COMMERCIALIZATION STRATEGIES FOR A UNIVERSITY RESEARCH PROJECT

Putting theory into practice

Lappeenranta–Lahti University of Technology LUT

Master's Programme in International Business and Entrepreneurship, Master's Thesis

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Examiner(s): Professor Mikko Pynnönen

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ABSTRACT

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Commercialization strategies for a university research project: Putting theory into practice

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Academic entrepreneurship is the collection of activities that lead to the commercialization of technology developed at a university. In addition to the global challenges of new venture formation, academic entrepreneurs must grapple with the additional technical uncertainty. In addition, academic entrepreneurs usually come from a technical background and thus do not necessarily know how to develop the business elements of the commercialization process.

This study examines a university research commercialization project from the Lappeenranta University of Technology. Documents generated by the project were analysed qualitatively to reversal the strategies, activities and tools that academic entrepreneurs utilize in order to advance the commercialization of their technology. The researcher (who was also a project team member) engaged in action research, yielding an iterative process wherein conclusions from the literature were introduced into the project, modified based on the input of project stakeholders, and ultimately implemented.

The academic contribution of this study is to show how the theory of entrepreneurship can be translated into the practice of entrepreneurship. The study also contributes to the practice of entrepreneurship by developing a generalized strategy for entrepreneurship that can be implemented by entrepreneurs.

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I am originally from San Diego, California, where I was the controller for two high-tech, grant funded start-ups. My first interaction with the International Business and Entrepreneurship program at LUT was my admissions interview. Wearing a suit in my apartment during the middle of the night was a surreal experience, but the ensuing conversation gave me the impression that LUT would provide a great environment to both live in and pursue my interest in technical entrepreneurship.

After a few months, I joined the BRAIN project, a grant-funded commercialization project out of the School of Energy Systems. The goal of the BRAIN project was to commercialize a simulation tool for rotating machines. The project brought me on board because they wanted guidance on the commercialization process. I quickly reviewed the literature on academic entrepreneurship and presented my findings. The reception to my presentation can be summed up in the following response from the Professor Jussi Sopanen. He said something like, “That is great, Alex, but what do we actually do?” My academic work since that point, including this thesis, has aimed at answering that question.

I would like to thank my lovely wife Daria for supporting me while I worked on this project, and throughout the entire term of my Master’s degree. Thanks to Emil Kurvinen for recruiting me to the BRAIN project and introducing me to the PATE project. Thanks to Miia John and the rest of the PATE project team for engaging with the workshops and strategy discussions. Thanks to Mikko Pynnönen and Luke Treves for supporting me with feedback and guidance on this thesis.

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1. Introduction

This thesis follows the commercialization process of a technology developed at the Lappeenranta University of Technology (LUT). The goal of the thesis is to evaluate the strategic considerations of the commercialization team.

1.1 Background

The Academy of Management Entrepreneurship Division, in a call for papers, defined the domain of entrepreneurship as "the creation and management of new businesses, small businesses and family businesses" and related topics (Gartner 2001, 30). New firm creation can an important driver of regional employment growth, at least when job-creating startups are nurtured in the region (Fritsch 1997, 446). Firms are created when founders go through the startup process, which ends with the offering of a new product or service by that firm. (Korunka et al. 2003, 23) The literature has firmly concluded that New Technology-Based Firms (NTBFs), defined by Delapierre et al. (1998, 989) as "independent firms established within the last 25 years for the purpose of exploiting an invention or technological innovation," are an important contributor to growth in local employment (Storey & Tether 1996, 9-12). NTBFs are also viewed as a critical mechanism that enable technology to solve society's problems (Konig et al. 2018, 3). While NTBFs and their associated technological innovations can originate from entrepreneurs without an established support network, many are corporate or university spin-offs (USOs) (Storey & Tether 1996, 75-78).

Universities have been identified as a significant source of NTBFs that exist to commercialize the technology developed within (Storey & Tether 1996, 75-78). The commercialization of university research is referred to as academic entrepreneurship in the literature (Bradley et al. 2013, 629). University research is generally commercialized by either licensing the technology to an existing firm or by forming a new firm (Wood 2009, 929; Bradley et al. 2013, 574-575; Vohora et al. 2004, 156; Clarysse et al. 2002, 30;

Pattnaik and Pandey 2014, 48). Gartner (2001, 30) questions whether there could ever be a single theoretical framework to unify the broad diversity of business activities that fall under the umbrella of entrepreneurship. Academic entrepreneurship is a similarly wide field. As a result, this study will focus specifically on the commercialization of high-tech university research, which, if commercialized via a spinoff company, would result in an NTBF.

In order to be a contributor to the societal benefits associated with new venture creation, a university spinoff needs to successfully navigate through the startup process and continue as a standalone venture. For an NTBF, this process involves developing and validating a sustainable business model (Osiyevskyy et al. 2018, 51-52). Academic entrepreneurs are often unfamiliar with how to do so efficiently, which impedes the commercialization of their research (Vohora et al. 2004, 156). This deficiency in knowledge and expertise can be addressed by coaching the technical team members (Clarysse et al. 2002, 20).

1.2 Research Gap, Objectives, and Questions

A recent literature review by Shepherd and Gruber (2020) aimed at closing the gap between the academic study of the startup process and the practical execution of it, identified 27 research opportunities within the realm of the startup process. The common theme among these 27 opportunities is a micro-level perspective of the activities and strategies employed by nascent entrepreneurs and a strong connection to the academic literature on various aspects of entrepreneurship. They can be summarized as seeking to answer the same question that I ran into in my earlier experiences at LUT: "What do entrepreneurs actually do?"

While all 27 opportunities cover different aspects of the startup process, three resonated with the experiences of the PATE project during the study period. They include: "1) Investigate how founders can engage in distant or global search to answer the question 'where to play,' i.e., investigate the identification and composition of a portfolio of market opportunities and the process of choosing the most promising starting position." (Shepherd and Gruber 2020, 21.) "2) Investigate how conditions of uncertainty differ between opportunities and what these differences mean for important process and outcome

variables such as the possibility to establish successful ventures, the challenges associated with each venture creation process, and the managerial/entrepreneurial abilities required to exploit the opportunity." (Shepherd and Gruber 2020, 21) and 3) "Explore the role of the termination decision in conjunction with the decision to pivot or persevere." (Shepherd and Gruber 2020, 23.)

The literature on USOs was reviewed by Miranda et al. (2018). They found 82 papers on USOs which use the firm as the unit of analysis; of these, only 31 focus on characteristics of the firms (as opposed to outcomes or antecedents.) While the authors identify a small stream of research that focuses on the academic entrepreneurship process, only a single article (Wood 2009) is identified as belonging in this stream. The authors called out a need for additional case studies "in high added value and knowledge-intensive sectors characterized by high levels of uncertainty…to assist the decision-making of…company managers." (Miranda et al. 2018, 1020.) This research gap can once again be summarized by the question I am seeking to answer: "What do [academic] entrepreneurs need to do?" Djokovic and Souitaris (2008, 244) recommend that future research into USOs focus on "practical phenomenon-specific questions but then tackle them with the most theoretical explanations," supporting the joint theory and practice approach called for by Shepherd and Gruber (2020).

My mission and the gaps identified in the literature support the same objective: Develop practical guidance for commercialization teams. This objective is reflected in the following primary research question:

Q1: What does an academic entrepreneur need to do in order to commercialize their research?

Implementing this guidance can take many different forms, ranging from completely outsourcing the required commercialization tasks to an outside consultant to having the core commercialization team take ownership directly. The management of NTBFs, however, must jointly manage the technical and business elements of the business (Luggen and Tschirky 2003, 342-344), implying that commercialization advisors should serve as

coaches rather than consultants (Radosevich 1995, 890-891). A related research question is thus:

Q1a: How can a commercialization team ensure that the technical and business resources on the team are fully integrated?

As the literature proposed several strategies, tools, and methods for navigating through the commercialization process, another set of sub-questions are:

Q1b: What strategies and tools support the commercialization process? And
Q1c: How do academic entrepreneurs learn about these strategies and tools?

This study aims to begin investigating these questions through a qualitative, single-case study that implements an Action Research approach. Abductive reasoning is utilized to synthesize a strategy from the literature, which is then deployed by the case project and analyzed as part of the study. Due to the limitations of this approach, another goal of the study is to identify and develop themes and theories that can be further explored in subsequent studies.

1.3 Theoretical Framework

The theory presented in this paper is divided into two sections. First a framework for the phenomenn of entrepreneurship is presented based on a broad review of the literature on entrepreneurship and the startup process. The narrower theoretical framework utilized directly by this thesis is then presented afterwards. The framework for the phenomenon is summarized and synthesized into a strategic framework for academic entrepreneurship, which is subsequently incorporated into the framework of the thesis.

1.3.1 Framework of the Phenomenon

Kirzner defines entrepreneurship as the exploitation of profit opportunities (Kirzner 1973, 1979, 1992 cited in Klein 2008, 177). The theoretical framework for the phenomenon of

entrepreneurship first looks at the origins and characteristics of opportunities by looking at several different theories at both the micro and macro levels. Next, the framework explores several challenges to opportunity exploitation. The framework then looks at methods for exploiting opportunities before finally describing ways of optimizing these methods. An overview of the Framework Elements and their contribution to the Framework is presented in Table 1 below.

Table 1: Elements in the Framework for the Phenomenon of Entrepreneurship and their Contribution to the Framework

Framework Element	Contribution to Framework
Origins and Characteristics of Opportunities	
Perfect Competition	Idealized economic model where all opportunities are exploited already
Knightian Uncertainty	Opportunities exist due to imperfect information, which varies between firms. Opportunities can be exploited by gaining information.
Transaction Cost Economics	Unexploited opportunities exist because of the costs of doing business, which vary between firms. Opportunities can be exploited when a solution to these costs is developed.
Resource Based View (RBV)	Unexploited opportunities exist because existing firms lack the resources to exploit them. Opportunities can be exploited when those resources are acquired.
Opportunity Discovery	Opportunities are an inherent concept that exist despite being undiscovered. With sufficient data and analysis, the opportunity can be defined and exploited.
Opportunity Creation	Opportunities cannot be fully defined at the outset. The opportunity is developed or created through entrepreneurial actions.
Opportunity Exploitation Challenges	
Opportunity Creation / Knightian Uncertainty / Path Dependency	Additional risk to the opportunity exploitation process because the endpoints cannot be determined at the outset.
Liability of Newness	Additional risk to opportunity exploitation for new firms or business units due to a lack of experience and credibility
Resources Based View – Accumulating Resources	Developing resources often requires having other resources
Methods for Opportunity Exploitation	
Business Model	A construct to describe how resources are used to exploit opportunities
Innovation Process	Process description for innovation in general and as applied to Business Model Innovation
University Technology Commercialization Modes	Possible organizational solutions for implementing a business model

University Technology Commercialization Process	Processes for achieving the identified commercialization modes
The Lean Startup	Methods and tools for reducing risk in the commercialization process

The starting point for the phenomenon framework is the neoclassical economic theory of perfect competition which describes an idealized economy with no unexploited opportunities. Knightian uncertainty, Transaction Cost Economics and the RBV are then presented; each theory relaxes a different assumption from perfect competition to create room for unexploited profit opportunities at the macro level of the entire economy. The Resource Based View is adopted as the primary model to explain the existence of opportunities since it has sufficient flexibility to account for the insights presented by the other theories. Opportunity discovery and opportunity creation are competing theories that describe the origin of opportunities at the micro level. Each theory presented in this section of the framework implies that opportunities contain a different set of characteristics which are relevant to the exploitation of opportunities. Some of these characteristics are then further expanded upon as they represent specific challenges to opportunity exploitation. In addition, the general challenges of engaging in new business activities (Liability of Newness) are presented.

The phenomenon framework then presents methods for opportunity exploitation. The Business Model is presented as a construct that explains how exactly the resources called for by the RBV exploit an opportunity. University Technology Commercialization Modes are presented to demonstrate the organizational requirements for implementing a business model. Several versions of the University Technology Commercialization Process are presented to show the steps that a university-based commercialization team must take to accomplish these modes. Finally, The Lean Startup methodology is presented as a set of tools and methods for reducing the risk of this process.

1.3.2 Theoretical Framework for Thesis

This thesis will explore the application of entrepreneurship theory in practice. Table 2 shows the theoretical framework utilized by this thesis.

Table 2: Theoretical Framework for the Thesis

Framework Element	Contribution to Framework
Implementation of the Lean Startup	Applying The Lean Startup methods for specific commercialization projects
Educating Academic Entrepreneurs	Methods for communicating commercialization process methods to academic entrepreneurs
Summary and Synthesis	Summary and synthesis of the phenomenon framework into a condensed, actionable algorithm

The theoretical framework for this thesis first presents methods for implementation of The Lean Startup. The next element of the framework looks at how insights from The Lean Startup and from the framework for the phenomenon are communicated to academic entrepreneurs so that they can be implemented. Lastly, the overall framework of the phenomenon is summarized and synthesized into a general strategy for navigating through the commercialization process.

1.4 Methodology

I have dual roles in this project as both researcher and commercialization team member. The methodology used is participatory action research, with a dual mission of producing academic research and imparting positive change to the commercialization team. The use of a synthesized theory from the literature is an example of an abductive research philosophy. Ultimately, one case project is evaluated in an exploratory case study. The data collected for analysis consists of a variety of English language documents generated by the commercialization team. Document analysis is used to extract themes from the documents that are relevant to the research questions.

1.5 Limitations

Due to the large theoretical gap, this thesis will utilize abductive reasoning in its analysis. One consequence of using abductive reasoning is that the results are merely plausible and will require further investigation before they can be relied upon by other entrepreneurs (Shank 2008, 1-2). This weakness with regards to generalizability is further compounded

by using a single case in the study. It is not clear that the conclusions, even if accurate, would apply to other university commercialization projects in different contexts.

