

Exploring Engineering Faculty Members' Experiences with University Commercialization
Utilizing Systems Thinking

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ACADEMIC ABSTRACT

Since the Bayh-Dole Act of 1980, commercialization (e.g., patenting discoveries, licensing technologies, and developing startups) has become increasingly prominent at universities across the nation. These activities can be beneficial for universities as mechanisms to increase research dollars, unrestricted funds, student success, institutional prestige, and public benefit, while developing an innovation and entrepreneurship culture. However, although faculty members are a key source of human capital within the university commercialization process, studies of faculty members' experiences with university commercialization are scarce.

To better understand these experiences, I conducted a multiple case study exploring engineering faculty members' commercialization experiences at three land-grant universities, using Activity Theory as an analytical framework. Each case consists of in-depth, semi-structured interviews with 5-6 engineering faculty members, 1-2 university administrators, and a technology transfer officer, as well as university commercialization documentation (e.g., university commercialization policy documents and web resources). I analyzed the data using provisional coding (activity system elements, supports, challenges, and affect), inductive coding, and within and cross-case analysis techniques. The study's findings include characteristics of the university commercialization activity system, supports for and challenges to faculty engagement, and provisional recommendations to enhance the university commercialization work system. Key findings include faculty members' desire to make an impact with their work, lack of training and expertise relative to commercialization, conflicting attitudes towards commercialization from colleagues and administrations, and tensions about the place of commercialization within the university's mission.

This study highlights an important and underrepresented voice in university commercialization research—the voice of the individual faculty member. By understanding how faculty members experience university commercialization, university leaders are able to make well-informed decisions regarding the university's mission, culture, work structure, resource allocation, and incentive systems related to this increasingly-prominent faculty activity. Moreover, faculty members and industry collaborators interested in university commercialization can use the study's results to make decisions regarding if and how to best proceed with university commercialization activities. Accordingly, this work not only contributes to faculty work system design, but it also contributes a unique systems research approach to the university commercialization literature.

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GENERAL AUDIENCE ABSTRACT

Pursuing patent protection, licensing discoveries, developing startups, and other forms of commercialization have been increasing at universities across the nation, and faculty members play a key role in these activities. These activities benefit the public by bringing university discoveries into the marketplace, providing a real, tangible return on tax dollars invested. They also help universities not only increase revenue and reputation, but also create a culture of innovation and entrepreneurship that supports students' preparation for the global economy. However, even though faculty are central to university commercialization, we currently know very little about their experiences, including why they do it, how it impacts their teaching and research activities, and what factors support or hinder their experiences.

To address this gap, I conducted in-depth interviews with 17 engineering faculty members at 3 different land grant universities (5-6 per university). I also interviewed 4 university administrators (1-2 per university) and 3 technology transfer officers (1 per university), and examined relevant university policies and documents. I analyzed this data to identify similarities and differences across faculty members' experiences. The findings indicate that faculty report pursuing commercialization primarily to increase the impact of their research; they want to see their work move beyond journal articles and into the products and services that meet increasing public needs. Equally important, they saw themselves as part of a community that included not only other members of the university, but entrepreneurs, marketing experts, business people, and others in the larger community. That is, university commercialization represents dynamic engagement among universities, the business community, and industries.

Faculty also identified a number of different resources and characteristics of their universities that both supported and hindered their efforts, leading to provisional recommendations that can make university commercialization more effective, efficient, and equitable. By understanding how faculty members experience university commercialization, university leaders can now make more informed decisions about both how commercialization fits into the the university's mission as well as how to establish cultures, work structures, resource allocations, and incentive systems related to this increasingly-prominent faculty activity.

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Chapter 1: Introduction

1.1. The Need for this Study

There is changing demand on academia to expand the research enterprise beyond just basic research and to contribute directly toward tangible economic development. Basic research is important for future innovation and funding should continue in this area.... However, societal expectations of universities now go beyond just research, teaching, and public service. University missions are expanding to include economic development, of which translation of university research is a major part. The greatness of a university is not just in its research grants and contracts metrics but also in how the university impacts and changes the world and society at large. To unleash the innovation potential of university research, there is a need for conducting scholarly activity that translates basic research into commercially viable processes and technology. However, addressing this need often requires faculty members with a different working mindset and modus operandi than those conducting purely basic research. It also requires engagement of the researcher in a period of translational work that does not necessarily result in outcomes that are traditionally counted in career advancement...

(Sanberg et al., 2014 p. 6542)

Since the Bayh-Dole Act of 1980, technology transfer, technology commercialization, academic entrepreneurship, academic capitalism, university-industry collaborations, and other *knowledge translation*¹ activities have become increasingly important at academic institutions across the nation (de Melo-Martín, 2013). This importance extends into public policy through programs such as the National Science Foundation’s Small Business Innovation Research (SBIR) program, the Small Business Technology Transfer (STTR) program, and, more recently, the Innovation Corps (I-Corps) program. Broadly, such programs support university commercialization activity, which occurs when knowledge, typically held and valued primarily

¹ Knowledge translation is the conversion of “research findings for appropriate dissemination and implementation into the targeted industry or public” (McCoy et al. 2012, p. 265)

in academic settings, is intentionally transitioned into a marketable product or process that can be patented, licensed, or developed into a spinoff company. These forms of knowledge transition seek to realize what some researchers call the “third mission” of the university (i.e., beyond research and teaching): social and economic development (Etzkowitz, 2008).

Knowledge translations through commercialization offers universities a wide range of benefits, including demonstrated increases in

- research dollars, unrestricted funds, scholarship, and student success (Bozeman & Gaughan, 2011; Lin & Bozeman, 2006);
- institutional prestige and public benefit (Sanberg et al., 2014);
- economic development activity (Feller, 1990; Bozeman & Gaughan, 2011);
- research productivity (Dietz & Bozeman 2005);
- reputational returns for faculty (Lam 2011); and
- innovation and entrepreneurship cultural development (McDevitt et al., 2014).

However, to reap these benefits, universities must understand and enable faculty engagement in commercialization, as evidenced by Sandberg et al.’s call for action, reports from top-tier organizations (e.g., the American Association of University Professors; see Sanberg et al., 2014 for full list) and research translation scholars (Blismas, McCoy, & Lingard, 2009; McCoy, Saunders, Kleiner, & Blismas, 2012). This study supports such work. In doing so, however, I am not suggesting that all faculty, or even all universities, need to or should engage in commercialization. Rather, my work seeks to understand faculty commercialization experiences in ways that can help both institutions and individuals who choose such paths.

1.2 Focusing on Individual Faculty Members and this Study’s Purpose

Understanding and enabling the third mission is challenging because faculty members’ professional activity systems are complex, dynamic, and open to a range of professional activities (e.g., researching, teaching, serving on committees, consulting, commercializing research). Moreover, commercialization activities, despite their increasing presence on university campuses, can be met with varying levels of professional acceptance. For example, faculty members’ differing views regarding how commercialization counts toward career advancement (promotion and tenure) can challenge engagement in university commercialization. As a result, faculty interested in the university’s third mission are often required to make difficult choices regarding their time and level of engagement.

Despite these challenges, the research is clear that faculty are the essential human capital for universities' pursuit of the third mission. In *The American Faculty: The Restructuring of Academic Work and Careers*, Schuster and Finkelstien (2008) describe how faculty members are increasingly taking on new professional activities such as commercializing technology:

Faculty at the research universities have been increasingly spinning off their own for-profit ventures in partnership with their campuses. For larger numbers of faculty, the social contract, it appears, is turning into a business contract—with the faculty member becoming the solo entrepreneur. (Ch.11, section 6, para. 3)

These new activities include not only direct spinoff commercialization alluded to in the quote (Boh, De-Haan, & Strom, 2012), but also acting as a stakeholder in all phases of licensing (Siegel, Waldman, Atwater, & Link, 2004). Siegel et al. (2004) state that in university spinoffs, academics often serve on boards of directors or as technical advisors, indicating their participation in later stages of the spinoff process. Boh et al. (2012) report similar findings and identify faculty as key stakeholders in three different pathways for university spinoffs although they also show that faculty effort decreases in later stages of spinoff execution. More generally, Perkmann et al. (2013) acknowledge that because of universities' overarching reliance on the initiative of faculty members, commercialization activities tend to be pursued and advanced at the level of the individual faculty member. Perhaps most importantly, Agrawal (2006) shows that the involvement of the academic researcher during commercialization enhances the probability of success.

Even as they demonstrate the centrality of faculty involvement, previous studies also demonstrate the need for a deeper exploration of faculty members' commercialization experiences. For example, Markman et al. (2008) specifically call for a need to better understand the individual level of university commercialization and proposed several research questions that would advance universities' ability to realize the third mission (p. 1412):

- “What differences are there in the commercialization activities of star scientists versus non-star scientists?”
- “What are the most effective configurations of entrepreneurial teams for the commercialization of research?”
- “How does the entrepreneurial experience of scientists affect the nature of commercialization?”
- “How does involvement in technology commercialization affect the quantity and quality of basic research?”

- “How does involvement in technology commercialization affect teaching performance?”
- “How does involvement in technology commercialization affect the career development of faculty members?”
- “What is the relative importance of pecuniary and non-pecuniary incentives in university technology commercialization?”
- “How important is training and human resource development for technology transfer officers?”

Perkmann et al. (2013) reinforce this need, citing a literature review by Rothaermel, Agung, & Jiang (2007) that analyzes 25 years of research (1981-2005). They note, “the literature on university entrepreneurship [has] neglected the analysis of individual researchers’ involvement in the process” (Perkmann et al., 2013, p. 425).

The limited individual-level research that does exist highlights factors impacting faculty engagement. For example, Lam (2011) conducted research on UK academics’ motivation for engagement in university commercialization and found that faculty members had different motivations depending on their commercial orientation. Perkmann et al. (2013) found that the entrepreneurial activity of academic researchers was linked to the culture of one’s departmental peers. They also found that commercialization activities were more common among male researchers and researchers who are “more scientifically productive” (p. 426). Finally, Sanberg et al. (2014) found that for untenured faculty, the promotion and tenure system’s failure to adequately credit knowledge translation activities beyond journal publications (e.g., spinoff formation) makes participating in such activities challenging.

As these and other studies suggest, researchers have looked at small subsets of faculty commercialization experiences; however, prior studies also point to more systematic research needs such as understanding the impact of academic culture on faculty behaviors and the influence of institutional structures and incentives on academics’ commercialization experiences. For example, McCoy et al. (2012) argue that a systems perspective is necessary to further study the dynamic, highly contextual environments in which university commercialization actually occurs. Despite this need, few if any studies have systematically explored faculty members’ commercialization experiences.

To help address these gaps in understanding and support universities and faculty members’ pursuit of the third mission, my study answers the following research questions:

RQ 1: How do engineering faculty members at land-grant institutions experience university commercialization?

