe lack of resources, it causes in software startups such phenomena as low priority of quality issues, an evolutionary

development approach, and deployment of light-weight methodology without applying standard development processes.

Less systematic deployment of standard development processes were also identified by Klotins et al. (2015a), studying software engineering in startups in accordance to the Guide to the Software Engineering Body of Knowledge (SWEBOK) (Bourque & Fairley, 2014). Also, the results of Coleman and O'Connor (2008) indicate that, instead of following standard processes, startups build the work practices on the basis of the founders' prior experiences.

2.5 Summary of prior studies in the context of this research

Prior literature on software startups is used in this research as the basis of the exploration, including lean startup model (Ries, 2011), ESSSD model (Bosch et al., 2013), and research into the characteristics and challenges in software startups (Giardino, Unterkalmsteiner, et al., 2014; Paternoster et al., 2014; Wang et al., 2016). The process described by the lean startup model starts with a product idea, the business value of which is validated with a set of minimum viable products in the build-measure-learn loop. The lean startup model does not address the question how the idea is formed. Thus, in the context of this research, the lean startup model is complemented by the opportunity discovery and creation theories (Alvarez et al., 2012; Sarasvathy, 2001).

Earlier research into the human capital theory, in the context of entrepreneurship, validates the assumption that human capital is a valuable resource of software startups (Bosma et al., 2004; Crook et al., 2011; Lazear, 2004; Shrader & Siegel, 2007; Unger et al., 2011). The human capital theory points out human capital's contribution to a company's business performance, while the resource-based view points out the uniqueness of resources as a basis for a company's sustainable advantage. Recent research on software startups, however, suggests such attributes of software startups as lack of resources, third-party dependency, small teams with little experience, short work history, and time pressure. As a consequence, software startups face such problems as less systematic deployment of processes, low priority of quality issues, and problems in building their products (Giardino et al., 2016; Klotins et al., 2015a; Wang et al., 2016).

3 Research methods and process

In this section the research methods and process of this thesis are presented. First, the research methods are presented together with the overall research approach, followed by the research process. As the research consists of four inter-linked studies, the section is complemented by presenting the research processes of each study in detail.

3.1 Research methods

This research is an empirical, exploratory, qualitative, multi-case study, structured following the principles of *triangulation*. Triangulation means studying the same phenomena from different viewpoints to increase the precision of empirical research (Runeson & Höst, 2009). This thesis consists of four studies, S1, S2, and S3, which are tied together by theory triangulation, and study S4 representing methodological triangulation.

Theory triangulation studies the same phenomena from the viewpoints of different theories or research traditions. The key triangulation angles of this research were the role of human resources in entrepreneurship and the recent research on software development in startups. The human resources viewpoint is combined with three interrelated theories, human capital theory, resource-based-view, and opportunity exploitation theories, as shown in figure 1.

To maintain congruence with the results over the studies, and to enable triangulation, the same study methods were deployed in studies S1, S2, and S3, while study S4 utilized a different research method. Table 2 presents a summary of the applied research methods.

Table 2. Research methods summary.

Study	Literature study	Empirical data gathering	Analysis method
S1	Systematic mapping study	Interview	Qualitative analysis
S2	Snowballing study	Interview	Qualitative analysis
S3	Snowballing study	Interview	Qualitative analysis
S4	Systematic mapping study	Student experiment	Qualitative and quantitative analysis

3.1.1 Methods for gathering the research data

As the objective of this study was to explore human capital in software startups empirically, selecting the methods for gathering the empirical research data was a key part of selecting the research methods to be utilized. Wohlin et al. (2012) lists three strategies for conducting empirical research of software engineering: a survey, a case study, and an experiment. Studies S1, S2, and S3 were multiple-case studies using interviews with case startups for the gathering of research data and qualitative analysis methods for data analysis. Study S4 used an experiment to research data gathering and quantitative methods for data analysis.

The interviews for studies S1, S2, and S3 were semi-structured, as presented by Runeson and Höst (2009). Semi-structured interviews were opted for because it was assumed that face-to-face interviews of key persons with a broad interview schema would provide a broad coverage of the early-stage phenomena in software startups. Semi-structured interviews allowed the interviewees to focus on areas that were especially relevant to their startups, and utilizing the key informant technique (Marshall, 1996) gathered a broad basis of research data fitting to the triangulation-type research approach.

Conducting surveys to cover the triangulation viewpoints would have required a broad survey or a set of surveys covering a limited number of viewpoints each. With a single broad survey there would have been a risk that it would be unpractical and time-consuming to answer, decreasing the response rate. Deploying several smaller surveys would have brought a risk of heterogeneous groups of respondents, jeopardizing the congruence of the results. Observations, as proposed by Seaman (1999), were not seen as an applicable method due to practical difficulties.

Startup ecosystems and the cooperation of startups in ecosystems has gained increasing attention among the entrepreneurs and researchers (Cukier et al., 2016; Olsson Holmström & Bosch, 2015). The research data gathered for studies S1, S2, and S3 revealed that the case startups were not active in any ecosystem, though two case startups had hired their premises at local startup incubators. To gather the research data for study S4, an experiment was conducted focusing on the cooperation in a virtual startup ecosystem. A group of students of the University of Oulu were used as subjects in the experiment. The quantitative research data for this study were gathered directly from the experiment by automatic means, while the participant reflections were gathered by a questionnaire.

The qualitative research data collected in the interviews for studies S1, S2, and S3 were analyzed following the guidelines for thematic and narrative synthesis

(Cruzes, Dybå, Runeson, & Höst, 2015), and the research data for study S4 were analyzed utilizing statistical methods for the quantitative data and narrative synthesis for the qualitative data, as described in more detail in section 3.1.2.

3.1.2 Methods for analyzing the research data

The research data for studies S1, S2, and S3 were qualitative, while the experiment of study S4 generated both quantitative and qualitative data. The analysis of the qualitative data of all studies was carried out by utilizing thematic synthesis methods, narrative synthesis methods, or combinations of the two (Cruzes et al., 2015). The summary of the research data analysis methods is presented in table 3.

Table 3. Methods of research data analysis.

Study	Analysis method
S1	Thematic synthesis
S2	Thematic synthesis, narrative synthesis
S3	Thematic synthesis, narrative synthesis
S4	Paired-sample t-test, descriptive statistics, narrative synthesis

The data analysis method used in studies S1, S2, and S3 was thematic synthesis (Cruzes et al., 2015), but it was complemented by narrative synthesis in studies S2 and S2, where thematic synthesis revealed a remarkable heterogeneity of the research data.

In study S4, the design of the experiment led to the utilization of the paired-sample t-test in the statistical analysis of the research data. The analysis was complemented by descriptive statistics and narrative synthesis of the participant reflections.

3.1.3 Literature study methods

The empirical studies, S1, S2, S3, and S4, were initiated by related literature studies, which provided the empirical studies with the background knowledge. The literature studies were conducted following the guidelines set up for systematic mapping studies by Kitchenham et al. (2011) and Petersen et al. (2008). Screening of the papers was conducted along with the systematic mapping process set up by Petersen et al. (2008).

The first literature study of this research, focusing on software startups in a broad manner, was conducted as a part of study S1. The other studies were conducted, and the publications written, fairly late compared to the first literature study. To identify the most recent literature, snowballing, as set out by Wohlin (2012), was utilized as a part of next literature studies in order to update the knowledge gathered in the first study.

Though the literature studies followed the guidelines of systematic mapping studies, no separate publications presenting their results were written. The results were used as a baseline for the empirical part of this research, as proposed by Kitchenham et al. (2011): as '*a means of identifying relevant literature for the "related research" section in other primary studies*' and as '*a baseline for empirical research of various kinds*'.

3.2 Research process

This research consisted of four interrelated studies, S1, S2, S3, and S4, and explored answers of the following research problem: "*What are the characteristics of the human capital in early-stage software startups and how does the human capital affect a startup's initial team and work processes?"*

The studies were conducted between May 2015 and July 2017. Publications P I and P II presented the results of study S1, publication P III the results of study S2, publication P IV the results of study S3, and publication P V the results of study S4. Each study consisted of four main parts, *studying the relevant literature*, *gathering the empirical research data*, *analyzing the research data*, and *writing publications*. Figure 2 presents the time-lined structure of the research, its studies, original publications, and the research questions explored in each study. As shown in figure 2, study S4 was conducted parallel to study S2 and before study S3 due to practical reasons related to conducting the student experiment.

The first step of each study was a literature review. In S1 this focused on the recent research on software startups, creating the knowledge basis of the whole thesis. After that, the literature studies for S2, S3, and S4 focused on the specific research into the triangulation angles of the corresponding studies: human capital and resource-based view theories in S2, opportunity exploiting theories in S3, and startup ecosystems in S4.

The empirical research data for studies S1, S2, and S3 were gathered by conducting two semi-structured interviews I 1 and I 2. Study S1 was based on the research data gathered in interview I 1, while studies S2 and S3 also utilized the

additional research data of interview I 2. Both interviews I 1 and I 2 generated qualitative research data. The empirical research data for study S4 were gathered from the student experiment, and were mostly quantitative in nature.

Each study had a data analysis phase of its own, as shown in figure 2. The research data of studies S1, S2, and S3 were analyzed by using qualitative analysis methods, and the research data of study S4 with quantitative analysis methods, as presented in section 3.1. Analyzing the research data and writing the publications were typically conducted at the same time, except for S1, which generated results presented in two publications P I and P II.

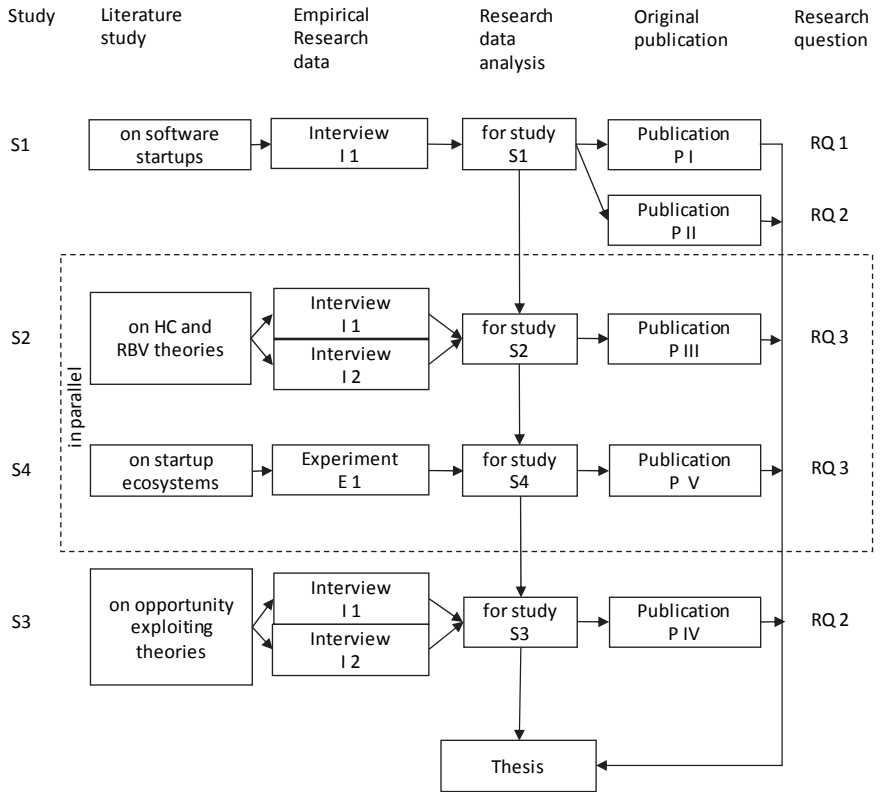

Fig. 2. Research process, original publications and research questions.

3.2.1 Study S1

Study S1 was the basic part of the research, exploring answers to the research questions RQ1: "*How are the human capital areas structured in the initial team of early-stage software startups?",* and RQ2: "*How does the founders' human capital affect the idea-related processes in early-stage software startups?"*

Study S1 was initiated by a literature review focusing on software startups with a broad scope. It was conducted following the guidelines set up by Kitchenham et al. (2011) and Petersen et al. (2008). The literature study began in January 2015 by searching Google Scholar with the search string "software startup". The search generated 947 hits.

Screening of the papers was conducted along with the systematic mapping process set up by Petersen et al. (2008). Screening resulted in 41 publications, focusing on a broad variety of research areas on software startups. Further screening narrowed down to the 11 most relevant publications.