Another limitation is related to the study timeline. For some industries or technologies, the startup process can be quite long. In any event, the PATE project was not able to complete the process during the study timeline as commercialization efforts are still mid-process. While this study is concerned with the success or failure of specific interventions, success or failure is defined by the acceptance of an intervention by the technical team (and a corresponding adjustment to technical team activities) as opposed to commercial success or failure. Future studies can address these weaknesses in order to strengthen the conclusions about academic entrepreneur strategies.

1.6 Structure of the Thesis

The first section of the thesis will introduce the topic and provide a high-level overview of the thesis. In the second section, a literature review will outline theories that explain why new firms are created as well as some of the processes involved in starting a new firm. These theories will ultimately be synthesized into a practical strategy for academic entrepreneurship. The third section will describe research methods and the relationship between my dual project roles as researcher and participant. The fourth section will introduce the case project and technical background. The fifth section will present the findings of the study, which will be discussed in the sixth section. Finally, the seventh section will summarize the role of this study and implications, both in terms of research and practical applications.

2. Literature Review

The literature review in Sections 2.1 through 2.3 represent the theoretical framework for the phenomenon of entrepreneurship. Section 2.4 outlines the theoretical framework for this thesis, which focuses on the implementation of the previously presented theory.

2.1 Origin of Opportunities

Several theories are presented below regarding the origin of opportunities. I first explore the origin of opportunities on the macro level of the entire economy, and then look at the origin of individual opportunities at the micro-level. As some of the theories presented in this section focus on different aspects of entrepreneurship, the section concludes by reconciling these apparent discrepancies.

2.1.1 Origin of Opportunities in the Economy (Macro Level)

Neoclassical economics assumes a "frictionless" economy. Known as perfect competition, this means that there are no transaction costs between economic actors, and each actor has complete information. (Madhok 2002, 535-538). In this model, there is only one product, made by combining a singular resource and labor. The result of these assumptions is an economy full of identical firms, fully exploiting any potential profit opportunities. Firm size is constrained by the assumption that production costs increase as the firm gets large with respect to the market, yielding numerous smaller firms in competition with each other. Firms are assumed to take actions that will maximize profits, but the result is a market equilibrium where no firm makes any more profits than the others. (Conner 1991, 123-124.)

Several different theories of the firm build off of this neoclassical model, relaxing the core assumptions of perfect competition in different ways to account for these missing elements. (Shane 2000, 449) Many of these theories reflect the thoughts of the "Austrian

School" of economics, which has historically focused on the entrepreneur as a driving force for economic activity (Lewis 2021, 2). Without perfect competition, the modeled economy contains unexploited profit opportunities. Knight[1] (1921, 232) takes aim at the perfect information assumption, concluding that profit opportunities exist because of missing information. A firm's ability to exploit these opportunities comes from the entrepreneur's ability to exercise judgement to make decisions with imperfect information. Under a Knightian view of the economy, individual firm profits can be attributed to good judgement. (Knight, 1921, 311.) Mises (1949, cited in Klein 2008, 178) similarly describes profit as a return for bearing risks through entrepreneurship.

Transaction Cost (TC) theories focus on the costs of doing busines as the trigger for the existence of heterogeneous firms with divergent profitability (Madhok 2002, 535-536). Coase (1937) identified the free market's price mechanism (for optimally matching buyers and sellers) as a potential source of these costs. Williamson (1981) applied the transaction cost perspective to the governance of the firm. The creation of a firm is a "choice between firm and market organization." (Williamson 1981, 558.) Building on Williamson's work (1981), Agency theory looks at different goals or incentives between the individuals within an organization as a possible source of market failure (Eisenhardt, 1989). Another source of transaction costs are inefficiencies in the flow of information between stakeholders. Economic activity ceases when the costs of organizing or coordinating that activity exceed the value of that activity. (Benkler 2001, 401-403.)

Under the Resource Based View (RBV) framework the market failures that bring about the formation of a new firm come from heterogeneity in firm resources. Different firms make different products from different inputs. The resources referenced in the RBV are whatever inputs are necessary for production. (Foss and Ishikawa 2007, 750.) Firms seek out unique sets of resources that are difficult to duplicate and can be used to generate profit (Conner 1991, 132-133). These resources form the basis of a firm's competitive advantage, a key consideration when formulating the firm's strategy. The accumulation of resources can also explain the process by which new firms are created. (Foss and Ishikawa 2007, 749-51.) The RBV and the Austrian school share a focus on resources. Schumpeter

[1] While Frank Knight was not actually a member of the "Austrian School" of economics, his methodological and philosophical approach has much in common with the Austrians. (Yu 2002, 3)

(1934, cited in Lewis 2021, 2) focused on unique combinations of resources as a source of innovation.

2.1.2 Expanding the Resource Based View

One critique of the RBV is that the definition of resources is somewhat ambiguous (Kellermanns et al. 2016, 28-29). Kellermans et al. (2016) found that both entrepreneurs and academics defined the resources referenced in the RBV in a very broad way to include anything that a firm requires to exploit an opportunity, including assets that are both tangible and intangible. This broader take on the definition of resources allows the RBV to capture the insight from the other theories on the origin of opportunities. Intangible resources can include the individual characteristics of entrepreneurs, such as their ability to identify and exploit opportunities (Alvarez and Busenitz 2001, 771), and the entrepreneur's ability to learn from prior experience (Conner 1991, 137). This broader view of resources is consistent with the economics treatment of information as an intangible production input (Conner 1991, 138), which allows the RBV to represent the Knightian view of information asymmetry as a source of opportunities as a special case of resource heterogeneity (Foss and Ishikawa 2007, 750). Similarly, the transaction costs that are responsible for opportunities from the TC perspective can also be represented as a deficiency of tangible or intangible resources that would allow the firm to resolve them (Williamson 1975 cited in Conner 1991, 138). The RBV can thus be used as a general theory representing the origin of opportunities in the economy.

2.1.3 Origin of Individual Opportunities (Micro Level)

There are two major perspectives on the origin of individual opportunities: They may be discovered (Shane 2000), or created (Alvarez and Barney, 2007). Klein (2008, 182) argues that the nature of opportunities is unimportant, so long as they are exploited after they are discovered. Alvarez and Barney (2007, 23), on the other hand, tie the opportunity creation theory back to the theory of the firm: If an entrepreneurial path is only created as the firm goes along, then there is inherent Knightian uncertainty.

George et al. (2016) conclude that opportunities with more uncertainty are created, while opportunities with less uncertainty are discovered. Zahra (2008, 243-244) argues that individual opportunities are both discovered and created, in an iterative cycle that is heavily influenced by context. One way of reconciling this plurality of views is to account for the fact that even risky opportunities may contain sub-elements that are not specifically risky.

2.2 Opportunity Exploitation Challenges

Once an opportunity has been identified, the next step is exploitation of the opportunity (Shane and Venkataraman 2000, 218). The characteristics implied by the theories of the origin of opportunities imply additional exploitation challenges.

2.2.1 Path Dependency

The Knightian uncertainty referenced within the theory of opportunity creation implies a certain level of path dependency. Path dependency means that the possible set of later outcomes (at the end of the entrepreneurial path, in this case) are constrained by things that occur earlier along the path. (Abatecola 2012, 5-6.) Abatecola (2012, 6) explores the characteristics beyond general uncertainty that lead to path dependency, concluding that there must be multiple potential outcomes (which would be represented by different branches to the entrepreneurial path), and there must be some barriers that prevent switching from one branch of the path to another. Vohora et al. (2004, 170) identify three characteristics that constrained eventual commercialization outcomes within their study sample: A lack of resources, a lack of entrepreneurial networks, and a lack of business management capabilities from within the technical team. Pattnaik and Pandey (2014, 47) show that resource weakness could be restrictions placed upon a resource (for example, a funding source with additional requirements) which can also lead to path dependencies. Path dependency can also be viewed caused by the fact that entrepreneurs learn how best to exploit their resources by gaining experience from the market as they go (Alvarez and Busenitz 2001, 769).

Path dependency can thus be triggered by the choices that entrepreneurs make (Alvarez and Busenitz 2001, 769) or by difficulties that are outside of their control (Vohora et al. 2004, 170). The scale of the choice or weakness becomes quite relevant in evaluating the criteria set out by Abatecola (2012, 6). For example, if the uncertainty associated with a specific choice can be resolved quickly and without expending too many resources, there is a lower level of commitment; the entrepreneur could still switch to a different path if the results of the choice are unfavorable. This conclusion echoes the conclusion made by Arrow (1971) in evaluating uncertainty and risk from a micro-economics perspective. He concluded that, over sufficiently small stakes, a risk-averse individual would still act as though he were risk-neutral. Put another way, risky or uncertain situations require a meaningful magnitude in order to impact the behavior of a rational actor.

As this study focuses on the development of new technology with a high degree of uncertainty, it assumes that path dependency is a factor of the entrepreneurial path, while allowing for the possibility that some sub-elements of the commercialization process might have less uncertainty.

2.2.2 Liability of Newness

All firms exploiting a new opportunity logically share at least one thing in common: The business activity is new, and there are liabilities associated with newness (Yang and Aldrich 2017, 36-37). The firm may be targeting a new market, exposing the firm to the challenge of defining who the customers are. (Blank 2013, 10.) Once the customers are defined and identified, the firm must address the fact that there is no historical track record associated with the new product or service, which can cause a lack of trust (Ulvenblad et al. 2013, 187; Politis 2005, 404). For a technology-based firm, this lack of trust can run even deeper than just the firm's track record, depending on how novel the new technology is. A new firm faces additional challenges: They may lack cash flow and the ability to raise financial resources (Politis 2005, 404; Ulvenbald et a. 2013, 188). The new firm might also be lacking in business processes or other organizational knowledge (Yang and Aldrich 2017, 38-39). The combination of these challenges means that entrepreneurs must achieve profitability for their new venture amid significant uncertainty (Politis 2005, 404-405).

Entrepreneurs can ameliorate the liability of newness by addressing one or more of these causes. The entrepreneur can bring resources to their new firm, such as financial capital from previous employment, or human capital from their previous work experience. (Yang and Aldrich 2017, 37-38.). This experience can include general business knowledge, specific knowledge of the industry which facilitates identification of an opportunity or development of a solution (Yang and Aldrich 2017, 37) as well as the communication skills required to coordinate the new venture's activities (Ulvenblad et al. 2013, 188). An entrepreneur can also form a team that has prior experience working together, allowing the new firm to quickly adopt the relevant organizational routines and workflow (Yang and Aldrich 2017, 38-39). Ulvenblad et al. (2013, 204) conclude that entrepreneurship education can also supplement prior experience and contribute towards overcoming the liability of newness.

2.2.3 Accumulating Resources

From an RBV perspective, a firm that wishes to exploit a profit opportunity must accumulate the necessary resources. They can develop resources themselves or participate in market transactions to purchase the resources or cooperate with another entity that has them (Barney 1999, cited in Pynnönen 2012, 2). A resource could be critical because it provides a solution for resolving a transaction costs barrier or other source of market failure.

The process of acquiring resources necessitates the firm to participate in a variety of market transactions. This can include the capital markets (for financial resources), labor markets (for human capital resources), and a variety of input factor markets as determined by the specific opportunity (Kellermans et al. 2016, 38-39). Each individual market transaction could be part of the reason why existing firms have failed to exploit the opportunity. The firm will need to overcome this barrier through some sort of innovation. Schumpeter (1934 cited in Śledzik 2013, 90) states that this innovation can happen on the level of a new product or service, or an innovation in the business processes that support the firm's commercial activities. However, not every resource used by the firm needs to be

innovative. In fact, it can be more cost-effective to access resources through cooperating with another firm. (Barney 1999, cited in Pynnönen 2012, 2)

The accumulation of human resources is reflected in the process of building an entrepreneurial team which can be a strong determinant of venture success (Tietz 2013, 20). Team roles include at least a technology developer, responsible for technical research, and an entrepreneur, responsible for developing the business elements and developing the technology into a relevant product or service (Carayannis et al. 1998, 4-5). The team should also include a business champion, responsible for pushing the overall commercialization project along. (Clarysse and Moray 2004, 65-66) When the venture is ready to be established, the team can also include an investor-partner who provides financing and potentially additional business expertise. Multiple roles can be filled by the same person, such as when the technology developer is also the entrepreneur (Carayannis et al. 1998, 4-5). In addition to their direct skillset, Entrepreneurial team members also bring social capital, which allows the venture to access additional knowledge, resources, and insight into opportunities from the team members' social networks. (Akhtar and Ort 2018, 37-38)

2.3 Methods for Opportunity Exploitation

In order to start a new firm, entrepreneurs must overcome these challenges. The following sections describe concepts and processes that help entrepreneurs to do so.

2.3.1 Business Models

The business model explains how a firm's resources (including human resources, financial resources, technological resources, and external partnerships) will be used to provide value to customers in a profitable way (Sorescu 2017, 691-693), forming a link between opportunities and their exploitation through entrepreneurial action (Trimi and Berbegal-Mirabent 2012, 454). Although there are divergent views about the definition of a business model (Felin 2020, 5) (Trimi and Berbegal-Mirabent 2012, 450), the literature generally agrees on the basic components of a business model, which contains "the firm's value

proposition and market segments, the structure of the value chain required for realizing the value proposition, the mechanisms of value capture that the firm deploys, and how these elements are linked together in an architecture." (Saebi, Lien and Foss 2016, cited in Foss and Saebi 2017, 202.)

This architecture covers "the rationale of how an organization creates, delivers, and captures value." (Osterwalder and Pigneur 2010, 14.) Osterwalder and Pigneur define nine building blocks of a busines model, presented in Table 3 below.

Table 3: Business Model Elements, Source: Osterwalder and Pigneur (2010, 16-17)

Business Model Building Block	**Purpose**
Customer Segments	Recipients of value
Value Proposition	Value that is being provided to the customers
Channels	Methods of delivering value, including "communication, distribution and sales channels." (Osterwalder and Pigneur 2010, 16)
Customer Relationships	Connections between customer segments and the venture
Revenue Streams	How each value proposition is monetized
Key Resources	Resources required to deliver value
Key Activities	How the Key Resources are used to deliver value
Key Partnerships	Relationships with other stakeholders
Cost Structure	Financial representation of the other business model elements

These nine building blocks are the core elements of the Business Model Canvas (Osterwalder and Pigneur 2010, 44), a framework that is widely used to create or modify business models (Felin et al. 2020, 3).