RQ 2: How do elements of the university system support or challenge engineering faculty members' commercialization experiences?

More generally, these answers contribute to my study's purpose of 1) enhancing our understanding of faculty members' experiences with university commercialization, 2) identifying supports and challenges for faculty members who engage in university commercialization and 3) providing recommendations for administrators and faculty interested in realizing the university's third mission.

1.3 Methodology

As described, prior commercialization researchers call for research that enhances our understanding at both the individual and systems level. To meet these needs, I utilized a systems framework (activity theory) to conduct a multiple-case study of engineering faculty members' commercialization experiences at three land-grant universities. I selected engineering faculty at land-grant institutions because of their propensity to participate in university commercialization (Lee, 1996) and as a means to achieve a balanced replication strategy across cases (Yin, 2014).

Importantly, the institution does not represent my case. Instead, faculty members' collective commercialization experiences at an institution represents each case. To this end, I conducted and analyzed semi-structured interviews with 17 total engineering faculty about their university commercialization experiences (6 at Site 1, 6 at Site 2, and 5 at Site 3). I also collected and analyzed additional case data including 4 administrator interviews (2 at Site 1, 1 at Site 2, and 1 at Site 3), 3 interviews with technology transfer staff (1 per institution), and commercialization documentation at each institution, all of which informed the case context and triangulated the faculty interview data.

Activity theory served as a guiding framework during protocol development and during deductive analysis. Activity theory, and particularly Engström's (1987) activity system, enhanced my ability to capture a systems perspective of university commercialization for each individual faculty participant. In addition to deductive analysis, I inductively analyzed transcript data and employed data visualization techniques (Miles, Huberman, & Saldaña, 2014) to arrive at my study's findings.

1.4 Significance of the Study

Together, the study's purpose, research questions, and guiding framework systematically explored individual faculty members' commercialization experiences. The results identify the similarities and differences across faculty members' commercialization experiences at three land-grant institutions and address multiple gaps in the literature previously identified. Importantly, this study provides a view into an understudied perspective; faculty members' experiences at public research-intensive institutions (not private elite or ivy-league institutions). Answers to my research questions increase our understanding of faculty commercialization experiences including the identification of the following similarities:

- participants were predominantly male, tenured, and had prior industry/commercialization experience;
- participants described being motivated primarily by the desire to have a societal impact beyond publications and presentations;
- funding, trainings, and formal commercialization tools such as university forms were the primary tools;
- participants identified commercialization community members both within and external to the university that were essential to the process;
- both formal and informal commercialization rules and attitudes influenced participants' experiences, and included both support for and stigmas against commercialization;
- participants delineated clear roles, activities, and levels of responsibility they both would and would not take on;
- multiple outcomes resulted from commercialization efforts, including not only licenses and startups, but also publications, student job placement, and increases in knowledge; and
- participants experienced both strongly positive and strongly negative emotions and attitudes associated with their commercialization experiences.

These answers also identified individual, resource, rules, and time supports and challenge impacting faculty engagement in university commercialization.

The frameworks and methods described in Chapters 2 and 3 also contribute to the study's significance. By analyzing faculty commercialization experiences from a systems perspective, my study advances both the engineering education and higher education literatures. To date, activity theory is not a widely used framework within engineering education or higher education: this study demonstrates its ability to capture and frame a systematic perspective of faculty work. Practically speaking, the findings lead to

- provisional recommendation for administrators and faculty members interested in progressing the university's third mission;
- the development and/or refinement of university policies and structures; and
- university commercialization training programs at the national, regional, and local levels.

This study also provides a strong foundation for developing additional studies (i.e., qualitative and quantitative studies) that can further enhance our understanding of faculty members' commercialization experiences across the diverse higher education landscape.

1.5 Limitations

As with any research study, this study has limitations. My study developed three cases that were purposely bounded by institution type and field of study and not generalizable to other settings. I sought to balance depth and breadth; therefore as Patton (2002) discusses, my study includes a smaller number of participants who provide greater depth (or "detail, context, and nuance." (pp. 227-228)) Regarding breadth, Yin (2014) describes case study research as an effective tool for making analytical generalization based on the theoretical prepositions that guided study development. These analytical generalizations add to the literature and act as a catalyst for additional research including larger qualitative or quantitative studies designed specifically to yield generalizable results.

Notably, while Yin recommends developing 6-10 cases when conducting a multiple case study, he acknowledges that this is often difficult due to time and resources limitations, both of which I was subject to in this study. Given the time and resource limits of my doctoral work, I selected only 3 case sites to produce a study that is more exploratory than explanatory. As a result, my findings and recommendations regarding engineering faculty members' commercialization experiences are necessarily provisional.

The participant pool represents another limitation of this study. All of the participants in this study self-selected to participate and most had significant university commercialization experience. Participants' eagerness to participate may have resulted in a sample that provided an edge-case perspective, and the broader population of faculty who participate in commercialization activity may have differing views. The level of commercialization experience may also limit this study's findings, as faculty members who are new to university commercialization may have different experiences. Lastly, the time gap between participants'

commercialization experience(s) and any associated changes in participants' beliefs or inability to accurately recall their experiences could limit the impact of my study's contributions.

1.6 Overview of Chapters

This chapter addressed the need, purpose, and significance of the study; stated the research questions; acknowledged potential limitations; and described how the study will enhance our understanding of engineering faculty members' university commercialization experiences. In Chapter 2, I review the literature regarding terminology used to discuss university knowledge translation, models for translating research into practice, faculty perspectives of technology transfer and commercialization, and systems perspectives. In Chapter 3, I describe the multiple-case study data collection and analysis techniques used to answer the research questions. In Chapter 3, I also discuss the participants of the study and provide a detailed overview of my site replication strategy. In Chapters 4 and 5, I present the findings for research questions 1 and 2, respectively, and in Chapter 6, I situate the findings within the existing literature, offer provisional commercialization work system recommendations for administrators and faculty, describe the limitations of the current study, and offer opportunities for future work.

Chapter 2: Literature Review

As described in Chapter 1, university commercialization is becoming an increasingly important knowledge translation practice for universities. After briefly describing knowledge translation broadly, this chapter reviews common models of knowledge translation and university commercialization, the rise of commercialization in universities and faculty work, faculty members' position as the essential source of capital in any university commercialization activity, ethical considerations related to university commercialization, and activity theory's ability to serve as a guiding framework for my study.

2.1 Mechanisms for Knowledge Translation

Historically, there are four primary mechanisms within universities to translate knowledge into society: publishing/presenting, service/extension, academic engagement (or university-industry partnerships), and commercialization. Publishing/presenting focuses on transferring knowledge primarily to academic peers through journal publications, conferences publications/presentations, and presentations at seminars and professional societies. Publications and presentations are widely valued in the faculty work system, as evidenced by promotion and tenure guidelines and the lengthy publications/presentations sections of faculty members' CVs. However, despite the high value placed on publishing and presenting by academics, this mechanism often reaches smaller, more specific audiences that are typically experts, or at a minimum, familiar with the field under consideration (i.e., other scholars within a discipline or scholars looking to span disciplines). While representing a useful and effective translation mechanism for scholarly work, publications and presentations are less likely to reach society-at-large or result in the formation of marketable products and services (Perkmann et al., 2013).

Service/extension occurs when faculty members translate their knowledge and expertise to give back to the local and national communities and respond to social and environmental needs (Boyer, 1990). Unlike publications and presentations, the intention of faculty service or extension is to return something (often knowledge) back to the general public, and consequently reach a broader audience than technical publications and presentations. Accordingly, while the products of service/extension can be papers and presentations, they often take on different forms including developing and conducting camps, offering specialized training programs, serving on federal and state commissions, and advising as a member of a non-profits' board of directors.

Both faculty members and the general public benefit from this mechanism of knowledge translation because faculty are able to test and refine their ideas through real-world experiences and the public gains access to specialized, and often needed, knowledge and expertise.

Academic engagement, a new term to describe university-industry partnerships, represents a third form of knowledge translation, in which university professionals interact with industry professionals, typically around a technical specialty (Perkmann et al., 2013). Academic engagement represents any collaboration between universities and industry where agreed-upon terms may produce financial or non-financial benefits (Perkmann et al., 2013). These activities can range from sponsoring student research projects to hiring a university research lab for testing and analysis. These partnerships add value because industry representatives can benefit from the knowledge provided by university scientists (e.g., faculty and graduate students) or the highly technical and expensive equipment owned by university. At the same time, faculty members can benefit from academic engagement because they can gather real-world understanding related to their expertise and leverage these collaborations to place students upon graduation. Academic engagement is also valuable because universities are increasingly looking to diversify their revenue sources and make education more authentic, and they can leverage these collaborations to enhance the reputation of the university.

Lastly, university commercialization, as it will be referred to throughout this document, represents activities intentionally focused on evaluating market potential, patenting, licensing, and developing spinoff companies. The most common phrases used by researchers to describe these knowledge translation activities are “technology transfer” and “technology commercialization,” but in actuality many other terms are used (e.g., academic entrepreneurship, academic capitalism). These activities typically require faculty members to disclose their intellectual property to a university technology transfer office, which then explores the marketability of the intellectual property and decides whether or not a patent is necessary. Although the literature is mixed in its representation, commercialization is not necessarily focused only on financial incentives (Lam, 2011; McDevitt et al., 2014), but also on the evaluation and development of marketable opportunities as a means to translate knowledge to benefit society. As a result, technology transfer offices operate using different models including, but not limited to, a service model (i.e., serving the state and helping faculty/universities

maximize societal benefits of academic research) and a profit model (i.e., acting as revenue sources for the university and seeking to make a profit – or at least break even).

2.1.1 Models of Knowledge Translation

Beyond describing the general mechanisms for knowledge translation, researchers have proposed a number of academic knowledge translation and commercialization models. Beginning broadly, several models detail the interaction between academic research and societal/practical implementation. This interaction is often depicted in the form of a cycle with directional arrows connecting key thoughts and descriptors of the cycle. For example, Booth and colleagues (2008) describe a general cycle showing how practical problems can motivate research questions, which in turn define research problems, and lead to research answers (Figure 1). This process can ultimately derive new practices, which create additional practical problems, and the cycle continues.



Figure 1: Booth et al.'s (2008) cyclic research/practice model

(Reprinted with permission from (Booth et al., 2008) © 1995, 2003, 2008 by The University of Chicago)

In their description of this research-practice cycle, Booth et al. focus on researchers' need to develop research questions (and answers) that individuals will think are "worth solving" or will have some impact greater than basic research (p. 51).