The empirical data for study S1 was gathered by conducting interviews with 11 key persons from nine software startups. The interviews followed the key informant technique (Marshall, 1996), where the interviewees were the founders or co-founders of the case startups. In two cases, where the founders did not have personal experience in software technology, a software expert participated in the interview. Interviews were of the semi-structured type, guided by a broad interview schema, which gave the interviewees the freedom to point out areas of special interest. The interviews are summarized in table 4.

Table 4. S1 Interview summary.

Startup	Location	Product type	Interviewees
A	Italy	WEB application	Founder
B	Norway	WEB application	Founder, software expert
C	Norway	WEB/Mobile application	Founder, software expert
D	Finland, Oulu area	Instrument, embedded software	Founder
E	Finland, Oulu area	Instrument, embedded software	Co-founder
F	Finland, Oulu area	IOT device, embedded software	Co-founder
G	Finland, Helsinki area	Aircraft maintenance software	Founder
H	Finland, Helsinki area	Graphical UI platform	Founder
I	Finland, Oulu area	Imaging system, embedded software	Co-founder

In the interviews, 106 pages of transcribed data were gathered for analysis. The data were used for writing two publications, I and II, as shown in figure 2. The data were analyzed separately for both publications, focusing on the viewpoints of the respective articles. Both analyses were conducted as a combination of deductive and inductive thematic synthesis, as recommended by Cruzes and Dybå (2011) and Cruzes et al. (2014).

The study resulted in one publication per focus area. Publication I handled the competency areas and related roles of the initial team members, while publication II took a look at the processes conducted to validate the product idea.

3.2.2 Study S2

Study S2 explored answers to research question RQ3: "*How is the human capital acquired in early stage software startups?"*

This study was triggered by the findings of S1, which revealed highly specialized roles within the initial team (publication I), and by the findings of earlier research into software startups, highlighting such characteristics as limited resources and small and inexperienced teams (Paternoster et al., 2014).

Study S2 was grounded in a literature review focusing on existing theories of human capital and entrepreneurship: the human capital theory (Becker, 1993), the resource-based view (Barney, 1991), and their recent refinements and derivatives. The literature study was conducted using the snowballing method as set up by Jalali and Wohlin (2012) and Wohlin (2014), and its results were used to broaden the literature basis built in study S1. The seed document of the snowballing was Väyrynen's doctoral thesis (2009), with its thorough summary of literature on the resource-based view and the capability approach. The literature review gained, besides the seed, 34 publications on human capital theory and 48 publications on the resource-based view. After screening, 14 publications on the resource-based view and nine publications on human capital theory were selected for study S2. The large number of publications on the human capital and resource-based-view indicated the longevity of the theories compared to research on software startups.

The empirical part of study S2 was based on the same research data as study S1. For the research targets of study S2, the data was broadened by four new case companies. Even this interview round was initiated by contacting a larger number of software startups with an invitation to be interviewed, but only four positive responses were received. The additional research data were gathered by using a

semi-structured interview, as in study S1. A summary of interviewed companies is shown in table 5.

Table 5. Additional interviews for S2 and S3.

Company	Location	Product type	Interviewees
J	Finland, Oulu area	WEB application	Founder
K	Finland, Oulu area	Instrument, embedded software	Hired CEO
L	Finland, Oulu area	Software development services	Founder
M	Finland, Oulu area	Special IT services	Founder

Case companies L and M were businesses that offered human capital resources to other companies. The research data gathered from them broadened the view of study S2, from startup-internal resource needs to external offering of human capital resources. Case company L was an established middle-sized software house focusing on providing client companies with highly-qualified software development resources on a subcontracting basis. Case company M was a startup offering special IT services to client companies. Software startups built a substantial part of the client base of both companies L and M.

The four broadening interviews for study S2 were conducted with an interview schema stripped from that of study S1. The interview schema focused on the human capital and human resourcing topics but, similarly to interview I1, the interviews also covered areas of special interest for the interviewees (Runeson & Höst, 2009). The interviews gained 25 additional transcribed pages of empirical research data.

In study S2 all of the interview data gathered for studies S1 and S2 were analyzed qualitatively by utilizing a combination of the thematic synthesis and narrative synthesis methods, as set up by Cruzes et al. (2015). A decision to broaden the analysis with narrative methods was made during the thematic analysis. The reason was the heterogeneous nature of the research data addressing the human capital acquiring in the case startups.

Study S2 focused on the means utilized by software startups to gather the human capital required to conduct the work items in the early stages of the evolution paths. The results of study S2 were published in publication III.

3.2.3 Study S3

Study S3 broadened the findings of study S1 by exploring further viewpoints to the research question RQ2: "*How does the founders' human capital affect the idea-related processes in early-stage software startups?"*

Study S3 was triggered by the findings of study S1. The results, published in publication II, revealed that the innovation validation is a longitudinal process expanding from the founders' first idea to the elicitation of the product requirements. Study S3 focused on the earliest stages of a software startup's evolution path, the innovation and business opportunity exploitation.

Study S3 was grounded in a literature review focusing on existing theories of opportunity creation and discovery (Alvarez & Barney, 2007), and the prior literature related to those theories. The literature review was conducted utilizing the snowballing method, following the guidelines of Jalali and Wohlin (2012) and Wohlin (2014). Snowballing was started from an empirical study of Ojala (2016a). The literature review of S3 expanded the existing literature study base by 19 publications, focusing on opportunity discovery and creation. During screening six publications were evaluated as primary papers for study S3.

The research data collected in the interviews of studies S1 and S2 were utilized as the empirical research data of study S3. Data were analyzed qualitatively following the practices of study S2, e.g. by utilizing a combination of the thematic synthesis and narrative synthesis methods, as set up by Cruzes et al. (2015). The weight was on the side of the narrative synthesis due to an even higher level of heterogeneity of the research data than in study S2.

Study S3 focused on opportunity discovery and creation as a triggering mechanism of founding a software startup. The results of study S3 were published in publication IV.

3.2.4 Study S4

Study S4, in turn, broadened the findings of study S2 by exploring further viewpoints of the research question RQ3: "*How is the human capital acquired in early-stage software startups?"*

While studies S1, S2, and S3 were empirical studies on real-life startups, study S4 was an experiment conducted with a group of master's-level students in a software engineering course at the University of Oulu. Study S4 was conducted parallel to study S2, as shown in figure 2. The experiment of study S4 simulated

the effect of an ecosystem-type cooperation of two startups in the effort estimation phase of the requirements elicitation process. The experiment was triggered by the findings of Giardino et al. (2014) and Paternoster et al. (2014), which highlighted missing or limited resources as a characteristic of software startups.

The experiment was conducted following the guidelines set up by Easterbrook et al. (2008), Runeson (2003), and Wohlin (2012). Thirty-three students participating in the experiment were divided into teams simulating two startups, a startup under study and a potential competitor startup in the ecosystem. The startup under study was further divided into an experiment group and a control group. The experiment group and the control group conducted a simulated project, one with and the other without co-operation with the potential competitor startup. Students with prior software development experience were selected to be part of the potential competitor team, which simulated additional human capital in the experiment.

Because the simulated project focused only on the effort estimation as a part of requirements elicitation, without corresponding design and implementation of the estimated features, a reference estimation was used when comparing the estimations of the experimental group and the control group. The reference was generated by the author of this thesis, having a broad experience in software development and management. The reference estimation was completed without the author's any other participation to the experiment, and it was based on the very same information that was given to the experiment groups. The reference estimation included a three-level complexity classification that was used as reasoning for the given estimations. The complexity levels were local supporting functionality, local key functionality, and distributed network functionality.

The results of the experiment were analyzed with quantitative methods, utilizing paired sample t-tests and descriptive statistics to compare the estimations of the experiment group and the control group. Participant reflections, collected in the experiment, were analyzed utilizing the narrative method (Cruzes et al., 2015). Study S4 focused on networking with other companies within ecosystems. The results of study S4 were published in publication V.

4 Original publication contributions

In this section, the original publications are presented. It covers the research questions and the results of the individual publications. Also, the author's contributions to the original publications as well as the publications' contributions to this thesis are presented. First a summary is introduced in a table format, followed by the original publications, one by one.

4.1 Summary of original publication contributions

This research was conducted through four studies, as presented in section 3.2. Out of those studies, five articles were published at well-recognized scientific conferences. A summary of the publications, their purpose, main findings and contributions to this thesis, and the author's contributions to the publications, is presented in table 6.

Table 6. Summary of the original publications, their contributions to the research, and the author's contributions to the publications of this thesis.

Publication	Purpose	Findings and contributions to the research	Author's contributions to the publication
P I Seppänen P, Oivo M, Liukkunen K: The initial team of a software startup, Narrow-shouldered innovation and broad-shouldered implementation. 22nd ICE/IEEE International Technology Management Conference (2016)	Opening publication of the research, focusing on the competency structures and roles within the initial team. Initiated by the prior literature on the software startups.	The findings revealed the key role of the founder, the role of the expert supplementing the human capital of the founder, and the strict focus of the rest of the team on implementation-related tasks. The key contribution to the research was the structure of the initial team, the founder, the expert, and the implementation team, providing the research with the basics of the concept of a balanced initial team.	The author was in charge of planning the research, gathering the research data, analyzing the data, drawing conclusions, and writing the publication.

Publication	Purpose	Findings and contributions to the research	Author's contributions to the publication
P II Seppänen P, Tripathi N, Oivo M, Liukkunen K: How Are Product Ideas Validated? The Process from Innovation to Requirement Engineering in Software Startups. 22nd International Conference of Software Business (2017)	Focusing on the key task of early-stage software startups. Initiated by the findings of publication P I and the findings of the prior literature, on software startups especially Ries (2011) and Bosch et al. (2013).	The findings highlighted idea validation as a key learning process, increasing the human capital of the initial team. The founders' prior human capital was found to contribute to the progress of the validation process: the stronger the existing human capital, the smoother the validation process. The basics of the concepts of uncontrolled iterations and the problem–human capital fit were identified.	The author was in charge of planning the research, gathering the research data, analyzing the data, drawing the conclusions, and writing the publication. Writing the sections related to requirements engineering was supported by the second author.
P III Seppänen P, Oivo M, Liukkunen K: Little Big Team: Acquiring Human Capital in Software Startups. 18th International Conference on Product-Focused Software Process Improvement (2017)	Focusing on the means, utilized in software startups, for acquiring the human capital of the initial team. Initiated by the findings of publications P I and P II, the theories on human capital and the resource-based view (Barney, 1991; Becker, 1993).	Deepened the understanding of concepts of the balanced initial team and the problem–human capital fit by focusing on the means utilized in software startups to achieve the status defined by the aforementioned concepts. The findings revealed that the uniqueness of the human capital resources is not a relevant topic in software startups per se, but the balanced initial team and the problem–human capital fit built by growth and learning create a unique capability of a software startup.	The author was in charge of planning the research, gathering the research data, analyzing the data, drawing the conclusions, and writing the publication.

Publication	Purpose	Findings and contributions to the research	Author's contributions to the publication
P IV Seppänen P, Oivo M, Liukkunen K: Opportunity Exploitation in Software Startups. A Human Capital View. Submitted to 9th International Conference on Software Business (2018)	Focusing on the earliest stages of a software startup, discovering the business opportunity and creating the product idea, from the viewpoint of human capital. Initiated by publications P I, P II, P III, and theories on opportunity discovery and creation (Alvarez & Barney, 2007; Sarasvathy, 2001).	Complemented the findings of publication P II by presenting a theoretical framework for the concept of uncontrolled iterations. Deepening the understanding of the human capital's role in defining the progress of the work processes in early-stage software startups.	The author was in charge of planning the research, gathering the research data, analyzing the data, drawing the conclusions, and writing the publication.
P V Tripathi N., Seppänen P, Oivo M, Liukkunen K: The Effect of Competitor Interaction on Startup's Product Development. 43rd Euromicro Conference on Software Engineering and Advanced Applications (2017)	Reporting an experiment studying the effects of ecosystem-type cooperation as a means to increase the quality of effort estimations as a part of the requirement elicitation process.	Complemented the findings of publication P III by focusing on a means to acquire additional human capital by cooperation in ecosystems. The findings of the experiment indicated that cooperation in ecosystems contributes positively to a team's human capital and to achieving the problem–human capital fit.	The author of this thesis was in charge of the reference estimations and descriptive statistics and, together with the first author, conducted the quantitative analysis and hypothesis testing, as well as writing the publication.