The development, validation and implementation of a business model to address a market opportunity is a key activity for entrepreneurs throughout the startup process (Blank 2013, 17). In the early stages of company formation, a new business model is full of uncertainty and unvalidated assumptions (Eisenmann et al. 2017, 1). The resulting business models can then be tested, evaluated, and improved (Bocken and Snihur 2020, 3) in response to "resource constraints and external environmental changes," (Vohora et al. 2004, 158) including a better understanding of customer demand (Blank 2013, 17). Business models

are also presented to investors in order to raise additional financial resources (Vohora et al. 2004, 167).

2.3.2 Innovation Process

Exploitation of new opportunities (and thus entrepreneurship) is driven by innovation. (Śledzik 2013, 90) The general innovation management process is often represented as a funnel. The wide opening of the funnel shape corresponds with an initially large list of potential innovations. Along the way, the ideas are also refined and improved upon, ultimately (and hopefully) reaching a small list of potential innovations that can be implemented by the firm, represented by the narrow opening of a funnel. (Bertoluci et al. 2013, 7211) The innovation process can be applied to "products, technologies, process, or organization." (Bertoluci et al. 2013, 726) The busines model itself can be the target of innovation when the firm's value proposition is meaningfully changed by the innovation process (Sorescu 2017, 692).

Business Model Innovation (BMI) is the process through which firms conceive of and implement new business models or update existing business models (Sorescu 2017, 692). Wirtz and Daiser (2018) reviewed the literature on BMI and synthesized it into an overarching process for creating new business models that largely follows the general innovation management process. This BMI process begins with an analysis of the status quo, which leads to ideas for new business models. The ideas are evaluated for feasibility before they are piloted. The firm then decides which business model to implement and then reviews the resulting ongoing performance to ensure that the business model continues to generate profit.

While the innovation management literature presents a general funnel, the exact structure and functioning of the innovation funnel are captured by a variety of different funnels with different physical representations. The main difference between the different types of funnels reviewed by Bertoluci et al. (2013, 727-730) is the exact processes under which ideas are evaluated and rejected from a research and development perspective. In some industries, such as the aerospace industry, the evaluation of ideas occurs slowly and deliberatively (Bertoluci et al. 2013, 727-730). This is due to inherently long engineering

development timelines, as well as extensive safety regulations (Eisenmann et al. 2017, 12). Other industries are more conducive to more rapid, open-ended innovation. Sometimes the development modes are mixed within a single innovation process. (Bertoluci et al. 2013, 727-730.) Bertoluci et al. (2013, 731) also argue that the stage of the company can influence the structure of the company's innovation process. Startup companies use more flexible processes, with less standardization. As the company grows and matures, the processes start to stabilize and become more deliberate. One side effect of this standardization is that more established companies start to cast aside true innovations, preferring incremental advances over truly disruptive ideas. (Bertoluci et al. 2013, 731-732.). This is because the market uncertainty associated with a radical innovation increases the risk that the establish company's existing infrastructure (such as manufacturing capacity and distribution logistics) won't be relevant to commercializing the technology (Clarysse et al. 2002, 5).

2.3.3 University Technology Commercialization Modes

The organizational structure of a firm can determine the amount and types of resources that are available for its business activities (Castrogiovanni 1991, 542-543). Universities are generally viewed as bureaucratic institutions with bloated decision-making processes that are not well suited to commercial activity, which is why the universities do not usually commercialize university research internally (Wennberg et al. 2011, 1141). In other words, university culture is not particularly entrepreneurial, so academic entrepreneurs generally seek out a different organization to conclude the commercialization of their research (Ndonzuau et al. 2002, 283) Bradley (2013, 574-575) concludes that university technology can be commercialized by licensing the technology to an existing firm or by spinning off a new venture. Licensing the technology, however, is only feasible when market uncertainty is low (Clarysse et al. 2002, 30) or when the technology has favorable characteristics for technology transfer as measured along four dimensions: codifiability, teachability, complexity, and system dependence. Taken together, licensing is an option when there is relatively low uncertainty, both in terms of framing the business opportunity and physically transferring the technology. Zahra and Van de Velde (2007, cited in Pattnaik and Pandey 2014, 49) indicate that spin off companies are more likely when the

research being commercialized is more innovative, pure research, as opposed to applied research.

The different commercialization modes can have an impact on the amount of innovation that is required to commercialize a technology. A technology-based firm is generally understood to be using its technology to create novel services or products. (Trimi and Berbegal-Mirabent 2012, 452) An existing company that licenses university technology might have the option of limiting its development to this level only, while continuing to utilize existing business process and organizational structures (Sorescu 2017, 69). Academic entrepreneurs who are launching new ventures, however, must develop all elements of the business model (Trimi and Berbegal-Mirabent 2012, 450).

2.3.4 University Technology Commercialization Process

Pynnönen et al. (2019, 341) describes the academic entrepreneurship process as an application of BMI. Gbadegeshin (2017, 6-7), Ndonzuau et al. (2002, 283), Aguirre et al. (2006, 161), Clarysse et al. (2002, 30) and Vohora et al. (2004, 152) describe similar processes through which "business ideas" or "opportunities" are evaluated. Those that pass the evaluation stage are ultimately implemented, yielding the step "establishing a company" (Pynnönen et al. 2019, 341) or "establishment of USO" (Gbadegeshin 2017, 7), a necessary step along the way to a "first sale" (Aguirre et al. 2006, 161). A few models continue to track the venture as it achieves "sustainable returns" (Vohora et al. 2004, 152), "creation of economic value." (Ndonzuau et al. 2002, 283), or a "validated growth expectation." (Clarysse et al. 2002, 30.) These are all examples of innovation funnels applied to the process of academic entrepreneurship, generated from cases from Finland (Gbadegeshin 2017, 1; Pynnönen et al. 2019, 341; Ndonzuau et al. 2002, 282), the UK (Clarysse et al. 2002, 4; Vohora et al. 2004, 149; Ndonzuau et al. 2002, 282; Clarysse et al. 2002, 4), Spain (Aguirre et al. 2006, 159), the United States and Canada (Ndonzuau et al. 2002, 282), Israel (Ndonzuau et al. 2002, 282), and other countries in Europe (Ndonzuau et al. 2002, 282; Clarysse et al. 2002, 4).

Several common themes emerge between these different bodies of work. One theme that is explored by all multiple authors is the challenges that academic entrepreneurs face when

switching from an academic context to a commercialization contest. A technology based USO must reconcile two different perspectives on science: "the 'scientific' conception, which considers science as an end in itself, and the 'economic' conception, which considers it more as a means to achieve other goals (in particular making money.)" (Ndonzuau et al. 2002, 283.) This includes answering questions such as, "What are the different applications of a given technology? Which are the most promising? Who are the key players in those markets? How high are the barriers to entry? Is the potential good enough to build up a viable company?" (Ndonzuau et al. 2002, 284) along with other questions that frame an idea in terms of a business opportunity (Vohora et al. 2004, 151) (Aguirre et al. 2006, 162). This business evaluation can pose significant challenges for academic entrepreneurs. (Vohora et al. 2004, 151) (Aguirre et al. 2006, 168-169) External consultants can help with these evaluations. (Pynnönen et al. 2019, 345-346; Aguirre et al. 2006, 168-169.)

This influence of business on the technical processes addresses Steve Blank's critique of traditional product development processes. He argues that traditional methods ignore the sales and marketing process, initially focusing only on the engineering process. (Blank 2013, 11-13) Traditional product development models invest significant time and energy before asking questions about the market size or who exactly will be the customers. If a startup company fails to focus on the economic conception of technology development, the risk is that they will expend their technical development and product launch resources to accomplish the wrong goals, which can be fatal for the venture. (Blank 2013, 1-8)

These challenges are a partial determinant of the next common theme: an iterative process. (Aguirre et al. 2006, 162). Academic entrepreneurs often must reevaluate early conclusions (Aguirre et al. 2006, 162) as they get more information because initial analyses are often vague, imprecise, or based off incomplete information (Vohora et al. 2004, 156). Gbadegeshin (2017, 15) similarly describes the commercialization process as "iterative or circular." This isn't just due to the inexperience of academic entrepreneurs: Blank (2013, 10) argues that even teams with a business background can have trouble making accurate predictions, particularly when the new product or technology is creating a new market or radically disrupting existing markets.

The last theme is related to the output of this process. Most university commercialization projects will need to continue seek out resources throughout the commercialization process such as additional funding (Ndonzuau et al. 2002, 286). Stakeholders such as investors want to see proof of the overall concept (Aguirre et al. 2006, 162), proof that there is a market to serve, and proof that the team has the capability to execute (Vohora et al. 2004, 156). Vohora et al. (2004, 152**)** describe this proof as meeting the "threshold of credibility," a critical juncture where the project must accumulate the necessary resources to exploit the opportunity. This proof can be packaged in a "presentation to the investors." (Pynnönen et al. 2019, 346.)

2.3.5 The Lean Startup

The commercialization team must split its resources between coming up with new ideas and evaluating them. A major challenge for the team is allocating whatever scarce resources are available between these two tasks. (Politis 2005, 408.) Aguirre et al. (2006, 162) describe the university research commercialization process as a "cyclic, curly and iterative process." These are three attributes that potentially lead to a long process before the team can identify a sustainable business model. A long process increases the chances that the entrepreneur will run out of resources before identifying a sustainable business model, leading to business failure. (Shepherd and Gruber 2020, 14.) The number of resources that a venture has on hand to support commercialization efforts is known as its *runway*. While *runway* is traditionally framed as the length of time that the startup can continue operating, Eric Ries, author of *The Lean Startup*, views runway in terms of the number of *pivots* a venture can make with its current resources. A *pivot* is a shift in strategy, the primary activity that causes the commercialization process to be iterative. (Eisenmann et al. 2017, 21.)

The Lean Startup (TLS) is a methodology designed by Eric Ries to reduce the risk of the commercialization process by reducing its length (Ladd and Kendall 2017, 31) Additional authors (Blank, Osterwalder and Pigneur, Gruber and Tal) have built upon TLS and proposed additional compatible tools and methodologies (Shepherd and Gruber 2020). TLS is a "business model validation (BMV) methodology based on rapid iterations" (Bortolini et al. 2021, 1757) Under TLS, Entrepreneurs are encouraged to develop

hypothesis about their "current and future prospects" and then design experiments to test them. (Shepherd and Gruber 2020, 10.) Ries described a "Build-Measure-Learn" cycle in order to shorten the time that it takes to successfully launch new products. (Eisenmann et al. 2017, 6) Within this cycle, Minimum Viable Products (MVPs) are built (Eisenmann et al. 2017, 6); then experiments are designed that will measure the performance of the MVP (Eisenmann et al. 2017, 6) (Gbadegeshin 2018, 57); and finally, the entrepreneur learns from the results, and decides whether to persevere with the current path, or pivot to another. (Gbadegeshin 2018, 57)

Shepherd and Gruber (2020, 5-17) distill TLS into five major building blocks which address different aspects of the startup process, sometimes with an associated tool.

Table 4: TLS Building Blocks and Tools

TLS Building Blocks (Shepherd and Gruber 2020, 5-17)	**Relevant Tools (Blank 2019; Harms and Schwery 2020, 1)**	**Purpose (Blank 2019)**
Finding and Prioritizing Market Opportunities	Market Opportunity Navigator	Evaluate the economic potential for different opportunities
Designing Business Models	Business Model Canvas	Collect the hypotheses associated with the opportunity
Validated Learning	Customer Development	Validate those hypotheses
Building Minimum Viable Products	Lean Engineering	Validate more hypotheses
Persevere or Pivot with Course of Action	Planning	Shorten the length of the startup process

Opportunities are the starting point of the commercialization process. The efficiency of the opportunity search process is determined by the quality of initial ideas, and the entrepreneur's ability to quickly prioritize worthwhile ideas. The Market Opportunity Navigator is a tool that helps entrepreneurs prioritize between different ideas by providing a framework for evaluating the potential customer interest. (Shepherd and Gruber 2020, 5-7.) Steve Blank refers to this tool as "front end customer development." (Blank 2019) The Business Model Canvas is a framework that allows the entrepreneur to collect the assumptions associated with the market opportunity. (Blank 2019) It thus serves the role

of a minimum viable business plan that can be updated and modified more quickly. (Shepherd and Gruber 2020, 7-9) Blank's customer development model (2013, 15-19) proposes experimentation and hypothesis testing with regards to what the customers' needs are, how to serve those needs, how to turn leads into actual customers, and finally how to build a company to generate profit from this earlier insight. Blank (2013, 17) presents customer development as a complement to product development. The customer development approach seeks to identify and validate potential customers as early in the startup process as possible. (Blank 2013, 12)

Steve Blank takes issue with business plans because traditional business planning is simply an extrapolation of historical data, which doesn't exist for new business ventures. (Bortolini et al. 2021, 1756) Without this data, the business plan is just an "untested business plan hypothesis" (Blank 2013, 10) that becomes irrelevant upon interacting with a customer (Blank 2010). Customer development addresses this critique.

The MVP validates hypothesis about the developed product's ability to perform, using lean engineering principles to ensure the product isn't over engineered. (Shepherd and Gruber 2020, 12-14) An MVP "represents the smallest set of activities needed to disprove a hypothesis." (Eisenmann et al. 2017, 1) According to TLS, entrepreneurs should launch MVPs as quickly as possible as a way of soliciting customer feedback. (Felin et al. 2020, 2) The 'minimum' part of an MVP can refer to simplified sets of features, simplified product functionality, or both. (Eisenmann et al. 2017, 6.) An MVP can even be a mere "smoke test," often a video description of an online service under development (Eisenmann et al. 2017, 17).