Interestingly, Booth et al. also distinguish between practical and conceptual research problems, noting that in order to solve practical problems, we often need an enhanced understanding obtained by first solving conceptual research problems. The key difference between practical and conceptual problems is the fact that practical problems require *action* by

an individual based on new understanding. Conceptual problems, on the other hand, do not require action but instead answer questions that promote enhanced understanding. In this framework, university commercialization represents one form of *action* taken by faculty to identify opportunities for implementing solutions to practical problems based on their research. Commercialization can also help faculty members develop new conceptual research questions that will advance the field. The Booth et al. cycle has been adopted, utilized, and adapted in prior engineering education scholarly work and is often referred to as the research-to-practice or research-practice cycle (Jamieson & Lohmann, 2009; Matusovich, Paretti, McNair, & Hixson, 2014).

Blismas, McCoy, and Lingard (2009) developed another general model that further supports our understanding of the place of commercialization activities within the larger research and knowledge translation cycle (Figure 2).

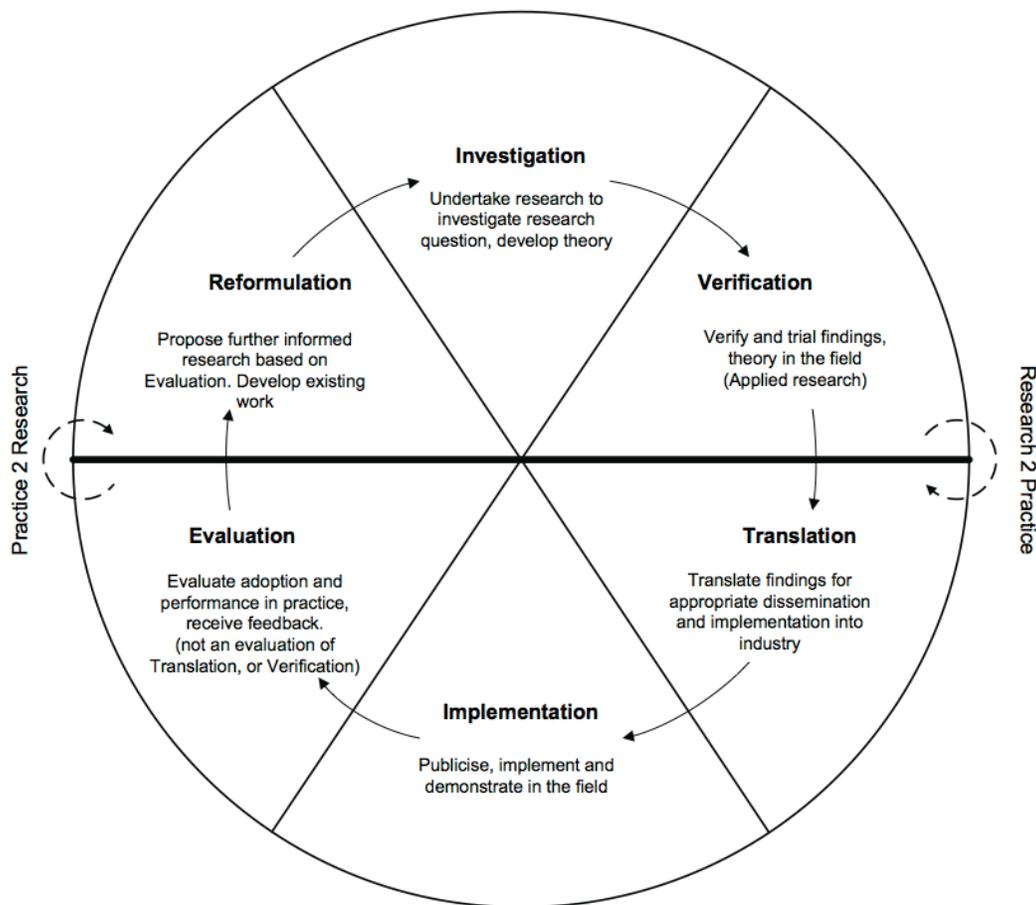


Figure 2: Blismas et al.’s (2009) ‘full cycle’ of translational research (based on Ledford, 2008)

(Reprinted with permission from (Blismas et al., 2009))

Their model describes six key phases of knowledge translation and includes a research-focused half and practice-focused half of the cycle, as indicated by the dark horizontal line in Figure 2, with the top half focused on research and the bottom half focused on practice. To further emphasize this distinction, their depiction adds circular arrows to the left and right sides indicating the move from research to practice and vice versa. As one might suspect, most commercialization activities begin around the transition from research to practice, and are captured in the Verification, Translation, and Implementation, phases of their model.

2.1.2 Models of University Commercialization

While these broad models allow us to position commercialization within the context of general university knowledge translation, researchers have also modeled the university commercialization process specifically. As summarized in Figure 3, Siegel et al. (2004), Boh et al. (2012), and the NSF Engineering Advisory Committee Subcommittee on Industry-University Partnerships (EACSIUP) (2008) provide schematics of the typical university commercialization process.

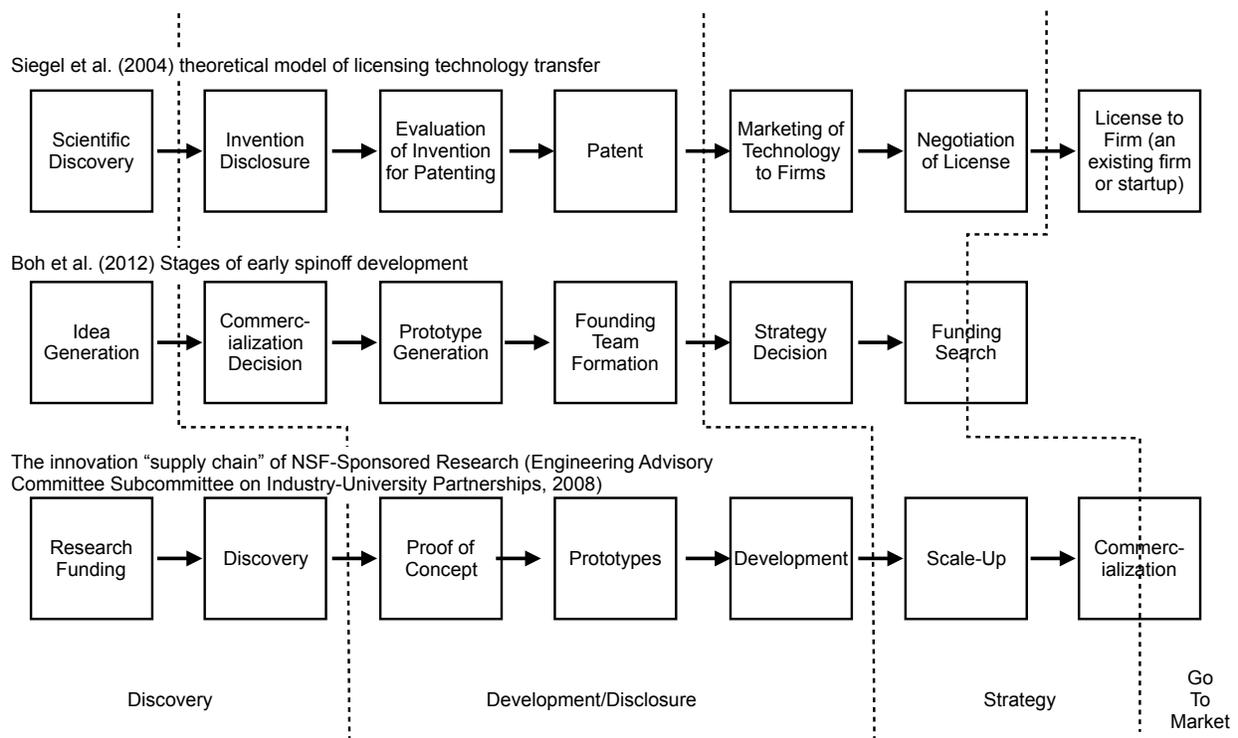


Figure 3: Summary of university commercialization models

To synthesize their models, I have separated the four essential phases of university commercialization; discovery, development/disclosure; strategy; and go-to-market. Each model begins with a discovery phase. This phase captures faculty members' basic research activity. After the discovery phase, the models detail a development and disclosure phase that includes activities such as prototyping, disclosing potential intellectual property, evaluating market potential, patenting, assembling a commercialization team, and commercially-focused research and development. Next, the strategy phase addresses the commercialization strategy, marketing plan, and scale-up activities. The last phase, the go-to-market phase, takes the product or service to market (typically via a license or a startup/spinout). In the figure, I split Boh et al.'s "Funding Search" between the strategy and go-to-market phases because securing funding can require both strategy and a proof of market acceptance. I also split the EACSIUP's "Commercialization" block between the same phases due to the fact that commercialization activities can be conducted during both the strategy and go-to-market phases. Overall, these four phases describe the typical commercialization process within academia.

2.2 Commercialization in the Faculty Work System

Having provided an overview of knowledge translation and university commercialization models, I turn to the ways university commercialization activities have impacted the faculty work system. To this end, this section discusses the Bayh-Dole Act's role as a commercialization catalyst, changes in faculty evaluation language, and faculty members' role as the essential human capital in commercialization.

2.2.1 The Bayh-Dole Act as a University Commercialization Catalyst

The Bayh-Dole Act of 1980 catalyzed university knowledge translation through commercialization and is considered largely responsible for the existence of technology transfer offices within higher education (Aldridge & Audretsch, 2010). Briefly, the act transferred intellectual property ownership of publically-funded research from the government to the universities in order to overcome the "bureaucratic red tape and illogical government regulations" that were holding back potential "innovative scientific breakthroughs" developed within academia (Aldridge & Audretsch, 2010, p. 583). Many scholars studying university commercialization cite the passage of the Bayh-Dole Act as a critical inflection point in university knowledge translation via commercialization (e.g., Rothaermel et al., 2007) because

the Bayh-Dole Act legitimized the potential commercial value of academic research, justified universities' resource commitment toward these activities, and encouraged the development of a commercialization ecosystem (e.g., rule, policies, trainings, experts). In effect, the Act may have initiated the "third mission" of the contemporary university.

2.2.2 Shifts in Faculty Activity

The Bayh-Dole Act and the rise of university commercialization necessarily impact the working lives of university faculty. Seminal works such as those by Boyer (1990) and Schuster and Finkelstein (2008), along with numerous other highlights three primary forms of faculty work: teaching, service, and research. As Boyer outlines, these domains reflect the larger trends in higher education in the United States.

Academic institutions were originally focused on developing civic and religious leaders through intellectual, moral, and spiritual development; therefore, faculty members' primary activities were teaching and advising students. As the country developed economically, institutions shifted priorities toward serving the nation's needs. Higher education was now important not just for teaching and civic responsibility, but also to advance and transform society in practical ways through service (largely agricultural extension). As a consequence, faculty activities comprised of teaching/advising and service to society (local and national). Over time, and spurred on by economic downturn, war, and collaborations between academic institutions and the government, the system shifted focus yet again. This time the shift was toward scientific advancement through research. Hence, research activity became a salient activity within the faculty work system.