4.2 Publication I: The initial team of a software startup, Narrow-shouldered innovation and broad-shouldered implementation

Publication I presented the findings of study S1, focusing on the roles and competency structures of the initial team of startups. It presented the answers to

two research questions: 1) *what are the characteristic competencies of the initial team in a software startup?,* and 2) *how do the characteristic competencies reflect the internal composition of the initial team?*

Publication I presented empirical research based on prior literature on software startups (Bosch et al., 2013; Klotins et al., 2015a; Paternoster et al., 2014; Ries, 2011). The findings revealed that, even in a small initial team of a software startup, there is a functional structure resembling those of bigger and more established companies. In a startup, the structure consisted of innovation-related functions and implementation-related functions.

Activities related to the innovation were *creating a business case, seeking funding for the development*, and *general ownership of the innovation itself*. The implementation-related activities dealt with getting the innovation implemented, and consisted of *software development, process development*, and *development in other disciplines but software*. The characteristic competencies needed to carry on each function differed from each other, highlighting the breadth of the competency palette of the initial team.

From the competency perspective, three key roles were presented in publication I: *the role of the founder*, *the role of an expert*, and *the role of the implementing team member*. Though the case startups varied from each other, the role structure and the responsibilities were found to be similar. The personnel structures, in turn, did not follow the role structures but varied between the case startups, especially concerning the founders; founders with strong prior experience in software development also played the roles of an expert and a software developer. In the case of founders without prior software abilities, such multi-role participation to the work was not identified.

The key findings presented in publication I were as follows:

1. The innovation-related functions—ownership of the idea, seeking funding, and creating the business case—were remarkably focused on one person only; the founder. Even in cases with several co-founders, the innovation typically originated from a single person, whose role in the initial team was to drive the innovation-related functions.
2. On the implementation side, the responsibility over software and other disciplines fell to every team member, and depended on them having the abilities required. This highlighted that the development work itself required

contributions from all members of the initial team, who had the corresponding skills, including the founder.

3. An expert's role in the initial team was twofold: to compensate for the human capital shortages of the founder, and to bring human capital to specific problem areas and technologies.

The findings of publication I highlight the significance of the founder's role in a software startup: founders were at least responsible for business-related tasks, and multi-talented founders brought several competency areas to the initial team. The key contributions of publication I to this thesis were: 1) *that innovation and innovativeness was focused on the founders*, and 2 *that each identified role had to be filled, and each competency area had to be taken care of, by persons with relevant abilities*. In other words, the initial team of a software startup needed to have an ability structure that is in balance with the problems that are likely to arise.

Publication I provided answers to the research question RQ1. This created the knowledge base that was used to create the concept of the *balanced initial team* by identifying its key roles. The findings of publication I also triggered the writing of publication II, as well as conducting studies S2 and S3.

4.3 Publication II: How to Validate a Product Idea? The Process from Innovation to Requirements Engineering in Software Startups

Publication II was based on the findings of study S1, in the same way as publication I. Publication II presented the characteristics of the work conducted in software startups in their early stages. It focused on the means, utilized in software startups, for validating and refining the innovation and turning it into an implemented product. Answers to two research questions were presented: 1) *what practices are utilized when transforming an innovation into a product in software startups?* and 2) *in what way do the prior competencies of the innovator/founder affect the idea validation practices?*

In publication II, 10 idea validation practices were identified. The practices fell into three categories: pure engineering-related, pure business-related and both engineering- and business-related. The engineering practices that were identified were: *technology feasibility study, prototyping* and *expert support*. In the business category, there were two practices: *market study* and *pivoting* (Ries, 2011). Five out of 10 practices had both engineering and business relations: *copying existing*

products, Minimum Viable Product (Ries, 2011)*, close customer co-operation, home company support* and *educational support*.

The key findings presented in publication II were as follows:

1. Though earlier research into startup models focuses on validating the business value of a product idea (Bosch et al., 2013; Ries, 2011), validating the technical feasibility was equally important.
2. The utilization of the idea validation practices varied a lot and was context-dependent in the case startups.
3. Borrowing ideas from similar existing products was very common in the case startups, raising questions of innovativeness.
4. Drawing detailed conclusions from the role of the founders' prior experiences and abilities was difficult due to context dependencies, but two extreme ends were identified: the founders with strong task-specific experience tented to rely on their own judgement and did not utilize many external parties for validating. On the other hand, the founders with limited experience utilized a broad variety of means.
5. The smoothest process from the idea to the product was identified in the cases when the founder had relevant human capital in the application area. Human capital shortages, in turn, tended to lead to iterative processes, in which the iterations were not under control, as is proposed in iterative startup models (Bosch et al., 2013; Ries, 2011).
6. Building a uniform process covering the practices or setting them in a priority order was not reasonable, as also noted in prior literature (Klotins, Unterkalmsteiner, & Gorschek, 2015b; Paternoster et al., 2014).
7. The idea validation practices were means to both tackle the uncertainty tied to the idea and the aimed product, and learning points filling the human capital gaps of the initial team.

In publication II, the key task of early-stage software startups, validating the innovation and bringing it towards the product implementation, was the focus. The findings revealed that the application area competencies available in the startup smoothen the way for the innovation of the product. The key contributions of publication II to this thesis were: 1*) that utilizing existing similar products as the basis of the startup's innovation process was a common means to reduce uncertainty*, and 2) *that idea validation was an excellent learning process, as pointed out by prior literature* (Ries, 2011). Learning within the validation process

were identified as an important means of acquiring additional human capital. The value of learning was further increased, because it created task-specific human capital and filled up the human capital gaps of the founders and the initial teams.

Publication II contributed to this thesis by providing evidence to answer the research question RQ2, focusing on the actual work practices deployed in validating the technical and commercial value of the product idea. Publication II created basic knowledge of the concept of *uncontrolled iterations* as the opposed to the *semi-controlled iterations* proposed by iterative startup models (Bosch et al., 2013; Ries, 2011). While missing human capital was identified as the primary reason for uncontrolled iterations, learning gathered along to the iterations was found to be a key means to increase human capital and to achieve the *problem–human capital fit* in the initial team.

4.4 Publication III: Little Big Team: Acquiring Human Capital in Software Startups

Publication III focused on presenting the means, utilized in startups, to get the human capital needed to realize innovation. Publication I focused on functional roles identified in the initial teams of startups, and publication II focused on the idea validation means, finding out that learning from the idea validation process was a valuable means of gathering additional human capital for the initial team. Publication III continued from the findings of publications I and II, and addressed more broadly the means to acquire human capital in software startups. It presented answers to the following three research questions: 1) *what are the engineering-related capabilities in a software startup*, 2) *what are the means of acquiring those capabilities*, and 3) *what are the reasons for deploying different capability-acquiring means*.

(Barney, 1991) defined human capital as a key resource of a firm. On the other hand, Paternoster et al. (2014) identify fifteen characteristics of software startups, out of which nine are related to the limited availability of human capital, as presented in table 1.

The key findings of publication III were as follows:

1. The founders' prior human capital was the basis of the human capital of a software startup in all identified capability areas; *application domain*, *special technology domain*, *systematic work domain*, and *software domain*.

2. A multitude of context-dependent drivers affected the deployment of the means for acquiring human capital.
3. All human capital acquiring means, besides the founders' prior human capital, fell into two main categories; *learning* and *growth*. Learning-related means especially contributed to the application and special technology domains, while growth contributed mostly to the software domain.
4. Human capital in software startups could not be identified as a unique resource ensuring sustainable advantage, as proposed by Barney (1991). Instead, a startup's ability to rapidly create difficult technology and complex products with a small team was the key component of its human capital, and represented the uniqueness of its resources.

Publication III broadened and deepened the findings of publication II, suggesting that learning gathered in the idea validation process are a means of increasing the initial human capital of software startups. It identified four capability areas and found that the human capital for all of them are results 1) *of the founders' prior capabilities*, 2) *of learning from a variety of sources, not only from the validation process studied in publication II*, and 3) *of targeted growth*.

In publication II learning from the idea validation process was found to bring task-specific and gap-filling human capital to the initial team. Learning from different sources, identified in publication III, were similarly valuable: *learning from existing products, from prototyping and testing, from customer cooperation*, and *from research*. Similarly, targeted growth by hiring experienced or inexperienced employees or using subcontractors increased the human capital of the initial team.

The findings of publication III indicate that human capital resources acquired by growth do not necessarily represent the uniqueness pointed out by resource-based view (Barney, 1991). The case startups selected additional team members fitting to their initial teams' capability needs, the startups' evolution phases, and the economic imperatives, without paying special attention on their uniqueness. Learning, in turn, created company-specific and task-specific capabilities, proposed in earlier research to be unique resources.

Publication III provided this thesis with answers to the research question RQ3. It broadened the knowledge base that was used to figure out the concepts of the *balanced initial team* and the *problem–human capital fit,* which were emerging based on the results of publications I and II.

4.5 Publication IV: Opportunity Exploitation in Software Startups. A Human Capital View

Publication IV complemented the studies by focusing on the very first phase of a software startup, exploitation of the business opportunity, and innovating a product addressing the opportunity. The perspective of publication IV is the founders' human capital, their prior experience, abilities, knowledge, and skills. The research applied opportunity creation and discovery theories, the resource-based view and the human capital theory as the theoretical framework (Alvarez & Barney, 2007; Barney, 1991; Becker, 1993; Sarasvathy, 2001).

Publication IV sought answers to the following research questions: *1) what are the characteristics of the software startups' opportunity exploitation processes?,* and *2) what are the effects of the founders' human capital on the opportunity exploitation processes?* The findings of publication IV tied together the publications II and IV by presenting a theoretical framework of the idea identification and validation processes conducted in the early stages of a software startup's evolution path.

The key findings in publication IV were as follows:

1. The characteristics of the opportunity discovery and creation co-exist in the same opportunity exploitation and idea validation process.
2. The founders take actions typical for the opportunity discovery and creation theories in a context-dependent and situational way, where the determining factor for the actions is the uncertainty of the future.
3. Uncertainty concerning the business opportunity and idea creates cyclic, iterative processes for opportunity exploitation and idea validation.
4. The founders' human capital is both a source of and a solution to the uncertainty. A lack of prior human capital increases the uncertainty and causes iterative processes. Learning in the iterations create new human capital for both the founders and the initial teams, decreasing the uncertainty.

Publication IV contributed to this thesis by providing answers to the research question RQ2, and by complementing the findings presented in publication II. The founders' human capital had a strong correlation with uncertainty and the iterative nature of the opportunity exploitation and idea validation processes. The founders' strong human capital tended to lead to a smoother and more linear opportunity exploitation and idea validation processes, while, in the opposite cases, the

processes were characterized by uncontrolled iterations. Compensation for the human capital shortages of the founders by learning from the iterations and by targeted growth of the initial team decreased the uncertainties and smoothened the processes.

The findings of publication IV were partly aligned to earlier research on the opportunity exploitation processes (Alvarez & Barney, 2007; Sarasvathy, 2001). While the opportunity exploitation theories (Alvarez & Barney, 2007; Sarasvathy, 2001) focus on the origin of the opportunity, discovered or created, as a determining factor of the process characteristics, the findings of publication IV reveal that the founders' and the initial teams' human capital is an important factor as well. Thus, the findings link the opportunity exploitation theories to the earlier research on iterative startup models (Bosch et al., 2013; Ries, 2011), pointing out the value of validated learning from the customer feedback.

Publication IV complemented the findings presented in publications I, II, and III by providing this thesis with a theoretical framework and empirical findings supporting its key concepts: the concepts of *uncontrolled iterations,* the *balanced initial team* and the *problem–human capital fit* as a solution to the uncontrolled iterations.

4.6 Publication V: The Effect of Competitor Interaction on Startup's Product Development

Publication V reported an experiment simulating the effect of the ecosystem-type cooperation of two startups in the effort estimation phase of the requirements elicitation. The research sought answers to the following research question: *does a potential competitor's interaction with a startup's internal team improve the effort estimation process of the startup?* The experiment was triggered by the findings of earlier research into software startups highlighting small and inexperienced teams, and general lack of resources (Paternoster et al., 2014).

In the context of this thesis, study S4 focused on a specific means of acquiring external human capital as compensation for human capital shortages, networking with other companies in ecosystems. Cooperation by building ecosystems is a recent trend in software industries and software engineering research (Jansen, Finkelstein, & Brinkkemper, 2009; Manikas, 2016).

In the experiment, the simulated potential competitor developed a product, having to a large extend the same functionality as the product of the experiment startup, but being targeted to a slightly different customer segment. Cooperation

with such an ecosystem partner was assumed to increase the human capital of the experiment startup.

The focus area of the research, effort estimation, was chosen due to its essential role in requirement elicitation. The minimum-viable-products and prototypes, used to validate the business value and the technical feasibility of the product idea, are recommended to be developed with a limited set of the key functionality (Ries, 2011). The following product development typically broadens planning to cover a wider set of functionalities. Effort estimation, as a part of the requirement elicitation, is the basis of the product development project planning (Verner, Evanco, & Cerpa, 2007), providing the startups with guidelines for resource allocation and team setups, and identifying possible human capital gaps.