Lastly, the team must periodically decide whether to continue pursuing an opportunity as new data is developed, or whether they should pivot and pursue a different opportunity. (Shepherd and Gruber 2020, 14-16) TLS recommends that this be a deliberate process, governed by learning milestones and other explicit targets. (Blank 2013, 12) A pivot might involve going down a different branch of the current path (if results are neutral) or a complete restart towards the beginning of the commercialization path (if results are negative) (Gbadegeshin 2018, 58). The last option is also referred to as a complete pivot. (Shepherd and Gruber 2020, 16)

TLS methods can be helpful for university research commercialization projects because they often only have access to limited financial resources, especially when they begin to develop a business case (Ndonzuau et al. 2002, 284). Some commercialization projects are funded by public R&D grants, which may only pay researcher salaries for a fixed term (Clarysse et al. 2002, 12-13). University commercialization projects often struggle to achieve a validated business model and make sufficient progress to attract funding from a private investor (Vohora et al. 2004, 159). By helping researchers validate their ideas faster, TLS methods have the potential to increase the chances that the commercialization process can advance sufficiently within the constraints of these limited resources.

2.4 Theoretical Framework for Thesis

One of the challenges for an entrepreneur is translating the theory of entrepreneurship into practice. This challenge is sufficiently meaningful that many entrepreneurs choose to ignore entrepreneurship theory (Shepherd and Gruber 2020, 1-2). Ultimately tools must be implemented in the form of entrepreneurial action to help advance an entrepreneurial project. Nominal knowledge of a tool or method is insufficient: An entrepreneur must also understand the purpose of the tool or method in order to implement it properly (Felin et al 2020).

2.4.1 Implementing TLS Methodology

There are two major critiques of TLS: (1) TLS does not provide much insight into what hypotheses to form or how to test them, leaving open the possibility that validated learning will be used to learn the wrong lesson. (Felin et al. 2020, 3; Bocken and Snihur 2020, 7) and
(2) The methodology may be more relevant for some industries or products than others (Frederiksen and Brem 2017, 177; Felin et al. 2020, 2-3). The first critique simply implies that the specific implementation of TLS is a determinant of its usefulness. The second critique similarly implies that the optimal implementation of TLS might vary between industries. This variation might include the optimal timing for engaging with customers

and external stakeholders (Felin et al. 2020, 5-6) or the role for business planning as a complement to TLS (Welter et al. 2021, 35).

Welter et al. (2021, 25) broke TLS and busines planning down into a menu of four and six activities (respectively) "from which an entrepreneur may select without needing to accomplish each task." The 5 activities are shown in Table 5, below, along with an indication of whether their findings supported the hypothesis that the specific activity improved the likelihood of success for new ventures.

Table 5: Summary of Findings from Welter et al. (2021, 31)

The Lean Startup Activities	**Business Planning Activities**
Interviewed Customers (Yes)	Write a Business Plan (Yes)
Created a Prototype (No)	Secondary Data (No)
Showed a Prototype (No)	Feedback on Business Plan (No)
Experiment (No)	Funding from Business Plan (No)
Preorders (Yes)	
Pivoted (No)	

Of the 10 activities, only writing a business plan, interviewing customers, and collecting preorders were correlated with success within the study sample. The other TLS activities, that were not correlated with success, could potentially be elements of TLS that vary between applications. For example, the activities "Created a Prototype" and "Showed a Prototype" might not be relevant to all types of startups. Shepherd and Gruber (2020, 20) ask, "What does an MVP look like for a social startup?" Brickmann et al. (2010, cited in Bortolini et al. 2021, 1769) argue that business planning can be valuable for new businesses under certain conditions. A business plan can serve as a communication tool with stakeholders beyond facilitating the pursuit of funding (Shepherd and Gruber 2020, 13). An entrepreneur can write a formal but lean business plan that has been adapted due to the lack of historical data (Bortolini et al. 2021, 1769), essentially applying the concept of the MVP to the business plan's structure (Shepherd and Gruber 2020, 14). A business plan can incorporate (and thus address) the path dependance of the technology's commercialization path or articulate the strategy and results of the firm's experimentation and hypothesis testing (Bortolini et al. 2021, 1770). For a project going through the

commercialization process, “A business plan is more an estimation of the way the technology will be developed, and the investment needed to complete this development than a real forecast of the marketing, strategy and finance of the eventual company.” (Clarysse et al. 2002, 20.)

2.4.2 Educating Academic Entrepreneurs

The challenges of entrepreneurship are sufficiently unique that an entrepreneur’s previous experience in a startup is a strong indicator of success. So too are other sources of experience that address the uncertainties of entrepreneurship, such as additional experience as a manager and within the relevant industry. (Politis 2005, 45.) High-tech startups can require specialized knowledge that is not necessary for managing other types of businesses (Clarysse et al. 2002, 20). Entrepreneurial learning is the process by which this prior experience is essentialized into knowledge that is useful for the success of an entrepreneurial venture (Politis 2005, 407). The same principles can be deployed so that the entrepreneur can leverage the experiences of other professionals through coaching and consulting services (Clarysse et al. 2002, 20). Since the entrepreneur exists in an uncertain environment, some entrepreneurial attributes center around managing that uncertainty. Entrepreneurs use a combination of causation and effectuation to make uncertain decisions. Causation includes more traditional, numerical analysis, whereas effectuation allows room for creativity and new ideas. (Politis 2005, 412.) Entrepreneurs must also both identify and develop profit opportunities for their firms to exploit. (Klein 2008, 177.)

However, most of this knowledge is foreign to the technical researchers and professors looking to commercialize their technology (Pynnönen et al. 2019, 346). High-tech ventures benefit from having access to experienced consultants or advisors that can share the specialized knowledge gained from other ventures. This knowledge transfer is carried out by service providers (such as lawyers or private business coaches) or through institutional support services (such as technology transfer offices). (Clarysse et al. 2002, 18; Vohora et al. 2004, 151.) Within a university, this support can be provided by a team of knowledgeable commercialization consultants that provide advice to different technical

teams (Pynnönen et al. 2019, 346) or having knowledgeable individuals join the project team as coaches. (Clarysse and Moray 2004, 61-62.)

This knowledge can be transferred in several ways. The consultants could manage the commercialization process themselves (Pynnönen et al. 2019, 346) or the consultants could guide the entrepreneurs through a hands-on skill development course. The latter option is utilized by the United States National Science Foundation's I-Corps entrepreneurial educational program for researchers, modelled after the Stanford University course "The Lean Launchpad." (Blank, 2021b.) Since the management of NTBFs must periodically reevaluate profit opportunities through the normal management of the firm, there is a clear need for the management team to develop this business skillset within themselves (Luggen and Tschirky 2003, 342-344).

2.4.2 Summary and Synthesis of The Literature

Entrepreneurs seek out profit opportunities to exploit. Profit opportunities exist because existing firms are unable to provide value to all potential customers. An entrepreneur that wishes to exploit a profit opportunity must identify the barriers to market entry that are keeping existing firms out, and collect the resources required to overcome them. This is a process characterized by uncertainty, so along the way, the entrepreneur will likely need to update and refine their understanding of the opportunity, both to improve their commercialization strategy and to increase the perceived profitability of the opportunity from the perspective of other stakeholders.

Technology developed in a university may have multiple potential applications, and within those applications there may be multiple opportunities. Not every investigation into a potential opportunity will yield a sustainable business model. The entrepreneur will not necessarily know how to differentiate between viable and unviable opportunities ahead of time, both because of a lack of prior knowledge and any path-dependence inherent to the specific commercialization path for that university technology. Entrepreneurs must jointly accumulate resources and manage risk. (Shepherd and Gruber 2020, 5.)

The risk within a specific application or opportunity is that the entrepreneur will fail to develop a sustainable business model, a result that simply leads to a pivot towards another application or opportunity. At the level of the entire commercialization effort, however, the risk is that the entrepreneur will run out of runway to sustain the opportunity development process. Care must be taken to navigate through this down-selection process quickly and efficiently. Stakeholders want to see some proof that the opportunity is viable before investing money or other resources into the venture.

I can thus generate a simple three-step strategy for academic entrepreneurs who wish to commercialize their research. 1) Map out the commercialization path. This includes using tools such as the business opportunity navigator to identify a target opportunity, as well as a map of the resource requirements and likely level of effort required for technology and market development. At this stage, potential sources of path dependency should be identified. 2) Resolve as many uncertainties as possible. This might require additional technical development, so the capacity to do so will be heavily determined by the amount of runway that the project has. Uncertainties are resolved by designing a technical or business experiment, executing the experiment, and evaluating the data. 3) Document the plan for resolving any remaining uncertainties. This plan should be used to solicit the necessary resources from the stakeholders who control them. A flowchart for this strategy is shown below as Figure 1.

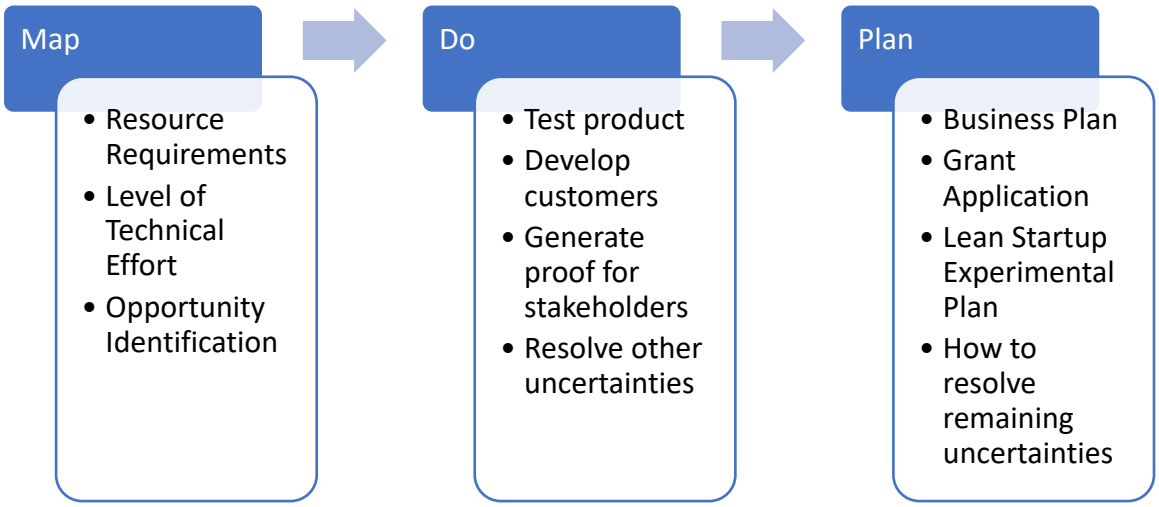

Figure 1: Actions for Commercialization Teams in 3 Steps

3. Research Methodology

> *"For every problem there is a solution which is simple, clean and wrong."*
>
> Henry Louis Mencken

Both the study and practice of entrepreneurship are complex fields (Schultz et al. 2016 3-4). Gartner (2001, 30) questions whether there could ever be a single theoretical framework to unify such a diverse collection of business activities. Van Burg et al. (2020, 1-7) outline the characteristics of entrepreneurship research that lend themselves to a qualitative approach, "namely the uniqueness, heterogeneity, volatility, and mundanity of entrepreneurial phenomena." The unpredictable nature of entrepreneurial action also invites a flexible, qualitative research approach (Neergaard and Ulhøi 2007, 1).

While a qualitative approach allows the researcher to choose the right analytical tools for the job (Neergaard and Ulhøi 2007, 1), it also poses challenges for the researcher. The plurality of specific research methods available to a qualitative researcher means that the researcher must identify the methods that meet the requirements of their study (Van Burg et al. 2020, 2), and then must justify those choices to future reviewers or readers (Gioia et al. 2012, 15; Van Burg et al. 2020, 1). There are also few guidelines for how to handle the data for a qualitative analysis, and the flexibility of the approach can translate into misunderstandings or a lack of clarity about the methodology employed (Schultz et al. 2016, 3). Navigating through these challenges can be particularly daunting for inexperienced researchers (Atkova 2018, 67).

3.1 Research Philosophy

The primary research question of this study asks about the actions that commercialization teams adopt to commercialize their research. A review of the literature with the goal of extracting a normative strategy has revealed several major contradictions and significant incompleteness. These contradictions exist at the level of theoretical constructs, strategic conclusions, and methods for implementing those strategies. Some authors have explained

these contradictions as being the result of heterogeneity between entrepreneurial projects (Frederiksen and Berm 2017; Felin et al. 2020; George et al. 2016), while other authors write about the heterogeneity among different elements within individual projects (Zahra 2008, cited in Atkova 2018, 33). This is a strong indication of complexity nested within complexity without any corresponding guidance to navigate through it. Stated another way, the literature is missing a specific set of instructions for determining the aspects and sources of complexity that are relevant to a specific commercialization project; nor does the literature provide concrete instructions for how to navigate through some of the complexity.

As part of the theoretical framework for this study, I have synthesized a simple version of this missing instruction set. This synthesized theory was then evaluated in the context of the qualitative data collected for this study to infer conclusions about its implementation. This process is an example of an abductive research approach (Shank 2008, 1-2). The logical argument is as follows, in the form originally developed by the 19th century philosopher Charles Peirce:

> The commercialization projects have decided to adopt strategy X, for which we have no full explanation.
>
> IF synthesized theory Y is correct, it would provide an explanation for X.
>
> Therefore, it is plausible that X follows from Y. (Adapted from Shank 2008, 1-2.)

This synthesized theory combines the concepts of opportunity identification and exploitation, entrepreneurial action, and busines model development, and incorporates them into the commercialization process.

Atkova (2018, 68) writes that Action Research (AR) is a research approach that allows researchers to experiment with interconnected concepts and frameworks that cannot be separated. Sirca and Shapiro (2007, 106) conclude that AR is an example of a constructivist approach, as both philosophies are at their core “a search for meaning.” (Sirca and Shapiro 2007, 106.) On a more practical level, AR is primarily concerned with

organizational change, in addition to making theoretical contributions to the literature (Shani and Coghlan 2019, 3).