Although these activities remain prominent in today's universities, there is evidence of another shift in higher education toward a model that recognizes the need for increased social and economic development (Etzkowitz, 2008) that moves beyond teaching, service, and research (de Melo-Martín, 2013; Dietz & Bozeman, 2005; McDevitt et al., 2014). Three trends are contributing to this shift at the faculty level. First, Schuster and Finkelstein (2008) note that faculty members' "social contract" has been in constant renegotiation for at least 25 years, particularly in terms of

- *mutual loyalty/commitment* between the university and its faculty with respect to serving in the university's best interests,
- the role of faculty in *academic oversight* and decision making, and

- faculty ownership of their own *intellectual property*.

Evidence of this renegotiation includes the introduction of more non-tenure track faculty positions that challenge traditional concepts of loyalty, the increasing role of administrators in university governance that limit faculty members' power, and the increasing level of faculty participation in the commercialization of their traditional academic outputs.

Second, based on data from the Association for University Technology Managers (AUTM) Statistics Access for Tech Transfer (STATT) database (AUTM, 2014), faculty commercialization activity is increasing. My analysis of this data, shown in Figures 4 and 5, demonstrates that over the past 10 years (2004-2013) the number of U.S. university inventions disclosed, new patent applications filed, total patent applications filed, startups formed, and startups in which the university has equity has increased continually year after year.

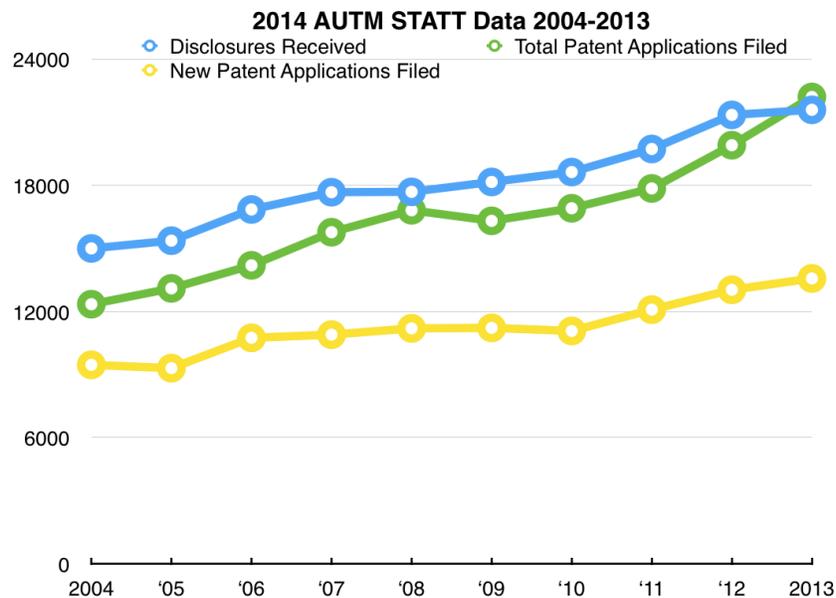


Figure 4: Trends in university intellectual property disclosures, new patent applications, and total patents applications filed from 2004-2013

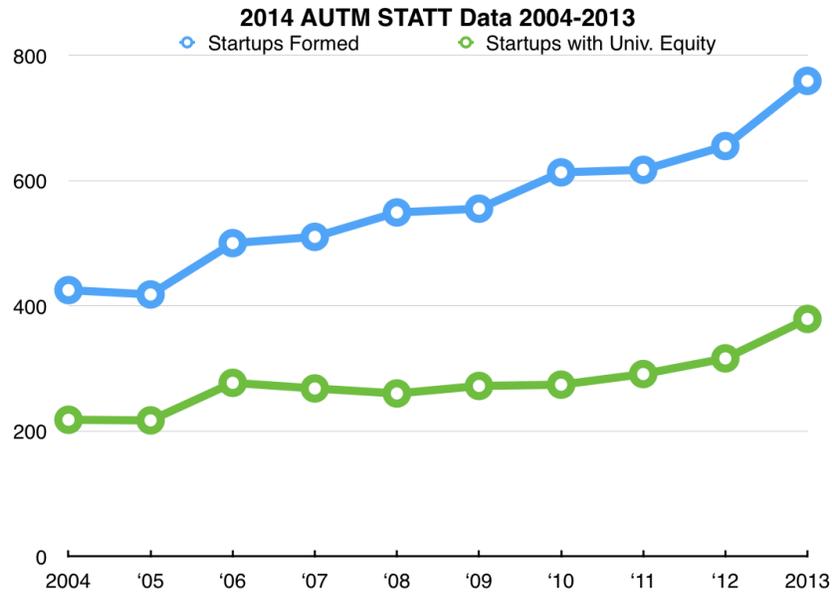


Figure 5: Trends in university startup formation and number of startups with university equity from 2004-2013

McDevitt et al. (2014) report similar findings from their analysis of the ATUM data and include increases in net product sales and number of full-time employees due to commercialization. These indicators further demonstrate that faculty are participating in more commercialization activity that ever before.

Third, faculty members have shown an increasing interest in research and programmatic initiatives targeting innovation and entrepreneurship education efforts. This increase is occurring both within engineering education and at universities more generally (e.g., Besterfield-Sacre, Ozaltin, Shartrand, Shuman, & Weilerstein, 2011; Giordan, Shartrand, Steig, & Weilerstein, 2011; Shartrand, Gomes, & Weilerstein, 2012; Zappe, Hochstedt, Kisenwether, & Shartrand, 2013). Within engineering education, three primary examples of this are the Kern Family Foundation's Kern Engineering Entrepreneurship Network (KEEN), the NSF-funded National Center for Engineering Pathways to Innovation (EPICENTER), and the growth of the American Society for Engineering Education's Entrepreneurship and Innovation Division. These organizations actively research and sponsor faculty development activities to enhance faculty members' entrepreneurial knowledge and expertise (e.g., KEEN's faculty development offerings and EPICENTER's series of technical briefs on entrepreneurship programs for undergraduate engineers (Gilmartin, Shartrand, Chen, Estrada, & Sheppard, 2014)). Anecdotally, the growth in entrepreneurship education is also evidenced by an increasing number of centers, majors, minors,

certificates, and courses on topics such as entrepreneurship, developing startups/ventures, innovation, and creativity. Overall, these innovation and entrepreneurship education efforts provide evidence that both universities and individual faculty members are interested in developing and understanding entrepreneurship and commercialization ecosystems within academia.

2.2.3 Commercialization & Faculty Evaluation Language

The shifts in faculty activity are, at least nominally, leading to changes in how faculty work is evaluated at some institutions. Sanberg et al. (2014) demonstrate this change by reviewing how promotion and tenure language at institutions across the country is changing to include more commercialization-specific language. Their list of 39 institutions, and the commercialization-oriented evaluation language used by each institution, shows that an increasing number of universities are adjusting their faculty evaluation systems to include evidence of commercialization activities. A few examples of this language are provided in Table 1. (Appendix A provides all 39 examples from Sanberg et al.)

Table 1:

Example Commercialization Language from Sanberg et al. (2014 supplemental pp. 1-3)

Institution (public/private classification)	Commercialization Language Used
The Ohio State University (public)	“2. List of creative works pertinent to the candidate’s professional focus:… Inventions and patents , including disclosures, options, and commercial licenses ”
Northeastern University (private)	“…the receipt of patents represents professional recognition of research activities. In some fields technical, procedural, or practical innovations made clinically or professionally are evidence of productive scholarship”
Virginia Tech (public)	“Economic contributions and entrepreneurship: 1. Start-up businesses (including competitive grants and contracts such as SBIR awards and other notable business achievements), 2. Commercialization of discoveries , 3. Other… Intellectual properties: 1. Software, 2. Patents, 3. Disclosures (pre-patent) ”
Texas A&M (public)	“ Patents or commercialization of research , where applicable”
University of Southern California (private)	“While patents cannot replace peer-reviewed publications in a candidate’s dossier, they are a sign of impact and productivity and will be considered accordingly ”
Note: Text was bolded to highlight commercialization language.	

By updating the policy language, institutions are taking a first step toward aligning faculty evaluation systems with the shifting goals and activities of universities and their faculty. As promising as this change is, however, whether this language is culturally accepted or validated within academic departments remains unclear.

Moreover, while alignment between faculty activities and evaluation languages is occurring in some places, the relatively small number of schools incorporating commercialization language in their evaluation language and the fact that this language permits but does not recommend or require commercialization activity may be disconcerting for untenured, tenure-track faculty who have an interest in commercialization. At most institutions, commercialization activities are by no means expected professional activities of faculty members: instead, they exist as one of many – and often less valuable or recognized – sources of evidence for creative work, additional contributions to the field, and opportunities for professional development in a research-, teaching-, and service-dominated evaluation system.

2.2.4 Faculty as Essential Human Capital in Commercialization

Given the emerging shifts and despite the the insubstantial changes to faculty evaluation systems, faculty remain necessary in the university commercialization process. Perkmann et al. (2013), after reviewing the university commercialization literature, acknowledge that university commercialization tends to be an individually driven activity at the discretion of faculty members. Because faculty are the linchpin of higher education institutions, it should come as no surprise that faculty are essential stakeholders in all phases of the commercialization process, as illustrated in Siegel, Waldman, and Link’s (2004) theorized stakeholder model shown in Figure 6.

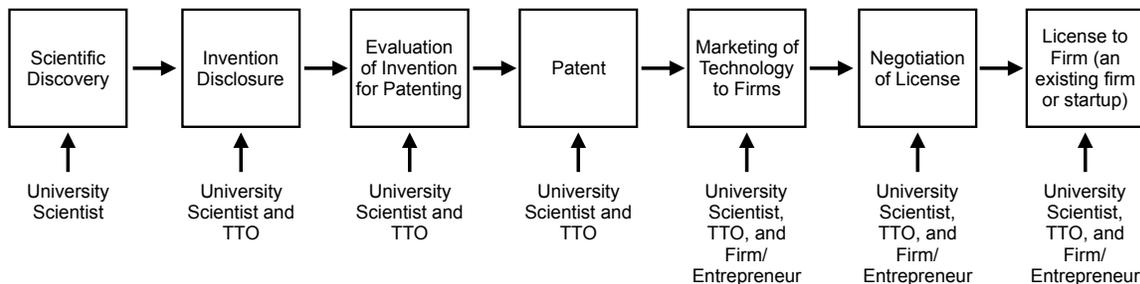


Figure 6: Siegel et al. (2004) theoretical model of technology transfer w/ stakeholders

(Reprinted from the Journal of Engineering Technology Management, 21, Siegel, Waldman, Atwater, and Link, “Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: Qualitative evidence from the commercialization of university technologies,” 115-142, Copyright (2004), with permission from Elsevier)

These authors also noted that in the case of spinoffs or startups, academic researchers often serve on the board of directors or as technical advisors – thus, indicating at least some engagement in later stages of commercialization. Interestingly, their model also theorizes the likely interactions between faculty and other commercialization stakeholders (i.e., the TTO, external firm, or entrepreneur). Similarly, Buenstorf (2009) adamantly states that the scientist is required in the disclosure, patenting and commercialization of inventions, and Agrawal’s (2006) work has found that the engagement of the inventor during commercialization enhances the probability of commercialization success. Collectively, these studies reveal that, as with other areas critical to the university’s mission, faculty represent an essential source of human capital for commercialization activity.