The key findings of publication V were as follows:

1. The effort estimation by the experiment group was closer to the reference estimation than the effort estimation of the control group. The difference was statistically significant.
2. The reflections of the participants confirmed the quantitative results by showing that they considered the external cooperation useful, as there was an opportunity to ask questions and discuss the user stories in the product backlog.
3. This, in turn, led to an increase in learning about the product domain requirements and finding appropriate solutions for the problems related to those requirements.

The results of publication V highlight the role of ecosystem cooperation as a means for acquiring additional human capital, assuming the partner has capabilities relevant for the development task in question. In the experiment, the situation was simulated through a potential competitor developing a similar type of product. In the context of this thesis, it is reasonable to assume that any ecosystem partner providing relevant capabilities and being willing to cooperate creates a similar effect as identified in the experiment. The participants' reflections indicate, as well, that partnering-type cooperation not only means an external addition of human capital, but also offers a possibility for a company-internal increase of human capital through learning.

Publication V broadened the palette of potential sources of additional human capital from those identified in publication III. The case startups addressed in studies S1, S2, and S3 did not utilize ecosystem networking for acquiring additional human capital, but used only traditional outsourcing.

The key contribution of publication V to this thesis was in complementing the knowledge gathered for answering the research question RQ3, and for defining the concepts of the *balanced initial team* and the *problem–human capital fit*.

5 Results

In this section, the findings of this research are presented, addressing the research problem: "*What are the characteristics of the human capital in early-stage software startups and how does the human capital affect a startup's initial team and work processes?"*. The findings are first presented by research questions RQ1, RQ2, and RQ3, summarizing the results of studies S1, S2, S3, and S4 that were reported in publications P I, P II, P III, P IV, and P V. Then the results are summarized by sketching two schematic models describing the initial structure and the evolution of the human capital in software startups.

5.1 Competency structures in early-stage software startups

The first research question was:

> *RQ1: How are the competency areas structured in the initial team of early stage software startups?*

In this research, four generic competency domains were identified as being common for the case startups: innovation and business competencies, special technology competencies (mechanics, hardware), process and quality competences, and software development competencies (publication I).

The presence and details of each competency domain varied in case startups, depending on the business case, product idea, product architecture, deployed technologies, and customer expectations. A division line was identified between the startups developing embedded products and the startups developing pure software products. The role of special technology competencies was remarkable in all startups developing embedded products (publications I and II). Several startups with embedded products were developing especially difficult technical solutions (publication III). In startups developing pure software products, the difficulty of the deployed technology varied depending on the application area and the deployed software solutions.

Though a small team was characteristic for the case startups, as also identified in earlier research (Giardino, Unterkalmsteiner, et al., 2014; Paternoster et al., 2014), three clearly separated competency roles were identified: *founders*, *experts*, and *the implementation team members*. The structure of the identified competency areas and the initial team roles is shown in figure 3.

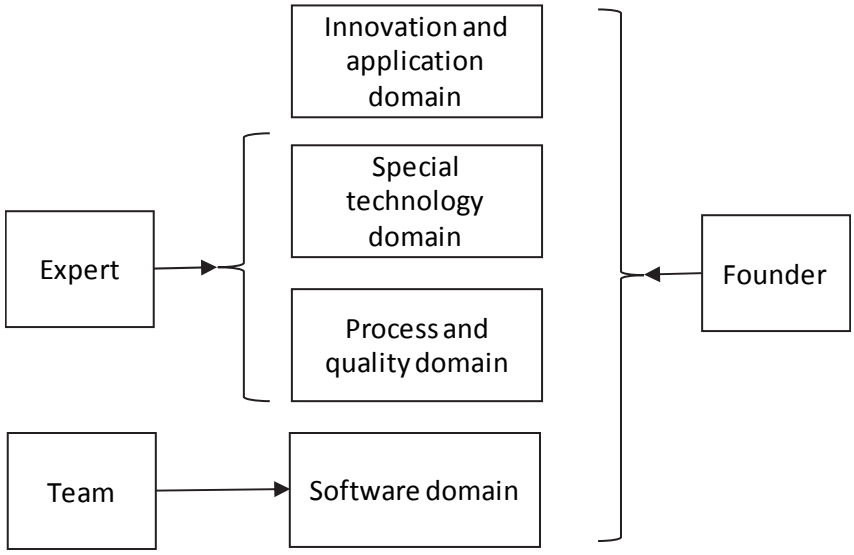

Fig. 3. Initial team roles and their contributions to competency domains.

The person responsible for the innovation and business competency domain was the founder. Participation of the other personnel segments in the tasks related to innovation and business was surprisingly small, though innovativeness is seen as a key characteristic of software startups (Giardino, Unterkalmsteiner, et al., 2014; Paternoster et al., 2014). The gathered research data did not enable the drawing of any conclusions concerning the question of whether a broader participation to the innovation-related actions would have benefited the case startups.

Besides being the key responsible for the innovation and business competency domain, the founders were involved in all other competency domains of their startups. Marvel and Lumpkin (2007) studied the depth and the breath of founders' experience. In the case startups, the founders' involvement depended on the depth and breadth of their own human capital—the deeper and broader the founders' human capital, the more they were personally involved in all competency domains.

The majority of the initial team was focusing on the software development domain— implementation-related tasks. The software development members were either employees or subcontractors. Employees in positions of software developers were typically younger and less experienced, while more weight was given to the experience of the subcontractors. This created business opportunities for qualified subcontractors, which were represented in this research by companies L and M (publication III).

The role of the experts in the case startups was twofold. Experts were focusing on the special technology competency domain or compensating for the missing or limited human capital of the founder. Experts were both external professionals and very experienced employees.

5.2 Idea-related processes in early-stage software startups

The second research question was:

> *RQ2: How does the founders' human capital affect the idea-related processes in early-stage software startups?*

In this research, there were founders with strong human capital, founders without almost any relevant human capital, and founders in between the two extremes. Human capital on software development was the most common strong human capital area. Human capital on business and on application-specific technology could also be limited in the case of founders being experts in software.

The founders were the key persons of the case startups and their human capital affected the startups in multiple ways. The founders' human capital: 1) *formed the structures and roles of the initial teams*, 2) *affected the opportunity exploitation and idea validation processes*, and 3) *affected the acquisition of additional human capital through growth* (publications I, II, III, and IV).

In the context of roles and responsibilities of the initial team, a key finding was that the founders bore the responsibility of the innovation-related and business-related topics alone, independently of their prior human capital. Experts were hired to compensate for human capital shortages, but only on topics related to implementation work, and on specific technology domains, as well as process and quality domains. The role of administrative tasks did not arise clearly in the interview data. This indicates that administration was not seen as a key challenge by the founders, which aligns with the findings of earlier literature (Giardino, Unterkalmsteiner, et al., 2014). In two cases, where CEOs were hired to take care of the administration, the driver was not a compensation for missing human capital, but an urge to free the founders to innovation-related tasks.

The founders' own human capital was also the main determining factor of how much the founders participated in the actual work outside the innovation and business domain. In case of strong capabilities in implementation technologies, the founders participated in the implementation work and set up the common work practices and processes. In cases of limited human capital, the founders left the

implementation work to dedicated implementation teams, and the setting up of work practices and processes to experts.

In the context of business opportunity exploitation and idea validation, the founders' human capital had a strong correlation with uncertainty and the iterative nature of the opportunity exploitation and idea validation processes. Independently of whether the opportunity was discovered or created, the founders' strong human capital tended to lead to a smoother and more linear opportunity exploitation and idea validation processes, while in the opposite cases the processes were characterized by *uncontrolled iterations* (publication II and IV). The founders' human capital in the application domain was an especially important factor in the idea validation. The better the founders' human capital in the application domain, the smoother the opportunity exploitation and idea validation processes were (publications II and IV). Also, with strong human capital the palette of idea validation practices was the most focused, while the broadest variation of practices was identified in the cases when the founders' human capital in the application domain was weak (publication II).

5.3 Acquiring the human capital in early-stage software startups

The third research question was:

RQ3: How is the human capital acquired in early-stage software startups?

The basic means to acquire the human capital for case startups was the founders' original human capital—the prior knowledge, skills, and experience brought by the founders to the initial teams (publication III).

Additional human capital was acquired by two main means: by learning during the opportunity exploitation and idea validation processes, and by growth. Learning was a continuous process, starting from the original idea discovery phase and continuing throughout all evolution phases. Learning were gathered from several sources: *from existing similar products*, *customer cooperation*, and *prototype-oriented development* (publication III). Learning from existing similar products represents the initial basis of external learning. Customer cooperation and prototype-oriented development were dynamic learning mechanisms during the idea validation process.

Copying from existing similar products was surprisingly common among the case startups; only two case startups developed products without existing archetypes. Another surprising finding was that case startups with very experienced

founders and initial teams omitted early customer cooperation, and did not deploy customer cooperation until the later phases of development.

Acquiring human capital through growth was achieved in case startups by employing additional personnel or by subcontracting. Partnering-type cooperation in ecosystems was not identified in the case startups, although startup ecosystems are a growing trend globally, and the experiment of publication V indicated positive effects. For in-house employment, both experienced and inexperienced individuals were hired, depending on the competency domain and role. The subcontractors were selected based on their prior experience and skills.

Although much of the earlier research into this subject is focused on the founders and their role in new startups (Bosma et al., 2004; Lazear, 2004; Marvel & Lumpkin, 2007), the need for a qualified implementation team was identified in this thesis. Careful selection of the implementation team members was taken up in the interviews with six case startups, as summarized in table 7.

Table 7. S1 Specific implementation team cases.

Startup	Problem	Product type	Selection criteria
B	Founder's missing software experience	WEB application	First development team fired after a total failure and a new team selected by the expert hired to compensate for the founder's missing human capital. *)
C	Founder's missing software experience	WEB/Mobile application	First development team fired after a total failure and a new team selected by the expert hired to compensate for the founder's missing human capital. *)
G	A very specific application area	Aircraft maintenance software	Prior software development skills and interest in aviation
H	Extremely high-quality targets	Graphical UI platform	A former work-mate with a well-known track record hired to support the team of students
J	Founders with only managerial experience in software work	WEB application	A former work-mate with a known track record as a full-stack developer hired to do the whole development work
K	Specific application area, embedded product	Instrument, embedded software	Developers being able to "do everything" were sought

*) The founders of case startups B and C faced the same challenges and used the same solutions

In other cases, issues with the implementation team did not arise, supporting the assumption that those startups had succeeded in building an implementation team with the needed capabilities.

Three main factors were identified as affecting the selection between in-house employment and subcontracting: 1) *specific human capital needs*, 2) *current economic imperfections*, and 3) *avoiding economic risks*. The weight of each factor varied between the case companies, leading to different setups in startups that were experiencing seemingly similar situations (publication III). Some commonalities were identified: 1) *the most inexperienced persons, such as students, were hired for implementation related tasks*, 2) *inexperienced team members needed support from experienced founders or experts*, and 3) *using subcontractors was affected by the subcontractors' experience and skills, subcontracting costs, and the avoidance of economic risks tied to in-house hiring* (publication III).

5.4 Human capital model of early-stage software startups

The human capital of an early-stage software startups consists of the initial human capital, brought to the startup from the education, experiences, knowledge, skills and competencies of the initial team members, and the additional human capital acquired by learning and the growth of the team. Figure 4 presents the relationships of the initial and the acquired human capital to the initial team roles and the competency domains.