AR researchers (Sirca and Shapiro 2007, 106) as well as constructivist researchers (Lukka 2000, 113) synthesize models to describe this complexity. There are several different AR methodologies, sometimes referred to as the AR "family" (Shani and Coghlan 2019, 3; Cassell and Johnson 2006, 786). An AR researcher must be flexible, "construct[ing] their plan and processes as they progress." (Sirca and Shapiro 2007, 106.) The goal of the approach is to respond to issues within an organization, in collaboration with the members of that organization (Shani and Coghlan 2019, 3).

A researcher needs access to the organization in order to conduct AR (Lukka 2000, 116-117). This involves not just an agreement with the leadership of the organization, but all the stakeholders that are relevant to the project. (Mumford 2001, 20-21) Gaining access is an ongoing process that can happen iteratively over time. In order to maintain that access, the researcher must maintain a positive relationship with the project participants and maintain their trust. (Leitch 2007, 150.)

Participatory research takes the collaboration between researcher and organization members to another level. In participatory research, the organization members are not merely collaborators, but rather further empowered as co-researchers (Boylorn 2008, 599-600). Some authors classify participatory research as a specific application of action research (Cassel and Johnson 2006, 789; Atkova 2018, 71). Thiollent (2011, 161-162) writes that the two research methodologies have distinct philosophical origins but have evolved to be similar over time. To further confuse the matter, Cassel and Johnson (2006, 789) also call out another methodology within the action research family: participant action research (PAR). The differences between participant action research and participatory research are more about the research setting and context than methodological in nature: PAR is utilized in the context of organizations, while participatory research is utilized in society at large (Atkova 2018, 71).

Given this fragmented landscape of similar terms, it is important to define the underlying philosophical approach and not simply rely on a label or named concept. Atkova (2018,

72-74) distills AR into three concepts that need to be explicitly defined for a specific study: *action, research,* and *participation*. In other words, AR necessitates the rejection of the "simple, clean and wrong" methodological approach.

The *action* element of AR encapsulates the change which is the goal of AR (Atkova 2018, 72). AR researchers, in collaboration with organization members, plan and execute interventions to cause this change (Somekh 2008, 4-6; Lukka 2000, 118). The change can manifest itself as change within the organization in the present, or long term future change as a result of the research itself (Schultz et al. 2016, 5). Shani and Coghlan (2019, 3) write that another dimension of change is developing the capability of organization members to develop the ability to help themselves. A good AR project will instill upon the organization the capacity for self-improvement, which can continue beyond the scope of the project (Mumford 2001, 24-25). In the context of this research, the change element refers to adjustments to the commercialization strategy and implementation of the commercialization process, as well as the organizational change that will enable the organization to continue to make such decisions in the future.

Research encapsulates the methodology for developing the practical knowledge that will bring about this *action* (Atkova 2018, 72). The AR methodology is cyclical and reliant upon reflective learning (Schultz et al. 2016, 6). Specifically, it is "an iterative cycle of problem identification, diagnosis, planning, intervention and evaluation of the results of action in order to learn and to plan subsequent interventions." (Cassel and Johnson 2006, 784.) Atkova (2018, 73) writes that most AR is heavily influenced by hermeneutics and the hermeneutical cycle. In this cycle, knowledge is discovered through an iterative process that jumps between the micro and the macro perspective and continues until there is harmony between these two perspectives (Atkova 2018, 73). This cycle can be implemented in different ways, depending on the type of knowledge that is being generated. Eden and Ackermann (2018) have adapted the hermeneutical cycle for research-oriented AR aimed at developing theories, as shown in Figure 2 below. In this adaptation, the two perspectives that must be reconciled are theory and practice. Lukka's (2000, 114-117) description of a constructivist research approach similarly emphasizes the dual missions of theory and practice.

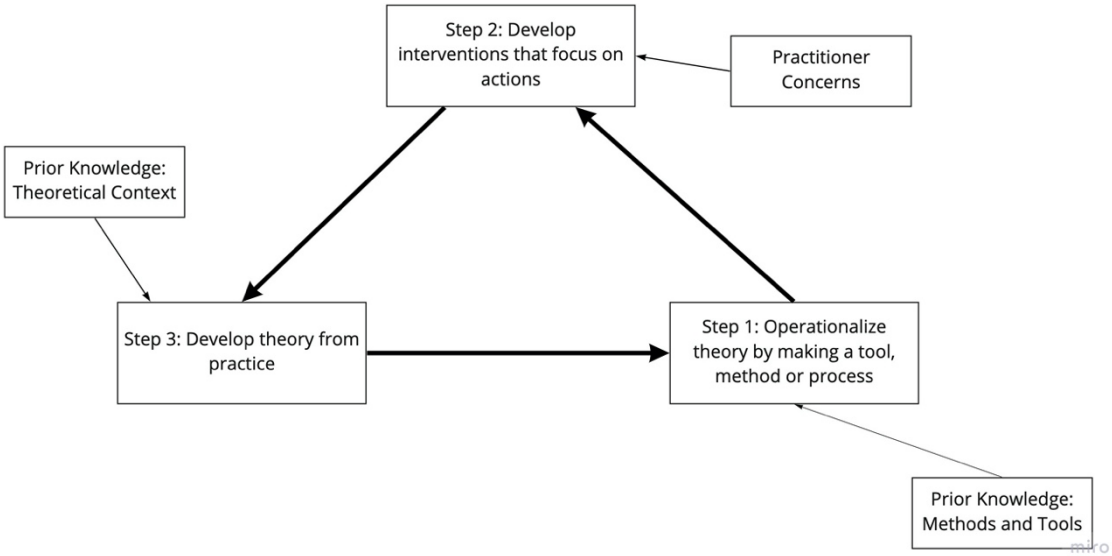

Figure 2: Action Research iterative cycle, applied to theory generation. From: Eden and Ackerman (2018, 1148)

Finally, *participation* refers to the relationship between researcher and other project participants (Atkova 2018, 72). While there is some variety in the literature regarding the exact nature of this relationship due to different research goals, the general theme is a relationship based on mutual understanding and consent (Cassell and Johnson 2006, 785). This follows from the philosophical origins of participation, which stem from "the humanist perspective that emphasizes the value of individual and collective agency of human beings and calls for democratic research that is done with people rather than on people." (Atkova 2018, 73.) Participation is not a binary yes/no quality of the research, but rather a spectrum with multiple values, ranging from the detachment and disinterest of no participation on one end, to active participation on the other. Active participation implies that research subjects have full engagement on both an intellectual and emotional level based on their own values and priorities. (Thiollent 2011, 168-169.) Relationships have two parties, so *participation* also captures the researcher's engagement with the research subjects. Mumford (2001, 15) writes that good AR projects require full investment and interest on behalf of the researcher, although the exact level of participation on behalf of the researcher can be limited by practical logistical concerns as determined by the research topic. *Participation* can also be influenced by structural aspects of the research topic: Some research projects and topics will have limits on the amount of participation based on practical issues (Atkova 2018, 74).

This study employs active participation and is methodologically an example of PAR[2]. The research has first, second, and third person elements. The researcher is fully invested in the research topic as it is one component in a larger personal research and career stream. Furthermore, the research topic is directly aligned with the goals of the project participants: Commercialization of their university research. This is the reason why the researcher was brought under contract for the commercialization project in the first place.

3.2 Research Approach

The specific implementation of *action, research*, and *participation* are heavily influenced by the specific first, second and third-person research approaches utilized by a project. (Atkova 2018, 74) The first-person perspective is my personal contribution as a facilitator or consultant. Learning within this perspective reflects the evolution of the way I engaged critically with the other project participants and introduced theory, ideas, and group discussions into the commercialization process. The second person perspective for this study is the impact of this study on the trajectory of the case commercialization process. This perspective is only possible due to the small number of case projects included in this study, and would likely not scale well (Atkova 2018, 76). The AR interventions and organization change can be viewed as parts of an organizational educational process. Within this metaphor, the second-person perspective is both the "curriculum" of this learning process, as well as the long-term impacts that result from it. The third person perspective is the project's contribution to the literature and theory development, and the extent to which these conclusions can have an impact on other commercialization projects or inspire future research. Thus, the first-person perspective is concerned with both research and practice, the second-person perspective is concerned with practice, and the third person perspective is concerned with research. Since the research-oriented AR cycle

[2] Atkova (2018, 74) writes that a "researcher cannot possibly participate in the creation of a new start-up" while explaining the limited participation present in her study. This study and the participation level therein provides a counter-point to that assertion, albeit with corresponding limitations.

presented in Figure 2 is only concerned with the generation of research knowledge, I have generalized the AR Research Cycle to address all three perspectives, shown in Figure 3

Figure 3: AR Research Cycle for This Study. Adapted from Dickenson and Watkins (1999, cited in Atkova 2018, 75)

Foreknowledge exists prior to the beginning of the study[3]. Research is knowledge gained during the study. These two knowledge sources are used to generate concrete actions[4]. These actions are proposed to the other participants, who have an opportunity to collaborate and modify them before the action are executed. The results are reflected upon and then finally generalized, before the cycle continues.

[3] Atkova (2018, 75) writes that the existence of foreknowledge is an explicit assumption of the hermeneutics tradition

[4] Atkova (2018, 75), citing, Eden and Huxham (2006), argues that foreknowledge should be set aside until later in the AR cycle to avoid biasing the research, at least from the first-person perspective. This normative target is infeasible given the large gaps in the literature, forcing the researcher to rely on foreknowledge to fill in the gaps. However, Atkova (2018, 84) also describes an inductive research methodology, whereas this study utilizes abductive reasoning. The bias introduced by this methodological step is one of the contributors to the fact that abductive reasoning results in weaker conclusions than does inductive reasoning (Shank 2008, 1).

3.3 Data Collection

Data was collected from project documents associated with the research project, including grant applications and reports. Data was also collected from verbal workshops and meetings, in the form of recordings, notes, and presentations. Lastly, some email correspondence between project team members was also utilized. Many documents and conversations were originally in Finnish, but English language summaries or translations were used for the study.

The workshops and participants are summarized below in Table 6.

Table 6: Workshops for PATE project

Workshop Name	**Workshop Topics**	**Participants**	**Date**
Workshop #1	Entrepreneurial commitment of team members. Customer Requirements How to Measure Requirements	All Teams	December 3, 2020
Workshop #2A – LUT	Commercialization Requirements	LUT Team, Commercialization Team	February 5, 2021
Workshop #3 – Steering Group	Customer Requirements	Technical Team Leaders, Commercialization Team, 2 Steering Group Members	April 12, 2021

The following documents, shown in Table 7, were collected for analysis during this study:

Table 7: List of documents used in study

Document Type	**Number of Documents**
Workshop Summaries	3
Project Meeting Presentations	11
Grant Applications	2
Grant Deliverables / Reports	2
Emails	10

3.4 Data Analysis

The final step of the research methodology is data analysis. Data analysis should yield conclusions that accurately reflect the analyzed relationships and that can be reproduced by other researchers (Gbadegeshin 2017, 10). One cautionary tale in data analysis comes from Gioia et al. (2013, 25). He writes about the dangers of using methodology developed by other researchers as a template, since "Different methodological approaches will naturally rely on different conceptualizations of data." A qualitative researcher should use at least two analytical methods in order to reduce the risk that bias from a specific source or medium inappropriately influences the conclusions of the study. The multiple data sources reduce the bias of the analysis through triangulation, wherein the conclusions that the different sources yield converge on a single result. (Bowen 2009, 27.)

Despite the multitude of data sources, all data was ultimately represented in English language written documents, either in the form of a translation, a summary, or because that was the original form of the data. This study uses document analysis to analyze this data. Document analysis allows the researcher to extract the meaning from written documents. (Bowen 2009, 27-28.) Bowen (2009, 27) defines documents by writing "Documents contain text (words) and images that have been recorded without a researcher's intervention."

Document analysis is conducted in two parts. First, content analysis is used to extract meaning from the documents (Gbadegeshin 2017, 10). The documents are first read superficially, and then more thoroughly. Information contained within the documents is categorized. Then thematic analysis is used to understand the meaning of the categories. In this study, the themes of interest are taken from the theoretical framework and research questions, the researcher's prior knowledge, and from other project participants. (Bowen 2009, 32.) Figure 4 is a visualization of this process.

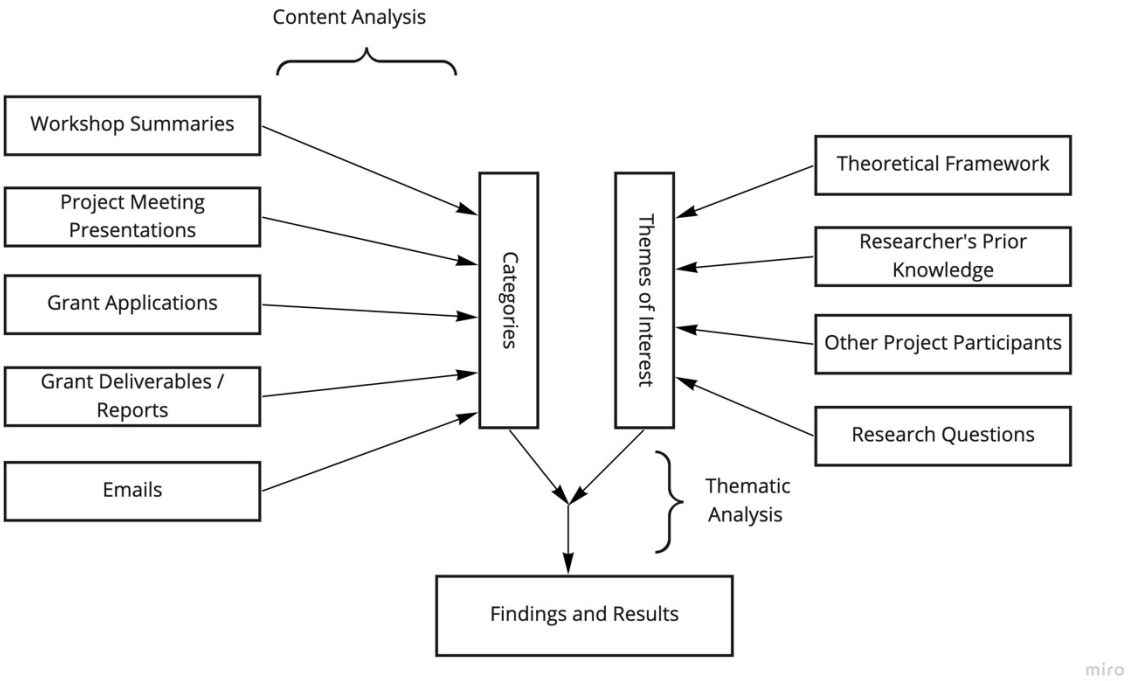

Figure 4: Data Analysis Structure

In implementing document analysis for his study, Gbadegeshin (2017, 10) utilized document analysis when analyzing a university commercialization project despite the fact that the author was a member of the commercialization team being studied. Although not explicitly addressed in the study, this is presumably justified by the author's dual but presumably separable roles as commercialization expert and researcher.