However, while essential, faculty engagement is not always sustained throughout the commercialization process. Boh, De-Haan, and Strom (2012) include faculty as a key stakeholder in three different pathways for university spinoff development, but show that faculty effort decreases in later stages of each spinoff process.

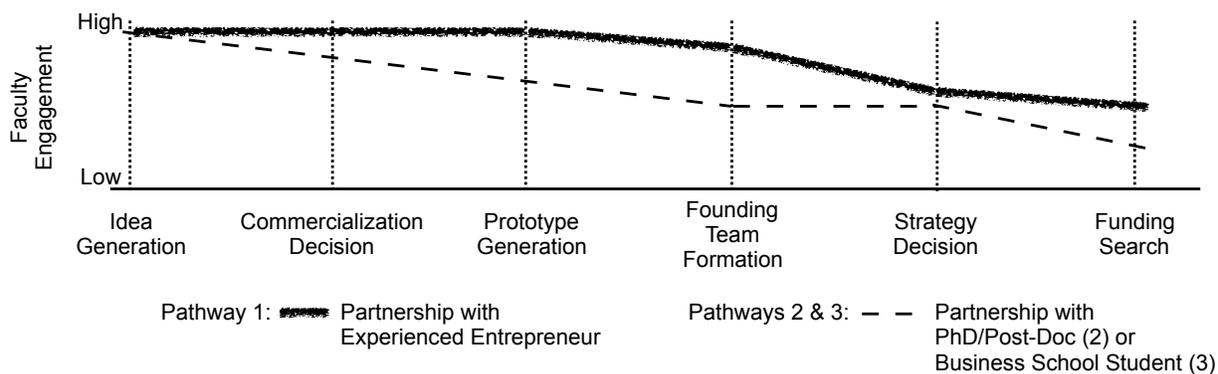


Figure 7: Faculty spinoff engagement - adapted from Boh et al. (2012)

(Note: Data was originally reported qualitatively as depicted here & pathways 2 and 3 are qualitatively identical.)

Considering Figures 6 and 7, one can hypothesize that as faculty effort trails off in the later stages of commercialization, it is replaced with effort by other commercialization stakeholders, especially in university startups. These studies and models also lead to questions about why faculty engagement trails off, how this lack of engagement impacts the success of university commercialization efforts, and whether there are additional commercialization models that support faculty engagement throughout the full commercialization process.

2.3 Universities and the Ethics of Commercialization

Despite the evidence for increasing faculty participation and the importance of faculty engagement in university commercialization, many faculty members choose to focus their efforts solely on discovery. This is not surprising considering the tenuous and limited acceptance of commercialization in the faculty evaluation and incentive systems at most institutions. However, there may also be cultural and ethical factors within the faculty work system that impact faculty members' engagement with commercialization. In this section, I summarize how the existing literature discusses some cultural and ethical issues associated with university commercialization.

2.3.1 Science as a Public Good

There is an ongoing conversation about whether or not the “third mission” or treating the products of teaching and research as a source of capital is appropriate or even ethical, particularly for publically-subsidized institutions (Powers & Campbell, 2011). In Larsen's (2011) review of the literature on this issue, she acknowledges the following

“Numerous scholars have however raised concerns that the increasing, and at times exaggerated, focus on enterprise in academia [e.g., commercialization] may have unintended effects on the long-term progress of science, namely that it will undermine the efficiency of the division of labor that exists between public and private science (e.g. Cowan, 2005; Dasgupta and David, 1994; Nelson, 1989, 2004; Rosenberg and Nelson, 1994), by shifting academic researchers away from the activities in which they are most efficient – that is, supplying a collective good (Feller, 1990; Metcalfe, 1998; Nelson, 1959, 2001).” (p. 6)

This quote exemplifies the crux of many objections to the commercialization of university research. These objections raise important questions:

- Should academic discoveries remain free and open to the public as a contribution to the collective intellectual commons?
- How should universities handle discoveries that require a profit motive, and subsequently, commercialization in order to supply a collective good?

While this study does not attempt to address these questions directly, they are important considerations for this study and the field of university commercialization.

One of commercialization's potential negative impacts to open science is the possibility that secrecy and exclusivity will impede or slow the public dissemination and accumulation of

knowledge (e.g., (Larsen, 2011; Perkmann et al., 2013) both citing other researchers). In their review of the literature Perkmann et al. cite prior studies (Campbell et al., 2002; Campbell, Weissman, Causino, & Blumenthal, 2000) that found evidence that academics who commercialize exhibit a higher level of secrecy than those who do not. Additionally, other commercialization scholars believe an emphasis on secrecy and exclusivity may impact the ability for tangential, follow-up technologies to emerge in the market and offer some evidence that exclusivity decreases publications and external collaborations (Pavitt, 1991; Powers & Campbell, 2011).

The debate concerning the appropriateness of commercialization also impacts individual faculty members and department cultures. Lee (1996) found that most faculty members who participated in his study believed that some forms of commercialization (e.g., start-ups and university equity investments) were unacceptable university activities (Perkmann et al., 2013). Moreover, commercialization scholars report that these attitudes may vary by field, with some disciplines and departments (e.g., science and engineering) more inclined toward and accepting of commercialization than others (e.g., the humanities) (Lee, 1996; Perkmann et al., 2013; Wright, Birley, & Mosey, 2004).

On the other side of the issue, scholars highlight the positives associated with university commercialization. Proponents claim that university commercialization contributes to the public good because it enables universities to have a greater societal and economic impact, and thus, make a more significant impact on the collective good than other forms of knowledge translation. For example, Blismas et al. (2009) caution that if academics don't move beyond basic science and focus additional attention on the societal implications and potential impacts of their research through commercialization activities, the distance between research findings and potential users may become greater and greater. They call for faculty members to participate in the full cycle of knowledge translation, and stress that expanded forms of translation should inform the research questions asked and the dissemination of new knowledge.

2.3.2 Research Productivity

Another concern discussed in the literature is the possible decline of faculty members' research productivity due to commercialization: here, however, the evidence is more clear in demonstrating that commercialization 1) does not significantly impact academics' research

productivity and 2) in most cases faculty members who also commercialize do more and higher quality research (e.g., higher number of citations) (Perkmann et al., 2013; Siegel et al., 2004). In one study of faculty productivity, Buenstorf (2009) explored potential positive and negative effects of commercialization on researchers' output at a non-academic research institute. While the institutional context is slightly different than that of a university, the scientists studied, like university faculty members, were primarily researchers who also engaged in commercialization. Specifically, he studied the potential negative impacts of

- time conflicts due to participation in commercialization;
- delays in publication due to legal requirements (citing (Stephan, Gormu, Sumell, & Black, 2007)) and the need for secrecy; and
- potential shifts from basic to applied that can compromise the “generality and relevance of their work” (p. 282).

Buenstorf also considered the possible positive effects of commercialization by studying the impact of learning through working with industry (e.g., identifying real-world opportunities/issues; learning new skills; access to new equipment; and access to extended expertise networks) and the impact of income realized through commercialization. Overall, Buenstorf found that *inventing* does not significantly negatively impact research output, and in actuality, academic inventors who license their research publish more and publish work that is more relevant. However, participation in *spin-off commercialization* had mixed results, ranging from no significant negative effects for short-term participation to possible negative effects for long-term spinoff participation. Buenstorf found no evidence that income earned from commercialization (licensing or spin-offs) positively impacted the research outcomes. According to Thursby and Thursby (2011), other scholars echo Buenstorf's results, finding that patenting and publishing are symbiotic activities and that scientist who patent are “more prolific” publishers than those who do not patent.

While Buenstorf found no evidence regarding the positive impact of commercialization income on research productivity, Thursby and Thursby (2011) arrived at a different conclusion. After conducting a series of research studies on the matter, Thursby and Thursby determined that income from licensing caused faculty to do more basic research because they would replace leisure activities, not fundamental research activities, with commercialization activities. Their conclusion at least partially addresses the topic of the next section; the belief that faculty

members' commercial profit motive will outweigh their desire for fundamental research that contributes to the public good.

2.3.3 Moving Away from Fundamental Research

In addition to the openness of research and faculty members' productivity, another commonly discussed ethical consideration for university commercialization is the belief that academics interested in commercialization will shift their focus from traditional faculty work (fundamental/basic research) to more applied work that can result in short-term commercial gains (Larsen, 2011); however, in her review of the commercialization literature, Larsen (2011) was unable to find conclusive evidence supporting this belief. In another analysis, Hicks and Hamilton (1999) found that the level of basic research remained unchanged from 1981 and 1995. This time period is important because, as I previously discussed, the Bayh-Dole Act catalyzed university commercialization activity beginning in the early 1980s.

Importantly, the “mutually exclusive” tone surrounding this belief has also been questioned. After an extensive review of the literature on the matter, Thursby and Thursby (2011) concluded that

“much of the research conducted by faculty, particularly in the life sciences, fits in what is known as “Pasteur’s Quadrant,” being quite fundamental as a basis for further academic research and having immediately obvious commercial applications. For such research, the notion of licensing diverting faculty (that is publication and invention disclosure being mutually exclusive) is, at best, simplistic, and, at worst, misleading.” (p. 21)

From this evidence, it is probable that conversation around the strict separation between “fundamental” and “applied” research is unwarranted, particularly in the context of university commercialization.

2.3.4 The Benefits of Commercialization

While the debate over the place of commercialization in university activities remains important, it is equally important to recognize the benefits of such work for universities, including funding, prestige, education, and social good (McDevitt et al., 2014; Sanberg et al., 2014). In their review of prior commercialization literature, Sanberg et al. (2014) provide

evidence for many of these benefits, as summarized in Table 2, McDevitt et al. (2014) also highlight similar benefits.