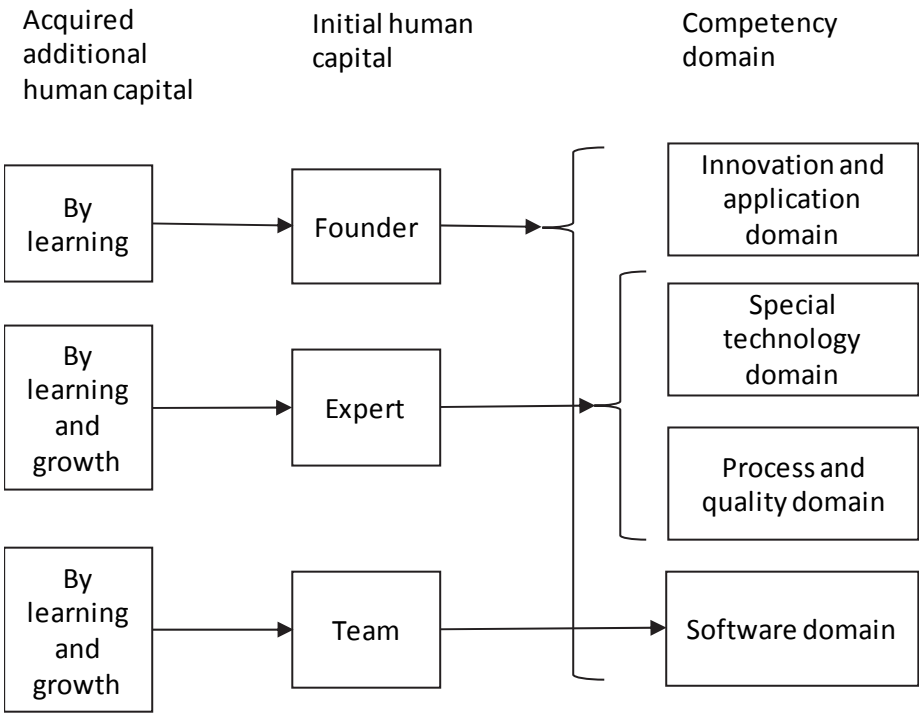

Fig. 4. Early-stage software startup's human capital model.

This model highlights the founders' key contribution to the human capital of software startups. The founder lays the groundwork for the human capital in all identified competency areas. The experts' role is to compensate for possible gaps in the founders' human capital in specific areas, and the rest of the team is focusing on implementation-related tasks.

Recent studies present the early stages of startups with dynamic, iterative models, such as lean startup (Ries, 2011), and ESSSDM (Bosch et al., 2013). The static human capital model presented in figure 4 does not address the dynamic nature of human capital that is also identified in this research (publication III). The software startup human capital model is complemented by exploring the iterations identified in the case startups.

The lean startup and ESSSD models present iterations as a *semi-managed* process, where the possibility of failure in creating a customer case is a basic assumption. Lean startup model (Ries, 2011) presents the iterative build-measure-learn loop as a means to control that uncertainty. The models was further extended

in ESSSD model by adding parallelism to the process (Bosch et al., 2013). A semi-managed iteration is a trial where a startup either succeeds or fails, but there is a predefined process of how to continue in case of a failure.

In this research, both iterative and linear development processes were identified (publications II and IV). In cases of iterations, the research did not reveal any systematic recovery processes as proposed by the lean startup and ESSSD models. Thus, the iterations identified in this research can be defined as *unmanaged*. Unmanaged iterations were identified in both business-related and technology-related areas, but those that were technology-related were dominant (publications II and IV). Unmanaged iterations were a sign of failures that were not taken into account when planning the development. The findings of this research show that the key cause of unmanaged iterations in the case startups were the founders' human capital shortages, while smooth and linear development processes were identified in cases where founders had strong human capital (publications II and IV). The findings further indicate that even uncontrolled iterations were learning points, in the same manner of learning proposed by semi-controlled iterations of the lean startup model (Ries, 2011).

Figure 5 presents a schematic model of human capital evolution derived from the results of this research. The model links the evolution to the progress of a software startup's idea validation and prototyping work. The iteration rounds, indicating missing human capital, provide all members of the initial team with additional knowledge on the actual problems and their possible solutions. A linear process, in turn, indicates that the team's knowledge is sufficient for a smooth progress of the work. Both the iterative and linear processes gather relevant human capital for the decision, whether to continue from the idea validation to product development or to idea abandonment, which is one of the key decisions of a startup (Ojala, 2016a; Ries, 2011; Wood & McKinley, 2010). In case of continued development the gathered knowledge is the basis of the next development phases.

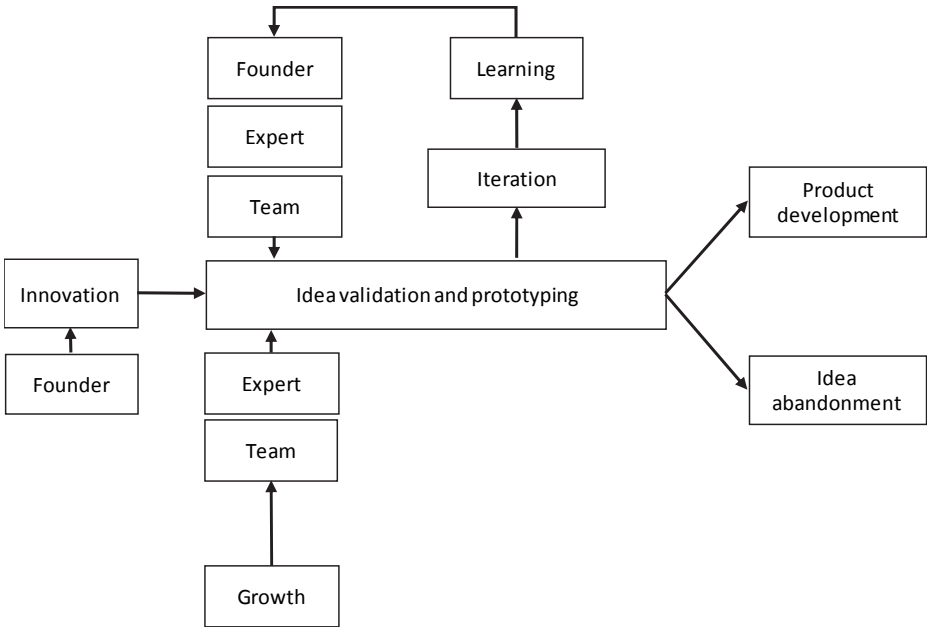

Fig. 5. Software startup human capital model, evolution view.

As mentioned in section 5.3, the case startups were growing the initial team by hiring both experienced and inexperienced persons. The research data reveals that experienced individuals were hired due to their prior knowledge and experience in the task-specific competency domains of the startups, while such task-specific human capital was not expected from the inexperienced team members.

Learning during the idea validation and prototyping phases, in turn, created task-specific additional human capital. The model of figure 5 does not differentiate between semi-controlled and uncontrolled iterations, because both created learning in the same manner.

6 Discussion

In this section the results, contributions and limitations of this research are discussed. Finally, conclusions of the thesis are drawn and future research directions determined.

6.1 Human capital structures of the initial teams of early-stage software startups

The founders played a central role in the case startups of this research. The founders bore the responsibility for the innovation-related and business-related areas, while the rest of the initial team focused on the implementation-related areas. In addition to innovation and business responsibilities, the founders also contributed to the implementation-related tasks in both expert and developer roles, to the extent of their skills and competencies in software development and programming. Thus, the results are well aligned to the earlier research, pointing out the role of the founders in new enterprises (Bosma et al., 2004; Marvel & Lumpkin, 2007).

The founders of the case companies had, however, varying levels of relevant human capital. There were seasoned software professionals with considerable experience and comprehensive knowledge on software-intensive product development, both from a developer's and a manager's perspective. On the other hand, there were founders with a lack of product development experience. Missing human capital was identified as an obstacle for the progress of the development-related tasks, rather than for the business-related tasks. The results of this research indicate that, for inexperienced founders, it was easier to learn the business-related tasks than the technology-related tasks. The results of study S3 revealed that the business cases of the ideas were figured out before founding the startups, explaining the phenomenon.

In the case startups the founders' missing human capital in development-related tasks caused difficulties, but not unresolved problems. The solution was in the *deployment of experts* to compensate for the founders' human capital shortages and to broaden the knowledge base of the whole initial team. While the majority of the initial team members were focusing on implementation-related tasks, the experts' main role was to support the founders in their weak areas. Experts were highly-qualified individuals in one or several human capital areas, and their tasks varied from distinct, difficult technology areas, to leading the software development or

setting up common development processes. Experts were employed directly to the initial team, and their human capital was deployed on a subcontractor basis.

The value of experts was further supported by the results of study S4, where a team of more experienced students supported a less experienced team in an experiment simulating the role of ecosystem stakeholders in the requirements elicitation process. Such support created a statistically significant improvement in the performance of the less experienced team of students.

The results of this study are thereby not fully aligned to the findings of the earlier research highlighting the importance of the founders' technical experience (Bosma et al., 2004), or studies that suggested the value of the founders' broad experience (Lazear, 2004). Instead, the results highlight the *necessity to successfully compensate* for shortages in human capital, leading to *balanced human capital* of the whole initial team – to a *problem–human capital fit*.

This research found out that in initial teams with balanced human capital the team members could be divided into three categories, *the founders*, *the experts* and *the implementation team members*, each having the responsibility area of its own. A close link was identified between the identified categories and the problem human – human capital fit, although the results did not enable one to conclude, which topic was the cause and which one the consequence. The founders seemed to build the initial teams in such a way that both the human capital gaps were filled and the balanced responsibility share was maintained.

The responsibility share within the initial team, identified in this research, supports the question of whether the whole team's participation in innovation-related tasks would have been more beneficial for the case startups than their actual setups, because all the case startups had implemented the same responsibility share. What can be assumed is that a clear responsibility share and balanced human capital in the initial team was more important for the founders of the case startups than sharing the innovation-related tasks and responsibilities with the other team members.

Growth was not the only means to increase human capital and build the problem–human capital fit in the case startups. Learning was an equally important means. In all case startups, the initial human capital was both broadened and deepened (Marvel & Lumpkin, 2007) by learning from different sources. The need for additional learning was also recognized in the case startups with experienced founders, because they tended to opt for a bigger innovation increment, such as more challenging technology. In the context of software startups, this indicates that the definition of human capital, outlined by Becker (1993) as a composition of

experience and education, should be broadened to cover on-going, collective learning, as proposed by Del Canto and González (1999) and Hatch and Dyer (2004).

Exploring the individual human capital of the personnel roles in the initial teams—the founder, the expert and the implementation team member—the principle of the original resource-based view of rare, inimitable resources (Barney, 1991) was not identified. Some founders did not have experience or knowledge relevant for the tasks, and the experienced founders tended to aim at products with a reasonable difficulty, which they did not master in the beginning. Employed experts had considerable experience in their specific areas, but they were hired from open labor markets available for potential competitors. Subcontracted experts offered their human capital in principle to every potential customer. Several implementation teams consisted of students and subcontractors, who cannot be ranked as rare and inimitable.

However, when exploring the initial teams from the perspective of the capability theory, the picture changes. Several authors have defined the capabilities as company-internal routines to improve the resource usage, or as core competencies in product development, gained by collective learning in the organization (Amit & Schoemaker, 1993; Del Canto & González, 1999; Väyrynen, 2009; Wagner et al., 2005; Winter, 2003). Further, the dynamic capabilities are claimed to address continuous changes in business and technology. Dynamic capabilities are defined in the prior literature as a company's ability to build, reconfigure and integrate internal and external competencies to address rapidly changing environments (Teece et al., 1997), or as specific organizational and strategic processes that follow best practices instead of being strictly company-specific (Eisenhardt & Martin, 2000). Eisenhardt and Martin (2000) also claimed that unique path of dynamic capabilities is shaped by learnings, such as practice, codification, mistakes and pacing.

The results of this research indicate that the *formation of balanced human capital* in the initial team, e.g. *creating the problem–human capital fit,* is a software startup's core capability. The capability is built on top of the founders' personal human capital through controlled growth and company-internal learning (Eisenhardt & Martin, 2000; Ries, 2011). The problem– human capital fit is thus a dynamic capability following the evolution paths of the startups.

The problem–human capital fit fulfills the rareness and inimitability criteria of the resource-based view (Barney, 1991): It is very problem-specific, company-specific, and evolution path-specific. Though its components are not unique or

inimitable, the composition of the human capital resources resulting from controlled growth and learning is unique.

6.2 Idea-related processes in early-stage software startups

The models proposed by Ries (2011) and Bosch et al. (2013) focus on validation of the product idea or product ideas from the business perspective. In this research, the validation of the technical solutions was found to be equally important, especially in cases with embedded products or deployment of new, difficult technology. In several cases, the business and technical perspectives seemed to be strongly interconnected. The business value was gained through new technical solutions, and customer expectations and requests were guiding the selection and development of those technical solutions.

The product ideas identified in this research varied: at opposite ends of the innovativeness scale were new innovative ideas, and fairly straightforward copies of similar existing products. The copies were typically targeted at new customer segments or new geographical areas, and they offered improvements to the existing products. The improvements included new functionality, new technology, or combinations of both, described from this point on as *innovation increment*. The balance between the available human capital and the innovation increment was the key determinant of how the work processes in case startups evolved.

The startup models (Bosch et al., 2013; Ries, 2011) and the opportunity exploitation theories (Alvarez & Barney, 2007; Sarasvathy, 2001) address the uncertainty a software startup faces during the early stages of its evolution path. The focus of the former is on the business value validation and customer case creation, while the latter also address the technology side.