In this study, however, the dual roles of researcher and project participant have significant overlap. This is due to the research question and the contemporaneous nature of the research. Furthermore, the research-oriented AR cycle promotes an interplay between research and practice that logically pierces the veil established by Bowen (2009). Integrity is maintained by reaching a consensus with project team members, ensuring that the ideas and conclusions are not simply a reflection of the researcher's opinion. Furthermore, the inclusion of sources that do fit Bowen's (2009) definition of a document, along with the methodological usage of triangulation, serves to minimize this source of bias.

4. Case Project Description and Background

The following sections 4.1 and 4.2 give some background on the specific case study utilized in this thesis. The background helps to contextualize the findings and actions undertaken by the case project during the course of the study.

4.1 Research Background

The case project is a Finnish university research commercialization project working under the PATE project. The English title of the project is "Development of freeze concentration facilities for industrial food processing and environmental applications."
Project participants include the Lappeenranta University of Technology (LUT), the University of Oulu (MITY), and several external stakeholders that make up the steering group for the project. Both universities are represented by a technical research team commercializing technology developed within, although only the LUT technical team is included in this study. Additionally, a business team from the LUT School of Business and Management (LBM) is supporting both technical teams through the commercialization process. I am a member of the LBM team.

The LUT technical team aims to commercialize a research stream that has been ongoing at LUT since the 1980s on purification of aqueous solutions through the formation of ice. The direct antecedent to this project was the JÄPÄ project, funded by a public commercialization grant. Under the JÄPÄ project, the LUT research team built a pilot freeze concentration device and conducted preliminary tests on its functionality. A preliminary commercialization report was also written to evaluate the different possible applications for the device. The goal for the PATE project is to incrementally improve the device, and conduct further tests that will support its commercialization.

Project team members are listed in Table 8, below.

Table 8: PATE Project Team Members

Member Title	**Sub-Team**	**Project Role**	**Educational Background**
Project Manager	LUT Technical Team	Overall management, LUT team technical management, Customer Development, Overall design of prototype	PhD, chemistry
Domain Expert	LUT Technical Team	Consult on wastewater separation applications	PhD, professor of separation sciences
Project Engineer	LUT Technical Team	Design physical elements of prototype	PhD, mechanical engineering
Domain Expert	LUT Technical Team	Consult on mechanical engineering and machine design	PhD, professor of mechanical engineering
Commercialization Manager	Commercialization Team	Manage commercialization team	PhD candidate in business
Commercialization Expert	Commercialization Team	Consult on commercialization activities	PhD, professor of business
Experienced Entrepreneur	Commercialization Team	Execute commercialization strategy discussions	Pursuing MSc in Business

4.2 Technical Summary

Freeze concentration is a method for increasing the concentration of liquid solutions. Under this method, the target solution is chilled to a low temperature, inducing the formation of ice. The ice is then removed, leaving behind a solution with a higher concentration of compounds. The exact concentration of the remaining solution is determined by the amount of ice removed and the purity of the ice. There are thus two possible value streams that result from freeze concentration: The resulting concentrated solution could be valuable , or the water removed as ice could provide value. A concentrated solution can be valuable because the lower volume makes it easier to transport, or because the application does not need

additional water. Water removed as ice could provide value as a water purification method, or to provide water to facilities that have limited access to fresh water

5. Findings and Results

The collected documents were analyzed. Themes from the documents that are responsive to the research questions are presented below.

5.1 Q1: What does an academic entrepreneur need to do?

The PATE project generally followed the synthesized strategy presented in section 2.4.2. The findings presented in this section provide more detailed examples of how the commercialization path was mapped out, what work was completed to reduce uncertainty, and plans for seeking out additional resources in the future.

5.1.1 Map out the Commercialization Path

Mapping out the commercialization path was a central focus of the commercialization team. One of the project tasks identified in the PATE project grant application was Task 3.1: Planning the Commercialization process. Several possible paths were identified. The project could commercialize research by forming a spin-off company or licensing the technology to a corporation. The choice between these two options could happen during the PATE project, or the research might need more development at the university level before being commercialized. In order to differentiate between these different paths and select the optimal set of choices for this project, the commercialization team looked at the resources required to exploit different opportunities.

5.1.2 Path Mapping Requires Resource Mapping

Requirements associated with specific resources can influence the commercialization path (Pattnaik and Pandey 2014, 47), so mapping out the commercialization path required

insight into the resources required for a specific path. The first resources that the commercialization team looked at were human resources. The team then looked at the current status of the prototype reactor to determine if additional development would likely be required. After determining that the project would indeed need more development, the team started searching for sources for additional financial resources.

5.1.3 Human Resources

During Workshop #1, the team members discussed their interest in continuing the project after the current grant. While the overall theme was that team members were indeed interested, almost all their interest was contingent on positive technical test results as well as the ability to identify project partners or potential customers. The team concluded that they were missing a business champion to head the business elements of the project. The team members with a business background indicated that they were interested in being project advisors or conducting academic research in conjunction with the project. Some business team members said that they might be interested in increasing their commitment to the project after seeing promising initial results. However, the team members generally preferred to continue working on the project in an academic role by finding a corporate or industry partner to continue the development efforts. Furthermore, the business team members did not feel like they had sufficient familiarity with the technology to serve as business champion. During subsequent meetings and workshops, the project manager assumed the role of business champion, spearheading efforts to evaluate the economic aspects of the different opportunities.

5.1.4 Partnerships

With corporate licensing identified as the preferred path forward, the commercialization team evaluated if there were any likely corporate acquirers, and what level of contact existed between the corporation and the project. A mining company with a wastewater problem was listed as a potential customer or acquirer. The technical team had reached out several years ago to establish a partnership for a demonstration project but had received no response, despite a warm introduction from corporate stakeholder. Ultimately the team

decided to continue to seek out corporate partnership opportunities, but to also keep an open mind about starting a new company.

5.1.5 Technical Resources

The status of the development effort was the focus of Workshop #2. Technical team members indicated that the current reactor was simply a proof-of-concept prototype and would need additional product development before being sold or deployed as a commercial product. Indeed, presentations from bi-weekly team update meetings show incremental progress developing core device functions, such as removing ice from the reactor or separating the ice from the concentrated solution. Device testing centered around validating the functionality, not on optimizing the design or operation of the device. The full development path is shown in Figure 5. Based on the budget and scope of work for the PATE project, it was determined during Workshop #2 that there wasn't any allocation in

Figure 5: Technical Development Path for PATE Project

the budget for this product development work. Furthermore, the technical team identified several aspects of the pilot unit that potentially needed to be redesigned. In summary, more development work was likely required, and the current funding was insufficient to support it.

5.1.6 Financial Resources

From the perspective of the RBV, a partially developed resource would need additional financial resources in order to be finished. The commercialization team began evaluating additional sources of funding. The need for additional development effort means that the commercialization path is longer than if the prototype were ready for commercial deployment. With a longer path, there are more opportunities for the different possible paths to diverge. The team began looking for possible sources of funding in order to

understand any additional requirements that the funding might impose upon the path. (Pattnaik and Pandey 2014, 47.) The team identified three sources of funding: Funding could come from potential customers (either through commercial sales, or via corporate partnership). Funding could come from an additional academic research grant. Or lastly, funding could come from an angel investor or other investment vehicle. Both the customer and investor funding were assumed to require a concrete understanding of the commercial opportunity, which the team was lacking. Focus instead shifted to identifying grant funding opportunities that would fund further opportunity framing.

An EU grant opportunity was identified to support product development within the wastewater space, while a Finnish technology foundation grant was identified to support earlier stage research without a specific domain requirement. An overview of the grant funding options, however, indicated that the grant applicants were required to show active participation from industry partners in the proposed projects. For the EU grant this participation manifested itself in a requirement for significant funding from an industry partner. The tech foundation grant was intended to fund new basic research, so while the application topic was unconstrained, it would only be suitable for an application that required additional technological elements. Within the PATE project, path dependency thus manifested itself primarily as a choice of application. The application choice then determines the amount of development required, as well as the subset of grants that might fund the development effort. The chosen application would also determine the list of potential industry partners. The team thus shifted its efforts towards further understanding the potential applications of technology.

5.1.7 Identify Opportunities and Applications

In order to exploit a profit opportunity, the opportunity must first be identified, usually during the early research stage, when the technology is being conceptualized as a university research project (Aguirre et al. 2006, 160). This involves a high-level view of potential uses for the technology. For this technology, the earlier research projects identified two major areas that utilize concentration or water purification: Wastewater treatment and food production.

As the team continued beyond the early research stage and began engaging in commercialization activities, these high-level use cases were framed to identify specific potential market opportunities (Vohora et al. 2004, 152-154). Since the technology primarily allows for the concentration of liquids, the initial list of applications was a list of products that might be created by such a process. The team then looked at the limitations inherent to existing solutions to identify what was stopping them from exploiting the identified opportunities. This approach was captured by the following questions, asked by workshop participants during Workshop #1:

> "*On the customer side there is a question on what are the current technologies/solution that companies are using, e.g., for wastewater purification; and how is it related to this PATE?"*
>
> *"One way to look at this is to think about what the salesperson positive selling points are. It could also be useful to think about the questions the customer may have, which usually cover negative aspects. Need to think about how these might be answered."*
>
> *"And, what will make them invest in our technology over what is currently on the market? How is our solution positioned against these?"*

Three types of opportunities were identified, displayed in Table 9 below.

Table 9: Opportunity Landscape for PATE Project

Opportunity	**Example Products**	**Weakness of Existing Solutions**
Concentrating Food Products	Berry Juice, Tree Sap, Beer, Plant Extracts	Heat from existing solutions alters the taste and reduces the quantity of valuable compounds such as nutrients or alcohol
Nitrogen Wastewater Concentration for Productive Use	Fertilizer, Aluminum Nitrate, Purified Nitrogen Compounds	Heat from existing solutions reduces nutrients
Wastewater Concentration for Easier Disposal	Concentrated Wastewater (for disposal) + Pure Water	Too expensive

5.1.8 Define Opportunities Quantitatively

After opportunities were identified, the team focused on generating data to further evaluate the list of opportunities. The first data that the team tried to generate was an estimate for the operating costs of the prototype machine. This would allow the team to evaluate the economic viability for each opportunity by comparing the value added by the process to the cost of the process. The technical team ran several test runs using a model salt solution and collected information on the power consumption and speed of the process. Initial test results revealed that the target concentration % was a meaningful determinant of cost, meaning that the cost per unit of output will likely vary between applications. During Workshop #1, the team also identified the scale of the opportunity as a factor that could potentially be important to quantify.

The project manager began the quantitative review of opportunities by evaluating the market size and value proposition for the nitrogen wastewater concentration opportunity. Initial results indicated that the total amount of wastewater produced by the two project partner companies was a relatively small amount per year. The specific wastewaters produced by these companies are somewhat unique, limiting the size of the market for this application. Furthermore, the fertilizer that would be produced from these wastewaters would not be suitable for use in food production due to remaining impurities, limiting the value of the concentrated product. The project team decided to continue with this analysis by evaluating the additional attributes highlighted by the Market Opportunity Navigator worksheets. This analysis is still ongoing as of the writing of this thesis.

The potential customers that participated in Workshop #3 were interested in understanding some of these same parameters, although the technical team was not yet ready to engage on this level. After conducting this workshop, quantitative customer requirements were emphasized in internal project meetings as captured in the following bullet point from a subsequent project team meeting: “Challenge: What kind of numbers are needed for commercialization?”

In general, technical team members reported that customers do not really know what their exact requirements are, making it difficult for the team to generate meaningful design specifications.

5.1.9 Reduce Overall Uncertainty

Although the PATE project has not yet identified an initial priority target application, the development work to reduce uncertainty that has been completed so far is largely agnostic to the application. Data collection to date has focused on the information required to evaluate the economic potential of the different opportunities that were identified.

The technical team conducted several experiments aimed at determining the general operating costs of the unit. The technical team broke the cost accounting into three phases: 1) The initialization phase, where the system is cooled in preparation for operating. 2) The cooling phase, where feedstock is cooled to near freezing, and 3) The ice formation stage, where the solution is cooled further until the desired amount of ice is removed.

This cost accounting breakdown allows the initial tests results to cover a number of different use cases. System initialization, for example, is a fixed cost associated with turning the machine on and off. Breaking out the operating costs of this phase allows the lab tests results to apply to a simulating continuous operating mode, even though the lab test was only conducted for an hour. The cooling phase was separated because of the potential to chill the feedstock as a pre-processing step using a different piece of equipment. Furthermore, the cooling phase energy consumption is sensitive to the starting temperature of the feedstock. Lastly, the cost of the ice formation stage will vary depending on the amount of concentration required. The primary source of operating costs is the electricity required to operate the equipment. Electricity consumption was measured based on the power draw of the cooling units and the motors and pumps that operate the equipment.