Table 2:

Benefits of university commercialization (Sanberg et al., 2014)

<u>Benefit</u>	<u>Description</u>
Increased opportunities for research funding	Access to funding from the NSF I-Corps, Department of Commerce's i6 Challenge program, NIH's National Center for Advancing Translational Science commercialization branding/success can attract philanthropic funds and support fund raising
Access to unrestricted funds for further institutional investment	Increased returns from licensing deals can support both the institution and faculty member
Sustained levels of high scholarship	Faculty with industry connections, which often linked to commercialization activities, are more productive and have a greater impact (published more, in higher impact journals, and cited more).
Increased student success	Provide students exposure to real-world research experiences with societal need Students gain experience with intellectual property management Nurturing students' entrepreneurial spirit
Increased university prestige	Opportunities for university engagement Ability to tangibly demonstrate the universities impact
Enhanced public benefit	University-based innovations such as the hepatitis B vaccine, Google, and FluMist provide a link to additional resources.
Enhanced economic development	From 1997-2007 <ul style="list-style-type: none"> - \$187 B impact on US GDP - \$457 B impact on US gross industrial output - created 279,000 jobs

At the level of the individual faculty member, commercialization activities have been correlated with increased industrial connections (Sanberg et al., 2014), and Bozeman and Gaughan (2011) found that faculty members who work with industry have a greater propensity for producing both social and economic benefit. Evidence of such benefits can be leveraged by the university for branding, recruitment, and fundraising purposes. Industry connections can also support faculty members in their effort to successfully place students after graduation (Lin & Bozeman, 2006). In addition, her study of academics' motivation to commercialize, Lam (2011) found that commercialization activities benefit faculty members themselves by satisfying a range of intrinsic and extrinsic motives, including

- curiosity and the desire for more knowledge,

- the ability to increase their research funding or reputation as an academic, and
- financial reward.

Lastly, Perkmann et al. (2013) found existing studies demonstrating that faculty members believe commercialization can positively impact their reputation as professionals.

Nonetheless, it is not my goal in this project to suggest that all faculty or all universities should engage in commercialization. Rather, I recognize the desire of some faculty and some universities to engage, and I see my work as a chance to explore that engagement in ways that can contribute to our understanding and help inform discussions and debates such as those described here.

2.4 The Need to Better Understand Faculty Experiences with Commercialization

As the previous section discussed, commercialization activities have the potential to provide a broad range of gains for universities, society, and individual faculty. University and policy leaders are acknowledging the benefits of commercialization activities and the need to develop policies, incentives, and professional development opportunities (Larsen, 2011). Despite these realities and faculty members' increasing engagement in the commercialization of university research, the acceptance of faculty members' engagement in university commercialization is still questionable, as evidenced through both the ethical rhetoric and faculty evaluation language.

Based on all of these emerging factors, some scholars call for additional “theoretical and empirical evidence on the underlying processes that govern the commercialization of research and technology across [academic] institution types.” (Markman, Siegel, & Wright, 2008, p. 1402) This is especially true at the “individual level” of the faculty member (Markman et al., 2008). Perkmann et al. (2013), citing an extensive literature review by Rothaermel et al. (2007) echoed this need highlighting that “the [existing] literature on university entrepreneurship [has] neglected the analysis of individual researchers' involvement in the process.” (p. 425)

I have chosen to focus this study on faculty members' experiences with university commercialization because it represents an underutilized, underresearched, and increasingly prevalent of knowledge translation within our universities (Markman et al., 2008; Sanberg et al., 2014). By exploring the individual faculty member level of university commercialization, my

study builds on the existing scholarship to identify new insights critical to our fundamental understanding of university commercialization ecosystems.

2.5 A Systems Perspective of the Faculty Work System

As described in previous sections, past researchers have explored university commercialization activities using a cyclic or phase-based perspective, but few studies have attempted to explore these commercialization activities using a systems perspective. McCoy et al. (2012) acknowledge that there are a combination of factors stemming from both the industry and academic sides that contribute to lack of university commercialization activity. They argue that systems perspectives are necessary that further study the dynamics environments in which commercialization activities occur. To this end, I utilized activity theory during data collection and analysis to enhance my ability to obtain a systems perspective of faculty members' experiences.

2.5.1 Activity Theory – An Overview

Activity theory (AT), developed out of the Soviet cultural-historical school of psychology beginning with Vygotsky, is founded on the premise that cultural artifacts (i.e., technical and psychological tools) mediate human activity (Engeström, 1987). This premise was developed from the work of many scholars² and led to Engeström's model of human activity as depicted in Figure 8.

² For a thorough description of activity theory's evolution from Vygotsky to Engeström refer to Chapter 2 of Engeström's (1987) *Learning by Expanding: An Activity-Theoretical Approach to Developmental Research*.

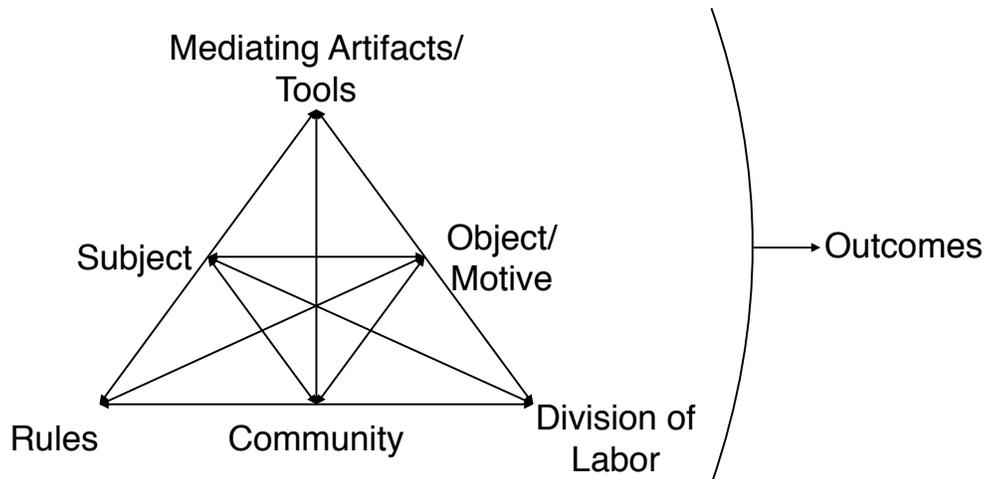


Figure 8: Engeström's (1987, 1989) structure of human activity

Engeström's model represents an *activity system* or the primary unit of analysis of human behavior (Cole & Engeström, 1993) (as cited in (Russell, 1997)). Murphy and Rodriguez-Manzanares (2008) summarize the elements of the activity system in the following way (all are quoted directly from p. 443)

- “The *subject* of an activity system is the individual or group whose viewpoint is adopted.
- *Object* refers to the 'raw material' or 'problem space' at which the activity is directed and which is molded or transformed into outcomes with the help of physical and symbolic, external and internal tools (Engeström, 1999, p. 67). It precedes and motivates activity.
- *Tools* mediate the object of activity. They can be external, material (e.g., a textbook, a computer) or internal, symbolic (e.g., language). Tools take part in the transformation of the object into an outcome, which can be desired or unexpected. They can enable or constrain activity.
- *Community* refers to the participants of an activity system, who share the same object.
- The *division of labour* involves the division of tasks and roles among members of the community and the divisions of power and status.
- *Rules* are explicit and implicit norms that regulate actions and interactions within the system (Engeström, 1999; Kuutti, 1996).”

These six elements of human activity contribute to the production of an *outcome*, or the result of the participant's engagement in an activity system. A key benefit of using activity theory is its ability to facilitate both the exploration of the activity system elements separately as well as the ways elements interact with one another, as shown with the bidirectional arrows in Figure 8.

Moreover, Engeström describes his model as a “root model of human activity” because it possesses the following characteristics (Engeström, 1987, Ch. 2, Triangles of Activity, para. 9):

- the model represents the simplest and smallest unit that maintains the unity and quality of human activity;
- the model does not limit one's ability to analyze historical transformations or change in human activity;
- the model emphasizes the systemic interconnections between the individual and the outside world; and
- the model holds to Vygotsky's cultural considerations in mediated human activity.

This brief description, and particularly the combination of activity theory's potential to represent the simplest quality of human activity while simultaneously emphasizing systemic interconnections, reveals activity theory's potential as a framework to explore individual faculty member's experiences with university commercialization.

Further supporting my use of activity theory to provide an integrated systems perspective, Engeström (1993, 1995, 1999, 2001) provides five principles to support its understanding and implementation.

1. In AT the primary unit of analysis is the activity system (Figure 8), which is a *collective, mediated, and object-oriented system* that generates actions to produce outcomes and reproduce itself.
2. Activity systems are *multi-voiced*, meaning that the many "points of view, traditions, and interests" of the participants should be considered collectively (Engeström, 2001, p. 136).
3. *Historicity*, or the nature in which changes and transformation have occurred both locally and globally over long periods of time, should be considered when using AT.
4. *Contradictions* act as a source of change and development within and among activity systems. Engeström (2001) defines contradictions as "historically accumulating structural tensions within and between activity systems" in order to distinguish contradictions from lesser conflicts or problems experienced in individual actions (p. 137).
5. The contradictions from principle four provide the opportunity for transformation within an activity system. When *historical, multi-voiced contradictions* are identified, the community or communities have the possibility to overcome these contradictions through the development and implementation of change efforts.

Based on these five principles, activity theory supports my study's purpose of enhancing our understanding of faculty members' experiences with university commercialization because it enables my ability to capture and analyze a *collective, mediated, object-oriented, and multi-voiced* university commercialization system that operates in the context of a deep *history* of knowledge translation. This combination of considerations is not only unique to the study of university commercialization but it also supports my ability to identify meaningful supports and challenges and provide useful recommendations for administrators and faculty.

Given the capacity of activity theory to serve as a useful lens, research efforts in a variety of disciplines have called on activity theory and the concept of an activity system as a theoretical basis for systematic studies. These research studies include, but are not limited to educational research, organizational research, and work systems analyses.

2.5.2 Activity Theory in Organizations and Work Systems

Activity theory has been used to study organizations and work systems in a variety of contexts (Artemeva & Freedman, 2001; Engeström, 1993, 2000, 2001; Holt & Morris, 1993). For example, Holt and Morris (1993) used activity theory in an organizational context to analyze the NASA Challenger accident. Their intentions were to familiarize organizational analysts with the potential benefits of activity theory in organizational analysis, which they posit as:

- AT enhances a current and future description of an organization's culture and its components.
- AT provides analysis methods that are likely to positively impact organizational functioning as well as present a systematic view of organizations.

Each of these benefits enhances the value of using activity theory to study faculty work system because I seek to describe faculty members' perspective of the commercialization activity system and to offer recommendations for positively impacting university commercialization.