The opportunity exploitation theories propose that the differences of the opportunity exploitation depend on whether the opportunity is of a discovered or created type. A product based on a discovered opportunity is claimed to be predictable and the process of the idea realization to be based on causation-type reasoning, while opportunity creation is a process heading towards an unknown future with lots of uncertainty and effectuation-type reasoning.

Opportunity exploitation processes with larger innovation increments were identified, as well as processes based on ideas derived from existing similar products. The former processes carried the characteristics of opportunity creation, being aligned with the opportunity creation theory. The cases with smaller innovation increments, in turn, did not follow any strict separation proposed by the

theories, but were mixtures of both opportunity discovery and creation processes. In those cases, the opportunity creation and discovery were parts of the very same opportunity exploitation processes, as noted by Alvarez and Barney (2007): "*It will always be possible after an opportunity is formed to describe the actions of a particular entrepreneur in both discovery and creation terms. Thus, debates about whether an opportunity is a discovery or a creation opportunity, by themselves, is without empirical content. However, these theories do have empirical content when entrepreneurs act based on one theory or the other.*"

The results of this research indicate that the level of uncertainty and the process characteristics were not directly linked to whether the idea was originally discovered or created, as proposed by Alvarez and Barney (2007) and Sarasvathy (2001). Instead, the results indicate that two items were the strongest determinants between the process types: the *founders' own human capital compared to the innovation increment* and the possibility of *compensating for their human capital shortages by growth or learning*. In cases of insufficient human capital compared to the innovation increment, effectuation (Sarasvathy, 2001) dominated, and the process followed a path with uncontrolled iterations. The founders' or the initial teams' strong, task-specific human capital tended to smooth the progress of the development.

The startup models presented by Ries (2011) and Bosch et al. (2013) propose means to manage the business-related uncertainty faced by a startup. Ries proposed, in the lean startup model, an iterative build-measure-learn loop and pivoting, and Bosch et al. in the ESSSD model suggested a repository of different ideas. This research did not identify utilization of alternative ideas. Instead, the founders were pushing the original ideas through even big difficulties. Iterations identified in this research were signs of human capital shortages instead of planned and controlled steps. Because no case startup was systematically following the recommendations of the lean startup and ESSSD models, this research was not able to address any difference between approaches keeping the single original idea and the approaches with alternating ideas.

What, then, were the reasons for only pushing the original idea? Simple stubbornness of the founders or something else? Several reasons can be discussed, although the research gives only indirect indications. One reason may be that the recommendations presented by the lean startup and ESSSD models had not reached the level of actual work in startups. The startup culture and funding practices in European countries, especially in Scandinavia, may enforce startups to focus the efforts on one idea only, in order to gain enough trust among the funding bodies.

The very strong focus of business-related tasks and responsibilities on the shoulders of the founders was identified in this research. This may have led to situations where the founders did not have time and energy to figure out alternative business opportunities and product ideas. Yet another reason might have been the fact that several ideas were discovered from similar existing products, and the business opportunity was to create an innovation increment on top of the original solution. Existing products may have been a sufficient proof of the new products' business value, and therefore creating alternative ideas was not seen as necessary.

However, early and close customer cooperation was one of the basic means to validate the idea, as proposed by the lean startup model (Ries, 2011), covering in the case startups both commercial and technical aspects. Customer cooperation during the later phases of the development work was identified in cases with strong human capital for product development. The approach of late customer cooperation may also be an indication that those startups did not face especially great uncertainty concerning the business value of the product idea.

Based on the results of this study, it is not possible to figure out any generic model describing the idea validation processes of the case startups. The steps and phases of the validation, and the means utilized, were well known, but the combinations of different validation means varied in startup-specific ways. The type of processes and their phases, as well as the validation means, were strongly dependent on the context, on the founders' and initial teams' human capital, and on the initial teams' learning.

The results of this research indicate that the innovation and idea validation processes of the case startups were only partly aligned to the earlier research into opportunity exploitation (Alvarez & Barney, 2007; Alvarez et al., 2012; Sarasvathy, 2001) or on the startup models (Bosch et al., 2013; Ries, 2011).

6.3 Limitations and threats to validity

In this section the limitations and threats to the validity of this research are discussed. The threats are divided into four categories and discussed following the recommendations set up by Runeson and Höst, (2009) and Yin (2009). The four validity threats relevant to this research are: 1) construct validity, 2) internal validity, 3) reliability, and 4) external validity. Each threat is discussed in a separate section below.

6.3.1 Construct validity

Construct validity addresses the topic of how well the applied operational measures represent the concepts that have been studied (Runeson & Höst, 2009; Yin, 2009). Studies S1, S2, and S3 were constructed as qualitative interview-based studies, while S4 was an experiment utilizing both quantitative and qualitative research methods.

Studies S1, S2, and S3 were constructed as multiple-case studies using semi-structured interviews as the data gathering method. Runeson and Höst (2009) define the construct validity as follows:

"*This aspect of validity reflects to what extent the operational measures that are studied really represent what the researchers have in mind and what is investigated according to the research questions. If, for example, the constructs discussed in the interview questions are not interpreted in the same way by the researcher and the interviewed persons, there is a threat to the construct validity*".

The possible threat of construct validity was addressed in several ways in this research. Planning and constructing the interview schema was done in co-operation with two experienced researchers of software startups, one being a university professor. The schema was constructed to cover the research topics broadly enough to address the various viewpoints of studies S1, S2, and S3.

Selecting the case companies is a possible source of bias in any research based on a limited number of case companies. This research gathered data from startups in four different geographical locations in three countries. Local startup incubators were used to identify potential case companies, and a large number of companies were contacted with an invitation to take part in the interview. The majority of the companies contacted did not respond to the message, and the final set of case companies can be considered as random.

Utilizing the key informant technique (Marshall, 1996) is another possible source of bias. The research data were collected by interviewing the founders or co-founders, because in the case startups only the key persons were able to provide this research with such a broad view necessary for a triangulation-type of research. In two cases, where the founders did not have a deeper insight on software development, experts were also interviewed.

Different interpretations of the phenomena discussed in the interviews between the interviewees and the researchers is a threat to validity in interview-based research. Further threat to validity comes from the key informant technique (Marshall, 1996) utilized in the interviews. The key informant technique was

subject to personal biases because most of the interviewees were founders, describing their own startups.

In this research, three interviews were conducted together with the researchers who participated in the interview schema creation, and the rest by the author of this thesis alone. The interpretation of the research data was built on three independent factors: *the author's comprehensive experience in the software industry over more than 35 years*, *the thematic analysis of the research data*, and *on grounding the findings with existing literature on the topics to be studied*.

The author has experience in the software industry from a master's thesis worker to director, all together in sixteen different R&D organizations. His area of special expertise was founding and scaling up new R&D teams, in all together seven cases in Finland, Germany, the UK, Sweden, and India. In addition to this, he has been a co-owner in a startup with software-intensive products since 2009. Such broad experience ensured the ability to understand the phenomena discussed in the interviews.

Cruzes and Dybå (2011) and Cruzes et. al (2014) define the thematic analysis as: '*a method for identifying, analyzing, and reporting patterns (themes) within data. It minimally organizes and describes the data set in rich detail and frequently interprets various aspects of the research topic. Thematic analysis can be used within different theoretical frameworks, and it can be an essentialist or realist method that reports experience, meanings, and the reality of participants.*' The findings of studies S1, S2, and S3 were identified and the conclusions drawn from the results of thematic analyses binding together detailed findings from the case companies. The key characteristics of the case companies were highlighted by complementing thematic analysis with narrative analysis, providing the research with analyzed knowledge on the differences between the case companies. Combining the common findings identified in thematic analysis and the differences identified in narrative analysis provided this research with the basis for interpreting the findings.

Results of the earlier research were used as frameworks when thematically analyzing the research data, and the findings and conclusions were discussed in each publication in the context of the existing literature to further address the potential threats to the construct validity.

The construct validity threats of the experiment study S4 were different. Utilizing students as research subjects in the experiment was a possible construct validity threat. The threat arises from hypothesis-guessing by the subjects, especially if the experiment is closely tied to the content of their course. The

experiment of study S4 was conducted with the students participating in the master's-level course on Software Development in a Global Environment. The experiment was not related to the key contents of the course, and the teaching material presented before the experiment did not discuss the context of the experiment, decreasing the possibility of hypothesis-guessing.

Evaluation apprehension by inexperienced subjects providing high but false estimations may decrease the validity of the experiment results. To address the validity threat, clear instructions were given to the subjects pointing out that they must make the estimations based on the credibility of the user stories.

Dividing the subjects into teams with different levels of experience was a planned construct of the experiment, aiming at clarifying the effects of additional external human capital to the quality of effort estimations. Besides that division, the students were allocated to different teams at random.

6.3.2 Internal validity

Internal validity addresses the causal relationships examined in a study (Runeson & Höst, 2009; Yin, 2009). When studying whether a factor affects the studied phenomena, internal validity requires that the causality between the studied phenomena and the studied factor is not affected by external, uncontrolled factors possibly leading to wrong conclusions in explanatory studies (Runeson & Höst, 2009).

This research addressed the role of human capital in early-stage software startups from different perspectives. An additional viewpoint was included in publications I, III and IV; how the founders' prior human capital affects the main phenomena addressed in the publications. The studies suffered from an internal validity threat by omitting a systematic exclusion of other possible factors affecting the phenomena under study, apart from the founders' prior human capital. The studies revealed that the phenomena varied considerably between the case companies, and were considerably affected by various context-dependent factors. The study design made it impossible to exclude those contextual factors, and publications I, III and IV presented the findings in an exploratory manner, also including the identified contextual factors. Publication II addressed purely exploratory research questions and was, thus, less prone to internal validity threats.

Regarding internal validity of the experiment in study S4, a threat could be related to the instrumentation. This threat was addressed by collecting most of the research data using electronic means. The same training sessions were arranged for

both the control and treatment groups, decreasing the threat of systematic misunderstandings by the students. Validity threats of the subject selection were addressed by conducting the experiment as part of a course and by allocating the students into individual groups in a random way.

Triangulation is a method of broadening a picture of the studied phenomena by addressing it from different angles, increasing in that way the precision of the research (Runeson & Höst, 2009). Triangulation was the means to address the internal validity threats of the conclusions and findings, summarizing the results of studies S1, S2, S3, and S4, as presented in section 5. Although individual studies were exploratory, triangulation over the studies provided this thesis with comprehensive insight to the role of human capital in software startups. Triangulation highlighted the key phenomena and contextual factors that stayed the same when studied from different viewpoints, creating the basis of the findings of this research.

6.3.3 External validity

External validity addresses the question of generalizability of the findings of certain research, and how interesting the findings are outside the scope of the research (Runeson & Höst, 2009; Yin, 2009). Studies S1, S2, and S3 of this research were conducted on a group of software companies in four countries, and five geographical locations. Two of the case companies were enterprises offering software-related human capital services to other companies, including software startups. The group of case startups was gathered in a random invitation–refusal process. They represented different product and business ideas, innovativeness, technologies, customer segments, and evaluation phases though all could be ranked as early-stage startups. The background and experience of the founders and other team members varied from just-graduated to seasoned professionals, and both in-house hiring and subcontracting were used when building up the team. The biggest threat of the external validity is, thus, in the limited size of the case startup group. The findings related to the service-offering case companies can especially be seen as supporting results, with only limited possibilities to generalize outside their specific context.

Because of the geographical range, it is reasonable to conclude that the results are, at best, generalizable in Europe, especially in Northern Europe. To generalize the results on a global scale, would require further research in other parts of Europe and other continents.

The experiment of study S4 focused on the effects of a potential competitor on the performance of the effort estimation process in a simulated startup working in a simulated ecosystem. In the context of this thesis, the design of study S4 enabled the generalization of the results to cover the effects of ecosystem-type cooperation with external partners as a means to acquire human capital. From this perspective, the findings of study S4 complement the findings of studies S1, S2, and S3. They can also be utilized as additional knowledge in the research addressing startup ecosystems.

Triangulation, used in all the studies, improved the external validity of the findings by compensating for the limited number of case startups. The findings of this research highlighted the specific characteristics of software startups in the context of each utilized theory, and broadened the applicability of the theories to different types of enterprises.

6.3.4 Reliability

Reliability addresses the question of how much the research data and the analysis depend on the specific researchers (Runeson & Höst, 2009; Yin, 2009). Such dependencies may arise from unclear interview questions or from biased analyses (Runeson & Höst, 2009). The data collection of studies S1, S2, and S3 was conducted with interview schema that were created together with two experienced researchers. Similarly, the experiment planning and data collection of study S4 was conducted along with established methods, and supported by experienced members of the research group.