The JÄPÄ final report indicates that potential customers wanted to know how well the freeze crystallization would deal with their specific wastewaters. From the customer's perspective, a proof of concept or demonstration would only be relevant if it was

conducted on similar feed stock. The PATE project's experience generating technical specifications supports this notion. The interconnected parameters of concentration requirements, throughput requirements and coverall cost levels make it difficult to predict what the performance will be for a specific application without directly testing the wastewater or food production. This is compounded by the possibility that different solutions might perform differently.[5]

Future device testing needs to model the relevant features of a specific application in order to validate the technology's ability to perform to the requirements of that application. This will require more information from potential customers in order to develop a responsive test plan.

Information gained from customers started with a nominal qualitative understanding of the opportunity. This included an indication of what type of value can be provided, as well as why existing technologies are unable to provide that value. For the PATE project, this initial skeleton of the opportunity was constructed for the grant application that solicited the funding for the project.

The team originally attempted to use Workshop #3 in order to add some quantitative details to this existing qualitative framework by asking the potential customers on the steering group for more information. This attempt largely failed because the technical team was unprepared to answer questions about the performance specifications of the device. Pynnönen et al. (2012) wrote about a busines model that was modified to account for customer preferences. The methodology that was used in order to extract customer preferences was a series of panels containing knowledgeable customers: In short, actual customers were asked what their preferences were. (Pynnönen et al. 2012, 7.) This is one way of implementing Steve Blank's customer development model (Blank 2021a). The PATE project team members reported that potential customers that they had spoken to did not have a set of specifications to share as they did not know exactly how they would use freeze concentration within their businesses. A potentially apocryphal quote attributed to

[5] As of the writing of this thesis, the technical team was primarily using salt solutions for testing, but proposed conducting further tests with a sugar based solution.

Henry Ford[6] yields the conclusion that customers don't always know what they want (Vlaskovits, 2011).

From TLS perspective, the PATE project faces a "chicken and egg" problem: Customer feedback is necessary to secure the additional funding that would be required to build an MVP, so building an MVP cannot be a requirement for getting the customer feedback. For the PATE project, a minimum viable product is not feasible at this stage of development for two reasons: 1) The current device is still a lab-grade prototype, that is missing the product development required to make an MVP; and 2) The physical nature of the device and limited financial resources mean that the technical team is not able to iterate through multiple device designs in search of the product that is viable. Thus, the PATE project needed to develop a solution for engaging with potential customers.

5.2 Q1a: How can a commercialization team ensure that the technical and business resources on the team are fully integrated?

There were several areas of the commercialization process that required a join techno-business approach, usually because and understanding of the technical limitations was required to advance the task. This was the case for opportunity identification and framing, including the related analysis of competing solutions. As the customers were not clear on how they would use the technology, a technical understanding was also required for customer development beyond the most superficial levels. Clarysse and Moray (2004, 56) refer to this as "technical business development," which requires a deep understanding of the technology being commercialized.

The starting point for opportunity identification was a market research report written for the previous JÄPÄ project, aimed at providing "a register of potential customers." The market research was thus conducted primarily form a business perspective and does not specifically reflect the technical capabilities of the technology. The introduction states, "This register of potential customers…has been….used during the JÄPÄ project when

[6] The quote is "If I had asked the customers what they wanted, the answer would have been a faster horse."

contacting companies and gaining information about customer needs," indicating that there is value to this approach at the beginning of the process. However, several sections of the report indicate that the next steps will require more technical integration. They include quotes such as:

> "The biggest factor that determines the business possibilities of JÄPÄ with each customer is the actual separation needs and whether JÄPÄ is able to meet those needs in a cost-effective way."
>
> "In conclusion, if JÄPÄ is able to technically separate the needed impurities and solve problems better than competitors, customers are willing to find new solutions and co-operate in pilot projects, as long as the price is on a reasonable level. "

Moving beyond these conditional statements required technical input. Preliminary cost data for the operation of the pilot device came from laboratory testing. A more detailed understanding of the different wastewaters and their processing needs requires projections with regards to the technical requirements of specific wastewaters, as well as an ability to reconcile these requirements with competing solutions.

The report also indicated that the technical knowledge of other processes required to further develop these applications extended beyond simply understanding the weaknesses of existing technologies, stating:

> "In addition to the various types and amounts of wastewaters in different companies, the range of currently used wastewater purification methods is wide. It includes combinations of mechanical, chemical and biological treatment methods. Treatment methods and their combinations are selected depending on the type and amount of wastewater flows in each case, and financial and environmental issues are of course a critical issue in the selection"

The same landscape was found within the food industry during the PATE project. During Workshop #3, a company representative interested in concentrating birch sap asked conversed with the technical team members about the concentration requirements for the proposed product. The technical team members indicated that freeze concentration would need to be combined with reverse osmosis concentration in order to hit the intended concentration.

This conversation was possible because the project manager took responsibility for advancing both the technical and business objectives. This ensured that both streams were coordinated and integrated. The business team members took on the role of entrepreneurial coaches. They helped set goals and generate strategies for achieving those goals, but the actual execution was handled by the project manager. In this regard, the project manager had multiple roles, serving as both the technology developer and entrepreneur.

The PATE project coordinated technical and business resources through bi-weekly project meetings that included both wings of the commercialization team. Both technical and business participants gave regular updates at these meetings and there was a forum for commentary after these presentations. The two teams primarily worked together on generating processes for identifying and quantifying opportunities. Team members quickly determined that defining the opportunity landscape was an inherently technical process. The chemical composition of input feedstocks, and of the resulting concentrates, was a strong determinant of their potential value. A detailed understanding of the industrial processes was also required in order to define the borders of one opportunity to determine things like market size.

The technical team also took the lead (with input from the business team) on evaluating competing solutions. An extensive literature review was conducted to attempt to determine a baseline cost for water purification or concentration. As the process costs seem to be sensitive to the target concentration percentage, overall scale of the operation, and assumptions about operating and capital costs, the comparison between the PATE project technology and competing solutions required a detailed technical understanding of the processes.

Lastly, the technical and business teams were forced to integrate their customer development activities due to language barriers. Most of the business team members do not speak Finnish. Most customers, however, preferred to communicate in Finnish. This forced the business team members to explain the goal of the customer development workshops to the technical team members, which also allowed the customer discussions to cover technical topics. For Workshop #3, for example, the Finnish conversation was

transcribed by the commercialization team member that speak Finnish and a summary was translated into English for distribution to the commercialization team.

5.3 Q1b: What strategies and tools support the commercialization process?

The appropriateness of a particular tool or strategy, as well as how that tool or strategy is used, can depend on the commercialization stage of the venture. As the PATE project continues to operate in the general area of opportunity recognition and opportunity framing, the tools employed were those that were most relevant to this stage of the venture. However, as the PATE project was also mapping out future activities, plans were also made for the future use of tools or strategies. The tools utilized by the PATE project are summarized in Table 10, below and then further defined in the following sections.

Table 10: Tools utilized by the PATE project

Tool	**Purpose**
Market Opportunity Navigator	Compare different potential applications and opportunities for the technology
Customer Development	Understand customer requirements
Simulated MVP	Describe the potential use case and value of an undeveloped technology
Workshops	Facilitate knowledge sharing between stakeholders

5.3.1 Market Opportunity Navigator

The main strategic goal for the PATE project during the study period was to evaluate and ameliorate the risk associated with the commercialization process. Based on the overall progress along this path, the primary activity was the identification and evaluation of different opportunities. Towards the end of the study period, the commercialization team introduced the Market Opportunity Navigator as a tool to help organize this process. The Market Opportunity Navigator worksheets build off the opportunity evaluation that was already being done by the project team, but in a way that adds a standardized structure to the process. Due to the incomplete understanding that the team has about the different

market opportunities, the commercialization team recommended that the worksheets be used as a framework that is filled in and updated over time, as opposed to serving as the foundation for a single workshop or meeting.

5.3.2 Customer Development

The Customer Development strategy calls for engaging with potential customers early in the commercialization process in order to understand the problems that customers are facing, and how the technology being commercialized can actually address those problems. (Blank 2013, 18-19) However, the order in which tasks are completed is only important if there are uncertain dependencies between the tasks (Gbadegeshin 2017, 12). Customer development thus becomes a way of justifying the technical development choices that have been made. For the PATE project, customer development was also viewed as a way of prioritizing different development tasks, as well as a way of deciding if further development was even needed. The PATE project also saw customer development as a way of justifying a request for additional grant funding by providing proof of market. In the future, the PATE project intends to use Customer Development to support the development of an MVP.

5.3.3 Simulated MVP

In the case of the PATE project, customers only had a vague idea of their needs, and a building an MVP was not feasible at the current stage of commercialization. The *Simulated MVP* was a customization to address these needs. From a broad perspective, this tool is an application of the strategy synthesized in Section 2.4.2 because the PATE project can't build an MVP for customer testing and evaluation, and customers were unsure of their required technical specifications. The Simulated MVP is a simulated list of performance specifications for the prototype that hasn't been built yet, as used by a specific application.

The PATE project settled on a compromise: Instead of asking customers for their preferences, the PATE project could project specifications and costs and see if they would

be nominally interesting to potential customers. This could be followed up with a corresponding MVP at a later stage of development. While this simulated MVP introduces additional sources of error (for example, the specifications could end up changing when an actual MVP is developed, or the queried customers could make false assumptions about how they would use a product that doesn't exist yet), the simulated MVP provides an opportunity to engage in customer development even though the customers do not fully understand the scope of the problem being solved. The simulated MVP addresses Felin et al.'s (2020, 1-2) suggestion that the exact approach to customer experimentation and MVPs might need to be adjusted to accommodate different technology or industry requirements, while providing a proposed solution for this technology and industry.

5.3.4 Workshops

Workshops were successfully used to create a venue for collaboration. This included collaboration between team members, between team members and advisors, and between team members and potential customers. For the PATE project, workshops were also useful for confronting knowledge gaps because they forced a conversation with customers. However, these two missions are mutually exclusive. Workshop #3, which primarily yielded insight into additional information that needed to be collected by the technical team, was, as a result, not otherwise particularly productive. Thus, while workshops are a useful tool, they may need to be complemented with other methods for interacting with customers.

5.4 Q1c: How do academic entrepreneurs learn about these strategies and tools?

The PATE project team members learned about these strategies and tools through a combination of methods and sources. Some tools were explicitly introduced by the business coaching resources on the team. Other tools were organically implemented by individual team members, with the coaching team's role being to merely redirect or refocus those existing efforts. The methods used to learn about these strategies and tools are presented below in Table 11, below, and further explained in the subsequent sections.

Table 11: Methods used to introduce tools to the PATE project team

Tool	**Learning Method**
Market Opportunity Navigator	Introduced by commercialization team
Customer Development	Organically introduced based on need to define technical requirements
Workshops	Introduced prior to the study period. Workshop topics chosen in collaboration with all team members.

5.4.1 Market Opportunity Navigator

Use of the Market Opportunity Navigator started out organically within the PATE project. Technical team members were familiar with grant funding and preparing grant applications. The potential grants that were identified included some aspects of commercialization in their evaluating criteria, both explicitly and implicitly. This provided a bridge between the team's prior knowledge and the commercialization process. As a result of this bridge, the technical team started evaluating opportunities organically, initially focusing on evaluating the market size of different opportunities.

When this organic process was compared to the approach proposed by the Market Opportunity Navigator, the two processes were very consistent. The Market Opportunity Navigator's process, however, was significantly more robust and thus gave the technical team additional questions to answer beyond market size. The coaching team presented the tool to the rest of the team, who then agreed to adopt it as a framework for evaluating opportunities.

5.4.2 Customer Development

The strategy of Customer Development was never explicitly discussed by the PATE project team. The themes of Customer Development became relevant as the team started to identify elements of path dependency within the commercialization path. For example, once the team identified that another grant would be required, there was a need to identify

the best combination of funding source, technology application, and industry partner. The team was unable to differentiate between these different paths with the current stock of customer information, prompting a renewed focus on customer development. A similar juncture appeared towards the end of the study period as the technical team began conceiving of future development initiatives. Customer preferences and needs were proposed by the commercialization team as a way of differentiating between these paths.

5.4.3 Workshops

The use of workshops was explicitly called out in the scope of work for the PATE project grant, and as such, the choice to utilize workshops was made prior to this study. The choice of topic and themes to explore during the workshops, however, was made during the study period. Workshop topics were selected to address questions or issues that came up during regular project meetings.

Ultimately all of the strategies and tools that were deployed by the PATE project team were the result of a process that started by having the coaching team ask questions about the
Commercialization of the technology, which identified knowledge deficiencies. The use of tools arose both organically and explicitly as a response to these questions.

6. Discussion

This study aims to address the practical strategic actions undertaken by academic entrepreneurs during the commercialization process. The main findings were that the PATE project commercialization team partially followed the strategy developed in Section X. Short term activities were split between mapping out the commercialization path and collecting data to resolve the uncertainties of that path. While these activities can nominally be divided into technical data collection (experimental results from the lab on device performance) and economic data (customer needs, market size, competing solutions), most of these data collection activities required a deep familiar with the underlying technologies, reflecting the need to jointly manage technical and business activities. As a result of this complexity, these tasks were primarily undertaken by the project manager, an engineer.

The insights of Customer Development were implicitly utilized as the commercialization team realized that more specific information was required from customers in order to prioritize potential market opportunities. A new tool, the *Simulated MVP*, was conceived by the project team but has yet to be implemented. This tool will allow Customer Development to continue although the customer's do not have a fully developed sense of how exactly they would use the technology or what the performance specifications would need to be. The commercialization team explicitly utilized the Market Opportunity Navigator and Workshops in order to organize, collect and analyze the information collected through Customer Development and prototype testing.