In the context of healthcare, Engeström has described methods for applying activity theory to studies of work practices and organizations. In an analysis of interviews with 16 doctors, 23 staff, and 85 patients, as well as 85 videotaped consultations each with comments, activity theory was used to analyze the work activities within an entire activity system and identify primary and secondary contradictions within the activity system (Engeström, 1993). While the present study does not attempt to identify contradictions, and instead seeks to better understand faculty members' activity system, Engeström demonstrated activity theory as an effective analysis tool and framework for developmental research in work systems.

2.5.3 Activity Theory in Education

Activity theory is useful for this study not only because of its overall value to work systems, but because of its history of use in educational settings. For example, Blanton, Simmons, and Warner (2001) used AT to study whether teacher preparation programs could influence pre-service teachers' perceptions toward teaching and learning. The researchers used

activity theory to analyze the activity systems of both a pre-service course on teaching and an after school field experience by populating each component of the activity system model with its relevant details. This activity systems analysis was then used to inform the researchers as they revamped the teacher preparation course and designed an after school experience for students and pre-service teachers. This work illustrates how activity theory, and specifically the individual and integrated analyses of activity systems, can improve and inform the development of training programs, and is an effective tool for theoretically grounded research.

In their study of virtual learning environments, Blin and Munro (2008) utilized activity theory to frame a research study that explored how virtual learning environments were being used and could potentially transform teachers classroom practices. The researchers used the activity system model to better understand and illustrate both an activity system for course design as well as the contradictions between the course design activity system and the technological activity system that was currently being implemented. The researchers populated each component of the activity system model with the contradictory relationships between activity system characteristics. This understanding informed their study design and the analysis of their results, specifically those used to determine whether the virtual learning environments were transforming teaching practices and why instructors would use or not use certain features of the technology.

Jonassen and Rohrer-Murphy (1999) explored activity theory's use in the design of constructivist learning environment. While they speak specifically to constructivist learning environments, I believe many of their practices and analysis techniques are applicable to contexts beyond constructivist learning environments. Based on their review of research, they provide the following accepted practices for using activity theory as a lens for analysis:

- Activity theory must be studied in real-life practice with researchers as active participants.
- Activity theory requires a qualitative approach to analysis.
- Activity theory allows a researcher to attempt to improve the outcome of the process being studied.
- The length of research study should capture both the objects of the activity, any changes in the objects, and how the objects relate to the objects of other contexts.
- The researcher should start with broad analysis.
- Researchers should use various sources of data (both in technique and in participant) in order to properly understand all perspectives of the activity system.

There have also been a variety of activity theory studies conducted in the fields of language, writing, and genre research within education contexts (Paretti, 2008, 2013; Powell, 2003; Russell, 1997; Russell & Yañez, 2003). In these studies, it is common for the researchers to use activity theory to justify the need for their exploration and/or to add clarity and impact to their research findings, along with its use for analysis. For example, Paretti (2008) has used activity theory in conjunction with qualitative case study research methods (a combination of student surveys, notes and observations from course sessions, observations of instructor/student meetings, and follow-up interviews) to highlight contradictions between student's activity systems, and the ways in which instructors impact students' development of communication skills. The other studies follow similar form in both their use of activity theory as well as their use of case study and qualitative research methods.

Based on the work system and educational studies described here, activity theory has been used effectively as a framework for exploring human activities (i.e., faculty commercialization) from both a systems and individual perspective. By using data to populate the activity system with its salient characteristics, these researchers were able to perform an in-depth analysis of the activity, and importantly, consider possible improvements to the system. Additionally, these study provide examples and recommendations regarding how activity theory is best implemented – an important consideration for this study's design.

Chapter 3: Methods

The purposes of this study are to 1) enhance our understanding of faculty members' experiences with university commercialization, 2) identify supports and challenges for faculty members who engage in university commercialization and 3) provide recommendations for administrators and faculty interested in realizing the university's third mission. To achieve these goals, I conducted a multi-case study to answer the following questions

RQ 1: How do engineering faculty members at land-grant institutions experience university commercialization?

RQ 2: How do elements of the university system support or challenge engineering faculty members' commercialization experiences?

Drawing on a social constructivist perspective, my case studies focus on faculty members' perceptions of their university commercialization experiences. A case is defined as the collective perspective of faculty members at a given institution regarding their experiences with university commercialization. University documents, websites, and supplementary interviews at each site provide the context for each case. I have illustrated my case definition in Figure 9.

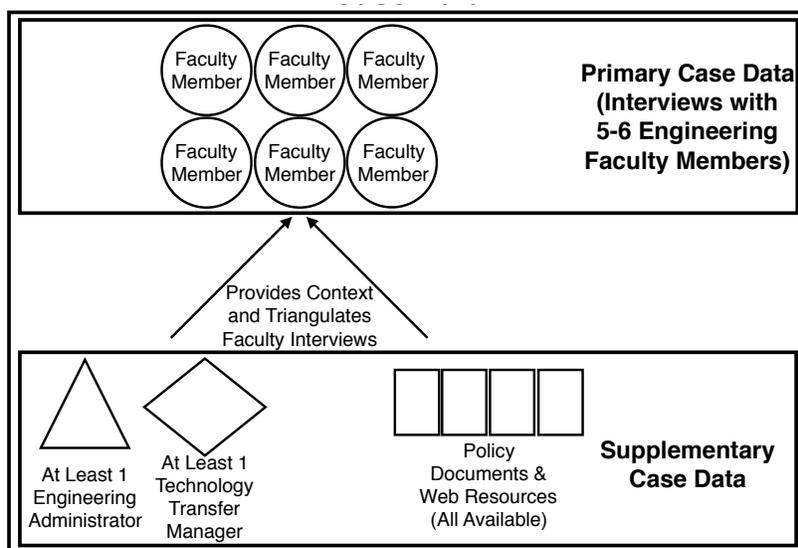


Figure 9: Illustrating my case definition; primary and supplementary data

To address my questions and achieve theoretical and literal replication across cases (Yin, 2014), I selected three land-grant universities based on the institution's entrepreneurial/innovation ecosystem, location, size, research expenditure, rank of the

engineering college/school, and university commercialization activities (e.g., licenses, startups formed, gross licensing income, etc.). I interviewed 5-6 engineering faculty members engaged in university commercialization at each university, collected university commercialization related documentation, and interviewed at least one engineering administrator and one member of the technology transfer office. I used *a priori* and inductive coding to analyze the data, then developed pattern codes for each case and iteratively displayed findings both within and across cases. This analysis process was guided by Miles, Huberman, and Saldaña's (2014) work on qualitative data analysis.

Section 3.1 summarizes the underlying worldview and theoretical framework guiding my research followed by Sections 3.2-3.5 describing the details of my study design. This chapter concludes with discussions of research quality (Section 3.6) and the strengths and limitations of my study design (Section 3.7).

3.1 Epistemology

Table 3 summarizes the epistemology, research focus and methodology guiding my research design.

Table 3:

Research design foundations

<u>Key consideration:</u>	<u>My position:</u>	<u>Description:</u>
Epistemology	Social constructionism	The belief that reality and meaning are jointly and socially constructed with other humans within larger social systems.
Research Focus	Engineering faculty members' commercialization experiences	RQ 1: How do engineering faculty members at land-grant institutions experience university commercialization? RQ 2: How do elements of the university system support or challenge engineering faculty members' commercialization experiences?
Methodology	Case study using <ul style="list-style-type: none"> • Interviews • Document analysis • Deductive/Inductive analysis 	Case studies acknowledge the impact of context, benefit from prior theory, and rely on multiple sources of evidence to complete an in-depth study of complex, contemporary phenomena.

Epistemologically, my study is guided by social constructionism. Willig (2001) describes social constructionism in the following way.

Social constructionism draws attention to the fact that human experience, including perception, is mediated historically, culturally and linguistically. That is, what we perceive and experience is never a direct reflection of environmental conditions but must be understood as a specific reading of these conditions. This does not mean that we can never really know anything; rather, it suggests that there are 'knowledges' rather than 'knowledge'. (pp. 2–4)

Accordingly, I believe that humans construct knowledge through social interactions with other humans and our world. This knowledge is based in the collective, cultural-historical experiences of humans and can therefore exist differently in various social realities. This epistemology shapes my study because it acknowledges and attends to the unique differences that influence each faculty member's university commercialization work system experience. The uniqueness of each experience derives from the convergence of personal (e.g., tolerance for risk and past experience), contextual/technical (e.g., university policies, department culture, and access to mentor networks), and dynamic/environmental (e.g., the market dynamics of the intellectual property) characteristics (Kleiner, 2006). At the same time, sharing and communicating knowledge and beliefs can create a collective social reality among groups of individuals. Thus even as I use AT to explore the system of university commercialization, I do so not from an objective or neutral perspective, but rather from the perspective of the individuals who experience it. My focus is on the meaning they construct regarding their experiences of the system, a focus that aligns with gaps in the research identified in Chapter 2.

Following Creswell (2009), I developed research questions based on social constructionism to explore human experiences; therefore, my study also benefited from what Koro-Ljungberg and Douglas (2008) refer to as an interpretivist perspective. They describe an interpretivist perspective as an approach to research that explores particular experiences/phenomena through interpretation in order to develop a deeper understanding. Crotty (1998) describes an interpretivist perspective as an attempt to understand the social world through cultural and historical interpretations. Research developed from this perspective is typically enacted through qualitative techniques (Borrego, Douglas, & Amelink, 2009; Creswell, 2009; Koro-Ljungberg & Douglas, 2008; Leedy & Ormrod, 2010), and Leedy and Ormrod (2010) list qualitative research as an effective research strategy for the purposes of interpretation—via its ability to “enable a researcher to (a) gain new insights about a particular phenomenon, (b) develop new concepts or theoretical perspectives about a phenomenon, and/or

(c) discover the problems that exist within the phenomenon” (p. 136). In summary, the interpretive perspective aligns with the overall goals of my study, especially my goal to identify supports and challenges within the university commercialization faculty work system.

My epistemology influenced multiple aspects of this study’s research design. First, I employed a multiple case study design because it supported data collection and analysis at both the individual and broader social/historical perspectives. Second, I conducted semi-structured interviews because of this technique’s ability to simultaneously capture individual’s perceptions of a specific phenomenon and the contextual factors relevant to that phenomenon. Once collected and transcribed, interview data also enhanced my ability to interpret each case because the data could be iteratively visualized, interpreted, and triangulated. Third, my case studies benefited from a guiding systems framework (activity theory), which further supported my ability to capture, analyze, and report the individual and social perspectives of faculty commercialization.