The interviews were recorded and transcribed by a professional transcription company. The analyses were conducted along with well-defined and accepted analysis methods for qualitative data (Cruzes & Dybå, 2011; Cruzes et al., 2014). The analysis of the quantitative research data of S4 was completed by two researchers together. Each analysis process was conducted with tools storing the stepwise results of the analyses. The data collection and analysis processes were presented in detail in each publication, I, II, III, IV, and V.

The extensive industry experience of the author may cause researcher-specific bias and a reliability threat. To address that threat and other potential threats, the findings of each study were reviewed by the co-authors. In addition to this, cross-reviewing was conducted with team-mates in the research group, also outside the list of co-authors.

7 Conclusions and future research

The recent developments of technology have enabled a change in process of society and human life, known as digitalization. Digitalization, integration of digital technologies and computer-based solutions into all aspects of everyday life, has already opened huge new markets for innovations and products built on software. It is reasonable to assume that this trend will continue at an accelerating speed. Digitalization is both a carrot and a stick for the players in the software industry: on one hand, it opens new, fast growing markets with fairly few entry barriers and reasonable initial investments. On the other hand, it requires speed and fast reactions to stay in the frontline of the development. Both factors have positively affected emerging software startups, as they are typically both innovative and highly reactive (Paternoster et al., 2014).

Software startups are, however, enterprises with a number of limitations. In the early stages, their business prospects are based on a single product, the first one. A failure with this may be fatal for the whole startup. The teams of software startups are small, often inexperienced, and have little common work history. In addition to this, the startups' economical and physical resources are limited. These limitations mean that software startups are highly risky and dependent on external support (Paternoster et al., 2014). In this research, the challenges of software startups presented in existing literature were identified in the case startups. However, all but two case startups were able to overcome these challenges at the time of the research.

This research addressed several viewpoints that are important for software startups to overcome their challenges:

1) Because of the dependency on a single product, the validity of it must be carefully evaluated. The evaluation must cover both business validity and technical validity, and should be started from the opportunity discovery and continue throughout the startups' evaluation.

2) The initial team and the work processes have to be set up carefully, balancing the team's abilities to the tasks and to the requirements set by the targeted product. Uncertainty and limited economical resources cause additional difficulties when setting up the team, and all available means to build a working team should be utilized.

3) The more innovative and new the product idea, the more important learning is in the early stages of software startups. Learning should be a continuous process tied to the progress of the work, and the lessons should be gathered from all possible sources.

The factor tying together the above viewpoints in this research is human capital. Human capital is explored here from the perspectives of both the founder and the whole initial team. Discovering an opportunity and figuring out a product idea is typically the founders' individual effort. The process of turning it into a real product or service is an organized set of collaborative actions of the founders and the initial team, together with the customers and other stakeholders. The role of the founders and the initial team is to carry out the development-related actions, while the stakeholders' role is to provide the startup with both feedback and support.

Human capital was identified as a key enabler of the progress in the case startups. Contrary to the notation of rare and inimitable resources (Barney, 1991), the results of this research indicated that commonly available and external human capital resources are also valuable for software startups when utilized for creating a *balanced team setup* and processes that fit the problems at hand. The identified *problem–human capital fit* in the initial team gives a framework for the abilities of the case startups to tackle the challenges with their limited resources and small teams. From that perspective the problem–human capital fit represents a core capability of software startups.

7.1 Relevance to academia and practitioners

This thesis addresses an area of the research agenda on software startups, proposed by Unterkalmsteiner et al. (2016). The aim of the common agenda was to draw a comprehensive map of areas of interest in the research into software startups.

This thesis contributes to the targets of the research agenda by providing academia with a broad, multi-viewed picture of the human capital's role in early-stage software startups. The results can be utilized both as a starting point of future research on individual topics identified here, and as guidelines in planning academic curricula. The balanced human capital, identified in this research and presented as a core capability, broadens the knowledge of the software startups, and provides academia with a foundation for further developments of the theories explored in this research. This research indicates that external human capital is equally valuable for software startups as in-house human capital, and thereby further confirms the value of ecosystems, cooperation and networking as a means to improve the performance of software startups.

For curricula aiming at educating students to software-related professions and entrepreneurship, the view of balanced human capital highlights the different roles and responsibilities required in software startups. Although the experiences of the

founders and the experts are typically gathered through life-long learning, the insight of different roles and the requirements the roles set for individuals is valuable knowledge for graduating students. Instead of offering the same entrepreneurship education to everybody aiming at a career in software startups, targeted education would give the students a more realistic insight into potential future careers and the possibility of deliberating which kind of role would best fit the individuals' objectives in professional life. Targeted education would also provide startups with graduates, fitting more directly to balanced initial teams.

For the practitioners planning to found software startups of their own, or expanding their current startups, this research offers several valuable viewpoints:

1) It highlights the importance of objective judgement of the founder's own strengths and weaknesses, and the importance of compensating for possible shortages with carefully targeted growth of the initial team.

2) It highlights the importance of learning as the other key means for gathering the human capital needed to solve problems.

3) It offers the founders a model of how to organize the structure and processes of the initial team in order to maximize its performance.

Possibly the most valuable for practitioners are, however, the positive findings that a product idea does not need to be revolutionary in order to be the basis of a valid business case, and the founders do not need to be superheroes with unbeatable experience and skills in order to overcome the inevitable difficulties of an early-stage software startup. A little big team is possible.

7.2 Future research

This research provides academia with several options for future research. The most intuitive is broadening the study with a larger sample of case startups, and targeting it to different business cultures outside Europe. Such research would be necessary to confirm the findings of this research, and to create a broader basis for the formation of new theories on human capital resources in software startups.

This research defines a set of roles in the initial team, and identifies differences in the actions and responsibilities of those roles. Further research focusing on these roles would deepen the understanding of their significance and provide academia with guidelines for education adjusted specifically for different personnel profiles of the initial team.

In this research, causal relationships between identified phenomena and affecting factors were addressed only to a limited extent. Focused research on the

causal relationships would deepen the understanding of the factors leading to iterations in the development process and causing delays and wasted investments. Earlier research highlights the role of false estimations of a product idea's business value as the key reason for iterations, and provides guidance on how to keep the iterations controlled. This research identified missing human capital as a reason for uncontrolled iterations, but did not study at a deeper level the other possible factors leading to similar uncontrolled iterations.

Previous research has found that software startups are not following strict, established processes in their work. The findings of this research indicate that software startups do not utilize purely ad-hoc processes but, instead, those that are based on the key persons' individual preferences and adjusted to fit to the problem and the team. More detailed research on how the early processes and practices emerge in software startups, and how they evolve towards more mature processes, would bring new knowledge into the software engineering domain.

Existing research also highlights the importance of problem–solution fit and product–customer fit as the cornerstones of the business value of the product idea. This research identified an additional fit, *problem–human capital fit* in the initial team, being a startup-internal phenomenon related to the startup's ability to find solutions to problems of the development process. This research did not, however, compare the three fits, and their roles, to each other. Nor were the causal relationships between the progress of the startups and three fits addressed. Further research is needed to gather more information on those three fits.

This research deliberately excluded the relationships between the findings and the business success of the case startups. As the final purpose of any industrial actions and achievements is to create value-add to society, research on the phenomena identified in this thesis from the viewpoint of business success would be highly recommended. Research related to success from the viewpoints of the findings in this research may, however, be challenging due to many uncontrolled factors affecting individual startups.

References

Alvarez, S. A., & Barney, J. B. (2007). Discovery And Creation: Alternative Theories of Entrepreneurial Action. *Strategic Entrepreneurship*, *26*(November), 11–26. https://doi.org/10.1002/sej

Alvarez, S. A., Barney, J. B., & Anderson, P. (2012). Perspective--Forming and Exploiting Opportunities: The Implications of Discovery and Creation Processes for Entrepreneurial and Organizational Research. *Organization Science*, *24*(January 2016), 8–13. https://doi.org/10.1287/orsc.1110.0727

Amit, R., & Schoemaker, P. J. H. (1993). Strategic Assets and Organizational Rent. *Strategic Management Journal*, *14*(1), 33–46. https://doi.org/10.1002/smj.4250140105

Ardichvili, A., Cardozo, R., & Ray, S. (2003). A theory of entrepreneurial opportunity identification and development. *Journal of Business Venturing*, *18*(1), 105–123. https://doi.org/10.1016/S0883-9026(01)00068-4

Barney, J. B. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, *17*(1), 99–120. https://doi.org/10.1177/014920639101700108

Becker, G. S. (1993). Human Capital: A Theoretical And Empirical Analysis, With Special Reference To Education. University of Chicago Press. Retrieved from https://books.google.fi/books/about/Human_Capital.html?id=9t69iICmrZ0C&source=kp_cover&redir_esc=y

Blank, S. (2013). *The four steps to the epiphany: Successful strategies for startups that win.* K&S Ranch Press. Retrieved from https://www.amazon.com/Four-Steps-Epiphany-Steve-Blank-ebook/dp/B00FLZKNUQ/ref=tmm_kin_swatch_0?_encoding=UTF8&qid=&sr=

Bosch, J., Olsson Holmström, H., Björk, J., & Ljungblad, J. (2013). The Early Stage Software Startup Development Model: A Framework for Operationalizing Lean Principles in Software Startups. *Lean Enterprise Software and Systems*, (February 2016), 1–15. https://doi.org/10.1007/978-3-642-44930-7

Bosma, N., Van Praag, M., Thurik, R., & De Wit, G. (2004). The Value of Human and Social Capital Investments for the Business Performance of Startups. *Small Business Economics*, *23*(3), 227–236. https://doi.org/10.1023/B:SBEJ.0000032032.21192.72

Bourque, P., & Fairley, R. E. (2014). *Guide to the Software Engineering Body of Knowledge (SWEBOK (R)): Version 3.0*. IEEE Computer Society Press. Retrieved from https://www.computer.org/web/swebok

Coleman, G., & O'Connor, R. V. (2008). An investigation into software development process formation in software start-ups. *Journal of Enterprise Information Management*, *21*(6), 633–648. https://doi.org/10.1108/17410390810911221

Combs, J. G., & Ketchen Jr., D. J. (1999). Explaining Interfirm Cooperation and Performance: Toward a Reconciliation of Predictions from the Resource-Based View and Organizational Economics. *Strategic Management Journal*, *20*(9), 867–888. https://doi.org/10.1002/(SICI)1097-0266(199909)20:9<867::AID-SMJ55>3.0.CO;2-6

Crook, T. R., Todd, S. Y., Combs, J. G., Woehr, D. J., & Ketchen Jr, D. J. (2011). Does

human capital matter? A meta-analysis of the relationship between human capital and firm performance. *Journal of Applied Psychology*, *96*(3), 443. https://doi.org/10.1037/a0022147

Crowne, M. (2002). Why software product startups fail and what to do about it. Evolution of software product development in startup companies. In *Engineering Management Conference, 2002. 2002 IEEE International* (Vol. 1, pp. 338–343). https://doi.org/10.1109/IEMC.2002.1038454

Cruzes, D. S., & Dybå, T. (2011). Recommended steps for thematic synthesis in software engineering. In *International Symposium on Empirical Software Engineering and Measurement* (pp. 275–284). https://doi.org/10.1109/ESEM.2011.36

Cruzes, D. S., Dybå, T., Runeson, P., & Höst, M. (2014). Case studies synthesis: a thematic, cross-case, and narrative synthesis worked example. *Empirical Software Engineering*, 1–32. https://doi.org/10.1007/s10664-014-9326-8

Cruzes, D. S., Dybå, T., Runeson, P., & Höst, M. (2015). Case studies synthesis: a thematic, cross-case, and narrative synthesis worked example. *Empirical Software Engineering*, *20*(6), 1634–1665. https://doi.org/10.1007/s10664-014-9326-8

Cukier, D., Kon, F., & Lyons, T. S. (2016). Software Startup Ecosystems Evolution The New York City Case Study. In *International Conference on Product-Focused Software Process Improvement* (pp. 600–606). Retrieved from http://ccsl.ime.usp.br/startups/sites/ccsl.ime.usp.br.startups/files/newyork-ecosystem.pdf

Del Canto, J. G., & González, I. S. (1999). A resource-based analysis of the factors determining a firm's R&D activities. *Research Policy*, *28*(8), 891–905. https://doi.org/10.1016/S0048-7333(99)00029-3