Some of these tools and strategies were explicitly introduced by the team members with a business background as part of an academic entrepreneurial coaching program. Other items arose organically. In all cases, tools and strategies were accepted and utilized by the commercialization team after the team was confronted with a decision or question that proved difficult to answer. The tools and strategies were presented or developed as a solution to this impasse.

This study aimed to answer the practitioner focused research questions about the activities that academic entrepreneurs should engage in while commercializing university technologies. Specific activities are heavily influenced by TLS methodologies as well as other literature on the startup process and opportunity identification and exploitation. While these theories have been developed, generalized and tested through numerous case studies, a gap in the literature existed with respect to how to apply the insight to a specific process. Drafting a specific action plan is a challenge for any entrepreneur, but this challenge is compounded for academic entrepreneurs who generally come from a technical background and are relatively unfamiliar with the startup process. The Findings and Results show how these methods and tools were implemented in the PATE project. The following sections show how this project's experience can apply to other commercialization projects.

6.1 Locate the Project on the Commercialization Path

It is important to accurately locate a project on the commercialization path. The PATE project, for example, ended up being in a relatively early stage of commercialization and needed to identify and evaluate opportunities. Nominally, however, the project had already identified a list of opportunities. It turned out that these opportunities simply needed to be defined further (and quantitatively). The commercialization team did not make much progress until this was resolved. The agenda for Workshop #1, for example, included specific questions that the workshop participants were not able to answer.

A misidentification of the current status of the project will lead academic entrepreneurs to spend their time pursuing the wrong activities. Using the process framework elaborated in Vohora et al. (2004, 152), a project that believes it is in the "pre-organization" phase while actually in the "opportunity framing" phase will likely experience rejection from investors because of an inability to demonstrate "proof of concept and proof of market to potential investors." (Vohora et al. 2004, 156.) These premature overtures will waste resources at best; at worst these failures might lead the researchers to conclude that the technology is not viable, when they are simply the result of either pursuing the wrong opportunity, or poorly communicating the favorable characteristics of the chosen opportunity (Shepherd and Gruber 2020, 16-17). Rushing into the later stages of commercialization can thus be

an example of decisions made earlier on in the commercialization process that can constrain a venture's options for successfully commercialization their technology (Vohora et al. 2004, 157).

6.2 Providing Proof

The synthesized strategy provides a roadmap for commercialization projects that require additional resources. The plan that is presented to stakeholders should satisfy their individual requirements for proof. Proof operates on a spectrum: Logically, the strongest proof that a target is achievable is to have already achieved it. This is an application of one of the primary mechanisms of TLS because "it elevates startup hypotheses from the realm of guesses to the realm of facts and data." (Felin et al. 2020, 2.) The "target" in this case is the hypothesis that needs to be tested, and achieving it is another way of saying that the results of the experiment were positive. However, not all uncertainties can necessarily be resolved at the outset, particularly for projects that require large amounts of funding to complete. One way of dealing with this challenge is to break the larger experiment into smaller, sub-experiments, some of which can be completed. These preliminary results, combined with a plan for the remaining experiments, provide partial proof. Early-stage projects may only be able to build an experimental plan, without any preliminary results, which is a lower level of proof. There is no global requirement for the level of proof required at any stage of development. Instead, the necessary level of proof is determined by the individual stakeholder.

6.3 Jointly Manage Business and Technical Strategies

In the PATE project, business activities were spearheaded by the technical team members with advice from the business team. The business team adopted a business coaching approach, nurturing the business skillsets of specific technical team members. This satisfied the general requirement of NTBFs to jointly manage business and technical strategies. However, there are other ways to fulfill this requirement as well. An external business champion could be recruited that already has the relevant business and technical backgrounds. Most likely this individual would also go through a learning process to adapt

that prior experience to the specific project. (Clarysse and Moray 2004, 56.) Alternatively, the technical team could coach the business team, nurturing the technical abilities and knowledge of specific business team members. The optimal strategy for a particular project might be determined by the specific human resources available, as well as their educational backgrounds, as well as their interest and ability to learn new domains.

6.4 Tools and Strategies for Commercialization

The Market Opportunity Navigator provides a qualitative framework for evaluating opportunities. Although some of the elements (like market size) can be represented by quantitative values, there is no specific formula for how to combine these elements into an overall evaluation. It is ultimately up to the entrepreneur, for example, to determine how exactly "implementation obstacles" can be overcome by a "compelling reason to buy." (Shepherd and Gruber 2020, 5-6.) There are thus two sources of potential error when conducting an analysis utilizing the Market Opportunity Navigator. The entrepreneur might have faulty information about the technology or the market causing them to feed bad information into the framework; or, the entrepreneur might have accurate information, but weigh it improperly. Furthermore, the results of the analysis can be very sensitive to missing information. A requirement for additional technical development funding can be an insurmountable obstacle, up until the point where a funding source is discovered.

The Market Opportunity Navigator should thus be used in an iterative fashion. Within the process of academic entrepreneurship, the Market Opportunity Navigator roughly corresponds with the step of "opportunity recognition." (Vohora et al. 2004, 160.) at the beginning of the process. The Market Opportunity Navigator tool should be revisited periodically as a part of the commercialization process to reevaluate early conclusions and add additional data, as part of the iterative process described in the literature (Aguirre et al. 2006, 162).

6.5 Risk in the Process

Entrepreneurship is risky, so it follows that most of the methods and tools available for use are aimed at reducing risk. Throughout this study we have seen different types of risk. Technical risk is the risk that the technology fails to perform as intended, while market risk is the risk that potential customers will ultimately be uninterested in the technology. These risks are inherent to the commercialization process. (Clarysse et al. 2002, 5.) TLS, for example, calls for entrepreneurs to test hypotheses but accepts the fact that some of those hypotheses will fail. In fact, according to Blank (2013, 17) the philosophy behind customer development is "It's OK to screw it up if you plan to learn from it." Another type of risk, however, is the risk of poor execution. Resolving the wrong uncertainties leads to wasted effort. According to Eisenmann et al. (2017, 6), an MVP allows "entrepreneurs [to] learn about customers before investing too much time in building features no one will use." This perspective assumes that there are other feature or tasks that the entrepreneur should be spending time on instead.

We can thus see that the strategies and tools for optimizing the commercialization of technology ultimately play a supporting role to the technology development process. If the underlying technology doesn't work, no amount of customer development or hypothesis testing can get around that fact. In some cases, however, the evaluation of whether the technology works could be dependent on the application. It may be suitable for some situations and not for others. Ultimately the optimizations of the commercialization process are optimizations of time and resource management. If a development path leads to a dead end, arriving at that conclusion quickly can allow the commercialization team to pivot to other options before running out of runway. (Shepherd and Gruber 2020, 15-17.)

6.6 Educating Academic Entrepreneurs

If the value of strategies and tools like TLS is measured in terms of more efficiently using time and resources, particular care should be taken when educating entrepreneurs about these topics so as to not drown those benefits in educational overhead. Tools should be introduced as needed using the entrepreneur's commercialization project as a concrete

example instead of a published case study. They should be connected to the concrete problems that need to be solved within the project.

As a result, consulting or coaching efforts should be spaced out over time, allowing the entrepreneur to develop, learn and execute a lesson before moving on to another one. Pynnönen et al. (2019, 346) showed how external commercialization advisors can assist with the commercialization process over a 4–6-month period. However, their model assumes that the necessary technological development has already been completed. The PATE project followed an alternative path, whereby the technological development continued in parallel with commercialization workshops. This is either an inherent characteristic of the PATE project and technology, or an indication that the workshops were initially scheduled too early in the commercialization process. The PATE project responded to this by extending my contract twice.

Academic entrepreneurs benefit from exposure to TLS methodology to help with opportunity identification, customer development, and overall shortening the commercialization process in order to preserve the venture's *runway*. Tools such as the Market Opportunity Navigator and Business Model Canvas can help to organize an entrepreneur's thoughts and draw attention to elements that might otherwise be ignored. Felin et al. (2020, 3) argues that these tools themselves do not unambiguously define the task. Instead, Felin. et al. (2020, 4) write that entrepreneurs should be focused on developing the underlying theory of value for the business venture. These tools can be introduced to arrive at that insight, rather than a shortcut to avoid developing it.

7. Conclusions

7.1 Theoretical Contributions

This study developed a theory for how to implement commercialization activities within a university research commercialization team. This synthesized theory proposes a method for utilizing limited resources to develop proof that can be used to accumulate additional resources from stakeholders. This theory is a contribution towards closing the gap being the study of entrepreneurship and the practice of entrepreneurship, as called for by Shepherd and Gruber (2020). The coaching or mentorship of academic entrepreneurs has been addressed in the literature as a clear need, but the methods for doing so have not been explored. This study does not attempt to determine an optimal coaching technique but provides a strong hint that coaching methods for academic entrepreneurs are a meaningful area worthy of further study.

This study also contributes to the theories on entrepreneurship and commercialization by looking at the intersection between TLS methodology and academic entrepreneurship. Gbadegeshin (2018) looks at the application of TLS to the commercialization of high technologies, which has some overlap with academic entrepreneurship. This study uniquely combines TLS with academic entrepreneurship looking at a specific but important niche within the larger world of entrepreneurship. Furthermore, there are strong indications that the unique characteristics of the commercialization of high technology in a university context have a meaningful impact on the choice and customization of methods and tools. Furthermore, this study contributes a fresh perspective into the commercialization process. Most of the literature on the commercialization or startup process looks at the entire startup lifecycle. If the PATE project were mapped onto the processes that re described, the entire term of my participation in the project would likely be in a single stage or step. Instead, this study has focused on how academic entrepreneurs navigate through that stage or step from a practical perspective.

Lastly, the study contributes to the study of entrepreneurship by utilizing unique qualitative methods for the field. Action research is not commonly deployed in the entrepreneurship

literature but provides tools for dealing with the complexity of entrepreneurship processes. Action research also provides a way of combining the research of entrepreneurship with the practice of entrepreneurship, particularly with regards to the coaching of academic entrepreneurs.

7.2 Managerial Implications

The goal of this study was ultimately to develop a practical guide for navigating through the university research commercialization process. One major implication for managers is the synthesized theory which provides practical advice for providing proof to stakeholders. With a clearer conception of what constitutes proof, managers can optimize the use of firm resources to generate such proof. Furthermore, this framework can be used to help effectively communicate the proof that a project has obtained to grant funding agencies, investors, or potential future team members.

Beyond that, the study proposes tools and methods that can be useful in the commercialization of high technology in a university context. These include the Business Opportunity Navigator, Business Model Canvas, along with customer development and the theory of action synthesized for the study. Since the way that the tools are used is an important consideration, the theory and discussion contained in this study provide insight into how to evaluate the proper use of these tools on a case-by-case basis.

Lastly, on a practical level, this study serves as an early proof of concept with regards to the interventions and general consulting approach employed during the project.

7.3 Limitations and Suggestions for Future Research

There are several points that should be considered when evaluating the validity, reliability and generalizability of this study. Structural elements such as my own background, the duration of the study, selection of cases, and research methods employed place limits on these characteristics that create opportunities for future research.

7.3.1 Validity

Validity refers to the accuracy of the findings with respect to the data, which can be affected by the researcher's bias in interpreting the data (Noble and Smith 2015, 34-35). For this study, the primary manifestation of this bias is through the categorization of themes contained within the documents used for this study. Methodologically I attempted to maximize the validity of these studies by facilitating explicit discussions of the topics covered by this thesis, through workshops, meetings and other correspondence. These communications were a direct result of implementing action research methods into the process (Mumford 2001, 22).

However, as a relatively inexperienced researcher, these efforts were imperfect. My understanding of the relevant themes evolved during the study, so these explicit conversations did not always perfectly line up with the study, creating some amount of room for interpretation on my part.

7.3.2 Reliability

Reliability refers to the ability of other researchers to arrive at similar findings and conclusions. Reliability is influenced by the level of documentation on methodology and decisions made during the study. (Noble and Smith 2015, 34-35.)

This study is jointly limited by the research methodology and case project selection. The study utilized action research methods as part of an abductive, exploratory case study on a single project. The main challenge for reliability comes from my dual roles as both researcher and project participant, which guarantees that I have access to more background data and context that could influence my interpretation of the documents. I mitigate this possibility by presenting the findings alongside the source, but the possibility remains.

7.3.3 Generalizability

Generalizability refers to the applicability of the findings to other cases in different contexts (Noble and Smith 2015, 34-35). Several structural elements impact the potential generalizability of this study. These elements include Case Selection, Study Timeline, Research Methods, and Research Philosophy.

This study was conducted on a single case, specifically a high-tech grant funded university research commercialization project in Finland. The project was developing freeze concentration hardware. The findings may not be relevant for a different case that differs from this case along any of those parameters (or others).

The study timeline was approximately 9 months. The commercialization process is potentially much longer than that, so the selected case project was unable to complete the commercialization process during the study period. This structural reality impacted the end point of the research. Actions or interventions were considered relevant when they were adopted by project team members. Since the project is still ongoing, there is no way to evaluate the effectiveness of these elements with respect to a commercialization outcome, so there is a chance that the strategies and tools adopted by the project team are detrimental to the project's success.

This study uses participatory action research as its research method. As a result, I was deeply involved in the studied project. This can impact the generalizability of the study if the findings and impact on the project were impacted by my personal participation.

Furthermore, the study utilizes abductive reasoning, whereby a theory was generated from the literature and then evaluated within the case project. Abductive reasoning impacts the generalizability because logically the findings are merely *plausible*, a lower level of evidence than an inductive approach. (Shank 2008, 1-2.)

7.3.4 Opportunities for Future Research

Despite these limitations, the research methods are justified as an exploratory case study that plants the seeds for future studies within an area with relevant research gaps. The limitations of this research can be addressed through these future studies. Thus, future research can evaluate the theoretical framework over multiple cases using less participatory methods. Data on the cases can be collected throughout the entire commercialization process, allowing a researcher to evaluate commercialization outcomes and how they relate to the theoretical framework. Eventually, quantitative research methods can be used to further support the conclusions.

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