Easterbrook, S., Singer, J., Storey, M.-A., & Damian, D. (2008). Selecting empirical methods for software engineering research. In *Guide to advanced empirical software engineering* (pp. 285–311). Springer. https://doi.org/10.1007/978-1-84800-044-5_11

Eisenhardt, K. M., & Martin, J. A. (2000). Dynamic capabilities: what are they? *Strategic Management Journal*, *21*(10–11), 1105–1121. https://doi.org/10.1002/1097-0266(200010/11)21:10/11<1105::AID-SMJ133>3.0.CO;2-E

Giardino, C., Paternoster, N., Unterkalmsteiner, M., Gorschek, T., & Abrahamsson, P. (2016). Software development in startup companies: the greenfield startup model. *IEEE Transactions on Software Engineering*, *42*(6), 585–604. https://doi.org/10.1109/TSE.2015.2509970

Giardino, C., Sohaib Bajwa, S., Wang, X., & Abrahamsson, P. (2015). Key Challenges in Early-Stage Software Startups. *Agile Processes in Software Engineering and Extreme Programming*, *0*(0), 1–12. https://doi.org/10.1007/978-3-319-18612-2_5

Giardino, C., Unterkalmsteiner, M., Paternoster, N., Gorschek, T., & Abrahamsson, P. (2014). What do we know about software development in startups? *Software, IEEE*, *31*(5), 28–32. https://doi.org/10.1109/MS.2014.129

Giardino, C., Wang, X., & Abrahamsson, P. (2014). Why early-stage software startups fail: a behavioral framework. In *International Conference of Software Business* (pp. 27–41). Springer. https://doi.org/10.1007/978-3-319-08738-2_3

Gray, J., & Rumpe, B. (2015). Models for digitalization. *Software and Systems Modeling*, *14*(4), 1319–1320. https://doi.org/10.1007/s10270-015-0494-9

Hatch, N. W., & Dyer, J. H. (2004). Human capital and learning as a source of sustainable competitive advantage. *Strategic Management Journal*, *25*(12), 1155–1178. https://doi.org/10.1002/smj.421

Jalali, S., & Wohlin, C. (2012). Systematic literature studies: database searches vs. backward snowballing. In *Proceedings of the ACM-IEEE international symposium on Empirical software engineering and measurement* (pp. 29–38). https://doi.org/10.1145/2372251.2372257

Jansen, S., Finkelstein, A., & Brinkkemper, S. (2009). A sense of community: A research agenda for software ecosystems. *2009 31st International Conference on Software Engineering - Companion Volume*, (June), 187–190. https://doi.org/10.1109/ICSE-COMPANION.2009.5070978

Kitchenham, B. A., Budgen, D., & Pearl Brereton, O. (2011). Using mapping studies as the basis for further research–A participant-observer case study. *Information and Software Technology*, *53*(6), 638–651. https://doi.org/10.1016/j.infsof.2010.12.011

Klotins, E., Unterkalmsteiner, M., & Gorschek, T. (2015a). Software engineering knowledge areas in startup companies: A mapping study. *Lecture Notes in Business Information Processing*, *210*, 245–257. https://doi.org/10.1007/978-3-319-19593-3_22

Klotins, E., Unterkalmsteiner, M., & Gorschek, T. (2015b). Software Engineering Knowledge Areas in Startup Companies: A Mapping Study (pp. 245–257). Springer. https://doi.org/10.1007/978-3-319-19593-3_22

Kon, F., Cukier, D., Melo, C., Paulo, S., Hazzan, O., & Technion, H. Y. (2014). A Panorama of the Israeli Software Startup Ecosystem. https://doi.org/10.2139/ssrn.2441157

Lazear, E. P. (2004). Balanced Skills and Entrepreneurship. *The American Economic Review*, *94*(May), 208–211. https://doi.org/10.1257/0002828041301425

Mainela, T., & Puhakka, V. (2009). Organising new business in a turbulent context: Opportunity discovery and effectuation for IJV development in transition markets. *Journal of International Entrepreneurship*, *7*(2), 111–134. https://doi.org/10.1007/s10843-008-0034-6

Manikas, K. (2016). Revisiting software ecosystems research: A longitudinal literature study. *Journal of Systems and Software*, *117*, 84–103. https://doi.org/10.1016/j.jss.2016.02.003

Marshall, M. N. (1996). The key informant technique. *Family Practice*, *13*(1), 92–97. https://doi.org/10.1093/fampra/13.1.92

Martin, B. C., McNally, J. J., & Kay, M. J. (2013). Examining the formation of human capital in entrepreneurship: A meta-analysis of entrepreneurship education outcomes. *Journal of Business Venturing*, *28*(2), 211–224. https://doi.org/10.1016/j.jbusvent.2012.03.002

Marvel, M. R., & Lumpkin, G. T. (2007). Technology entrepreneurs' human capital and its effects on innovation radicalness. *Entrepreneurship Theory and Practice*, *31*(6), 807–828. https://doi.org/10.1111/j.1540-6520.2007.00209.x

Ojala, A. (2016a). Business models and opportunity creation: How IT entrepreneurs create

and develop business models under uncertainty. *Information Systems Journal*, *26*(5), 451–476. https://doi.org/10.1111/isj.12078

Ojala, A. (2016b). Discovering and creating business opportunities for cloud services. *Journal of Systems and Software*, *113*, 408–417. https://doi.org/10.1016/j.jss.2015.11.004

Olsson Holmström, H., & Bosch, J. (2015). Strategic ecosystem management: a multi-case study in the B2B domain. In *International Conference on Product-Focused Software Process Improvement* (pp. 3–15). https://doi.org/10.1007/978-3-319-26844-6_1

Parviainen, P., Tihinen, M., Kääriäinen, J., & Teppola, S. (2017). Tackling the digitalization challenge: how to benefit from digitalization in practice. *International Journal of Information Systems and Project Management*, *5*(1), 63–77. https://doi.org/10.12821/ijispm40204

Paternoster, N., Giardino, C., Unterkalmsteiner, M., Gorschek, T., & Abrahamsson, P. (2014). Software development in startup companies: A systematic mapping study. *Information and Software Technology*, *56*(10), 1200–1218. https://doi.org/10.1016/j.infsof.2014.04.014

Peteraf, M. A., & Bergen, M. E. (2003). Scanning dynamic competitive landscapes: A market-based and resource-based framework. *Strategic Management Journal*, *24*(10 SPEC ISS.), 1027–1041. https://doi.org/10.1002/smj.325

Petersen, K., Feldt, R., Mujtaba, S., & Mattsson, M. (2008). Systematic Mapping Studies in Software Engineering. *12Th International Conference on Evaluation and Assessment in Software Engineering*, *17*, 10. https://doi.org/10.1142/S0218194007003112

Ries, E. (2011). *The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses*. Crown Publishing Group. Retrieved from www.amazon.com/Lean-Startup-Entrepreneurs-Continuous-Innovation-ebook/dp/B004J4XGN6/ref=tmm_kin_swatch_0?_encoding=UTF8&qid=&sr=

Runeson, P. (2003). Using students as experiment subjects–an analysis on graduate and freshmen student data. *Proceedings 7th International Conference on Empirical Assessment & Evaluation in Software Engineering*, (January 2003), 95–102. https://doi.org/doi=10.1.1.99.6046

Runeson, P., & Höst, M. (2009). Guidelines for conducting and reporting case study research in software engineering. *Empirical Software Engineering*, *14*(2), 131–164. https://doi.org/10.1007/s10664-008-9102-8

Sarasvathy, S. D. (2001). Causation and effectuation: Toward a theoretical shift from economic inevitability to entrepreneurial contingency. *Academy of Management Review*, *26*(2), 243–263. https://doi.org/10.5465/AMR.2001.4378020

Seaman, C. B. (1999). Qualitative methods in empirical studies of software engineering. *Software Engineering, IEEE Transactions on*, *25*(4), 557–572. https://doi.org/10.1109/32.799955

Shrader, R., & Siegel, D. S. (2007). Assessing the relationship between human capital and firm performance: evidence from technology-based new ventures. *Entrepreneurship Theory and Practice*, *31*(6), 893–908. https://doi.org/10.1111/j.1540-6520.2007.00206.x

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic Capabilties and Strategic Management. *Strategic Management Journal*, *18*(7), 509–533. https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z

Unger, J. M., Rauch, A., Frese, M., & Rosenbusch, N. (2011). Human capital and entrepreneurial success: A meta-analytical review. *Journal of Business Venturing*, *26*(3), 341–358. https://doi.org/10.1016/j.jbusvent.2009.09.004

Unterkalmsteiner, M., Abrahamsson, P., Nguyen-duc, A., Baltes, G. H., Conboy, K., Dennehy, D., … Kon, F. (2016). Software Startups - A Research Agenda. *E-Informatica Software Engineering Journal*, *10*(1), 1–28. https://doi.org/10.5277/e-Inf160105

Verner, J. M., Evanco, W. M., & Cerpa, N. (2007). State of the practice: An exploratory analysis of schedule estimation and software project success prediction. *Information and Software Technology*, *49*(2), 181–193. https://doi.org/10.1016/j.infsof.2006.05.001

Väyrynen, K. (2009). *Evolution of software business in industrial companies: Resources, capabilities and strategy*. (Doctoral Disseration, University of Oulu, Finland). Retrieved from http://jultika.oulu.fi/Record/isbn978-951-42-9311-5

Wagner, H.-T., Weitzel, T., & Koenig, W. (2005). Modeling the impact of alignment routines on it performance: an approach to making the resource based view explicit. *Proceedings of the 38th Hawaii International Conference on System Sciences (HICSS)*, *0*(C), 1–10. https://doi.org/10.1109/HICSS.2005.440

Wang, X., Edison, H., Bajwa, S. S., Giardino, C., & Abrahamsson, P. (2016). Key Challenges in Software Startups Across Life Cycle Stages. In *Agile Processes, in Software Engineering, and Extreme Programming: 17th International Conference, XP 2016, Edinburgh, UK, May 24-27, 2016, Proceedings* (pp. 169–182). Springer. https://doi.org/10.1007/978-3-319-33515-5_14

Winter, S. G. (2003). Understanding Dynamic Capabilities. *Strategic Management Journal*, *24*(10), 991–995. https://doi.org/10.1002/smj.318

Wohlin, C. (2014). Guidelines for snowballing in systematic literature studies and a replication in software engineering. *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering - EASE '14*, 1–10. https://doi.org/10.1145/2601248.2601268

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C., Regnell, B., & Wesslén, A. (2012). *Experimentation in software engineering*. Springer. Retrieved from https://www.springer.com/gp/book/9783642290435

Wood, M. S., & McKinley, W. (2010). The production of entrepreneurial opportunity: a constructivist perspective. *Strategic Entrepreneurship Journal*, *4*(1), 66–84. https://doi.org/10.1002/sej.83

Yin, R. K. (2009). *Case Study Research: Design and Methods*. (L. Bickman & D. J. Rog, Eds.), *Essential guide to qualitative methods in organizational research* (Vol. 5). Sage Publications. https://doi.org/10.1097/FCH.0b013e31822dda9e

List of original publications

I Seppänen P, Oivo M, Liukkunen K (2016) The initial team of a software startup, Narrow-shouldered innovation and broad-shouldered implementation. In press.

II Seppänen P, Tripathi N, Oivo M, Liukkunen K (2017) How Are Product Ideas Validated? The Process from Innovation to Requirement Engineering in Software Startups. International Conference of Software Business (2017). doi:10.1007/978-3-319-69191-6_1.

III Seppänen P, Oivo M, Liukkunen K (2017) Little Big Team: Acquiring Human Capital in Software Startups. 18th International Conference on Product-Focused Software Process Improvement (2017). doi:10.1007/978-3-319-69926-4_20.

IV Seppänen P, Oivo M, Liukkunen K (2018) Opportunity Exploitation in Software Startups. A Human Capital View. In press.

V Tripathi N., Seppänen P, Oivo M, Liukkunen K (2017) The Effect of Competitor Interaction on Startup's Product Development. 43rd Euromicro Conference on Software Engineering and Advanced Applications (2017). doi:10.1109/SEAA.2017.34.

Original publications are not included in the electronic version of the dissertation.

Book orders:
Granum: Virtual book store
http://granum.uta.fi/granum/

UNIVERSITY OF OULU P.O. Box 8000 FI-90014 UNIVERSITY OF OULU FINLAND

ACTA UNIVERSITATIS OULUENSIS

UNIVERSITY of OULU
OULUN YLIOPISTO

ISBN 978-952-62-1948-6 (Paperback)
ISBN 978-952-62-1949-3 (PDF)
ISSN 0355-3191 (Print)
ISSN 1796-220X (Online)