3.2 Research Design

Table 4 summarizes my study’s research design, which I describe and justify throughout the remainder of Chapter 3. Briefly, I conducted a multiple-case study of engineering faculty members’ experiences with university commercialization at three land-grant universities. I recruited faculty participants by identifying gatekeepers at each institution, and interviewed faculty members about their commercialization experiences. These interviews were then analyzed using deductive and inductive coding techniques, guided by Engström’s activity system framework.

Table 4:

Overview of research design

<u>Key consideration:</u>	<u>My position:</u>
Case development	Engineering faculty members' experiences with university commercialization at a single land-grant institution
Site selection	Land-grant institutions without medical schools. Other literal and theoretical replication (Yin, 2014) factors such as entrepreneurial ecosystem, location, size, research expenditure, and rank of the engineering college/school as well as overall university commercialization activity of the institution (e.g., licenses, startups formed, gross licensing income, etc.)
Recruitment strategies	<ul style="list-style-type: none"> • Identify gatekeeper at each site • Compile potential participant list • Distribute recruitment email and link to screening survey • Schedule interview
Data collection approaches	<ul style="list-style-type: none"> • Research and collect IP/university commercialization documentation • Conduct semi-structured interviews
Data analysis techniques	<ul style="list-style-type: none"> • A priori coding using activity theory elements, "Supports," "Challenges," "Affect," and "Other" • Inductive coding for insights not capture via the a priori coding. • Follow Miles, Huberman, and Saldaña (2014) approach to iteratively condense, cluster, and display data.

3.2.1 Multiple-Case Study Approach

A study of faculty members' university commercialization experiences is well-suited for a case study approach because the approach supports an in-depth study of phenomenon occurring in a real-world context. As described in Chapter 2, university commercialization activity is growing within academia and occurs at the intersection of personal, university, and industry/market contexts. It can be influenced by personal contextual factors (i.e., family status, financial independence, and prior experience), factors within the university (i.e., resources, rewards, other professional activities, and culture), and factors outside the university (i.e., patent portfolios, access to venture capital, and competitors). A case study approach enables me to complete an in-depth study of a phenomena that occurs across multiple contexts because it leverages collecting and analyzing a variety of data sources to develop each case. It also

encourages the use of guiding frameworks and supports my use of activity theory to simultaneously capture the individual and systems perspectives.

According to Yin (2014) case studies methods are meant to “investigate a contemporary phenomenon (the “case”) in depth and within a real world context, especially when the boundaries between phenomenon and context may not be clearly evident” (p. 16). Because university commercialization represents an activity where the boundary between the phenomenon and the contexts in which it occurs is vague at best, a case study approach is ideal for studying faculty members’ university commercialization experiences. Using case studies, I was able to capture in-depth insights about individual faculty members’ experiences via interviews with individual faculty members, and simultaneously maintain a systems perspective by using activity theory to guide the interview protocol and analysis process. Using a guiding framework helped mitigate the large number of potential variables associated with investigating a phenomenon in context (Yin 2014). Based on its historical use studying human activity and its use in prior case study research, activity theory served this goal well and supported my ability to meaningfully refine the number of potential variables and achieve my study’s goal.

Finally, the multi-case approach allowed me to study participants’ lived experiences in different contexts. As described, university commercialization occurs within a dynamic and boundary-spanning contextual system; therefore, the ability to collect and analyze similarities and variations across cases increased the value of my study’s findings, and provided more robust and compelling evidence for patterns than could have been achieved with a single case (Yin, 2014, p. 57). These benefits are especially useful for seeking insights into common experiences, as in my study, rather than insights into extreme, rare, or critical experiences, which lends itself to single case study design.

3.2.2 Overview of the Study

To achieve the study’s research goals, I implemented a three-phase research process. During Phase 1, the data collection phase, I familiarized myself with the technology transfer, IP, and promotion and tenure policies at each institution; recruited participants; conducted interviews; and collected university commercialization related documentation. Phase 2 represented the *within-case* data analysis phase in which I used both deductive and inductive coding to develop a codebook and condense the data independently for each case. After coding

and data condensation, I developed code clusters and pattern codes for each case and displayed the results using various mechanisms guided by Miles, Huberman, and Saldaña (2014). In Phase 3, I conducted a *cross-case* analysis to identify collective insights and determined the best approach for disseminating the study's overall findings. The remainder of this chapter provides additional descriptions of my research design.

3.2.3 Case Development and Site Selection

As noted earlier, the phenomenon under investigation in this study was faculty members' experiences with university commercialization; therefore, a case is defined as *engineering faculty members' experiences with university commercialization at a particular land-grant institution*. While the distinction is subtle, it is important to note that I am not defining my cases as *Faculty Member Y's experiences with university commercialization at land grant X* or *university commercialization at land grant X*, because this would move the emphasis to a single faculty member's perspective or instead focus on the institution itself, a focus where significant research already exists. My unit of analysis supported my ability to understand how faculty commonly experience university commercialization while avoiding a focus that was too specific (one person's experiences) or too broad (the entire university commercialization system). Importantly, this intentional distinction ensures the study's focus on faculty members' experiences to address the research gap identified in Chapter 2 and aligns with my social constructionist epistemology.

Each case included four data sources, summarized in Table 5. Given my emphasis on faculty experiences, semi-structured interviews with faculty are the primary data source. However, situating my study in the experiences of engineering faculty members does not remove the need to account for important contextual factors. Contextual information for each case was obtained by gathering university commercialization policy documents at the institution, interviewing administrators and technology transfer staff, and researching other sources deemed relevant in relation to university commercialization (e.g., university commercialization activity reports and university commercialization information found on the institution's website).

Table 5:

Case Data Sources

<u>Source</u>	<u>Quantity</u>	<u>Description</u>
Faculty Interviews (*primary data source)	5-6 per institution	Completed semi-structured interviews guided by activity theory to gather participants' experiences with the university commercialization activity system.
Intellectual Property/Promotion & Tenure Documents	1 set per institution	Collected and reviewed university commercialization documentation. <ul style="list-style-type: none"> • Policy documentation (e.g., conflict of interest/commitment policies and disclosure forms) • Website information • University commercialization activity reports (e.g., # of startups, # of licenses)
Administrator Interview	At least 1 per institution	Completed semi-structured interviews to provide context and a triangulation mechanism for faculty members' data.
Technology Transfer Interview	At least 1 per institution	Completed semi-structured interviews to provide context and a triangulation mechanism for faculty members' data.

When developing cases, Yin (2014) recommends cases that allow for both literal replication (similarities between cases that support the researcher's ability to make comparisons) and theoretical replications (intentional differences between cases to explore hypothesized influencing variables or to enhance the breadth of findings). As with many dynamic and contextual human activities, complete literal replication of faculty university commercialization experiences is difficult to achieve because of the number of potential variables influencing the activity. For example, each institution, college of engineering, and engineering department has its own policies, culture, and context that impact faculty members' experiences while participating. Furthermore, each faculty member has a unique combination of background, research agenda, and motivation that impacts their participation in university commercialization. Achieving theoretical replication is equally as difficult, again, due to the large number of potential variables influencing the activity, but also because of how little we currently know about faculty members' university commercialization experiences. For example, researchers have yet to conclusively determine what, if any, contextual factors impact these experiences; therefore, it is currently difficult to develop theoretical replication design criteria. To address these challenges, a balance of literal and theoretical replication was obtained by nesting theoretical replication (based on the institution's entrepreneurial/innovation ecosystem, location, size, research expenditure, rank of the college of engineering, and level of university commercialization activity) within an overall literal replication (based on one field of study at a single type of academic institution).

To achieve a useful level of literal replication, this study was bounded to engineering faculty (one field of study) at land-grant universities that do not have a medical school (one type of institution), as shown in Figure 10.

Variable Reduction During Site Selection

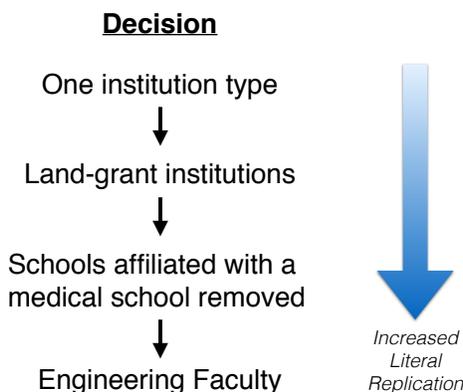


Figure 10: Toward literal replication

Land-grant institutions were chosen because they provide several key commonalities that enhance literal replication: the historical service and outreach/extension mission of the university, the historical emphasis on research-to-practice (although university commercialization was historically unsupported institutionally (Shane, 2004)), the generally high level of research expenditures and productivity, and the relatively rural locations of the land-grant institutions. However, land-grant universities with medical schools were excluded to help ensure the study's focus remained on engineering university commercialization. Universities with medical schools generally showed higher total research expenditures, more institutional income due to university commercialization, and more university commercialization activity (based on 2013 AUTM Licensing Survey Data (AUTM, 2014)) – activity that may be linked to an atypical, small number of commercialization successes in the medical sector. The magnitude of the income differential suggests that medical school activity may enhance commercialization resources (e.g., funding for patenting) in ways that are markedly different. Removing universities with medical schools, as noted, thus maintained the focus on engineering and limited the potential data collection sites to those that could be considered in peer institutions by most engineering and science land-grant faculty and administrators. Engineering faculty were selected

to further mitigate contextual variation and provide a participant pool with a strong record of industry funding, patenting, and commercialization experience. Additionally, little is known about the university commercialization experiences of engineering faculty members, supporting a study that focuses on them directly.

While I am positing that the commonalities among engineering faculty at land-grants universities without medical schools support literal replication, there are obviously differences in land-grant institutions, engineering departments, and individual engineering faculty. To account for these differences and achieve a useful level of theoretical replication, I “nested” variation within the similar characteristics described previously. “Nesting” in this sense means I selected land-grant institutions that varied with respect to their entrepreneurial/innovation ecosystem, location, size, research expenditures, rank of their engineering college or school, and general level of university commercialization activity at the institution. As shown in Figure 11, data from the 2013 Association of University Technology Managers STATT survey, the 2015 U.S. News & World Report Rankings, and the 2013 ASEE’s Engineering Profiles provided bounds for these variables revealing a wide range of values within each category.

**Variables Considered During Site Selection
(Theoretical Replication)**

Variable	Range of Values*
CoE Size	
· Faculty (2013 ASEE Profiles)	51 - 375
· Grad Students (2015 US N&WR)	79 - 3333
CoE Rank (2015 Engineering Graduate)	#8 - #129
CoE Research Expenditure (2015 US N&WR)	~\$3.4MM - ~\$249MM
TTC Activity (Avg. 2011-2013 AUTM Data)	
Invention Disclosures Filed per Year	10 - 226
Licenses Generating Income per Year	11 - 482
Startups Formed per Year	0 - 6
Gross Licensing Income per Year	~\$.019MM - ~\$10.1MM

Figure 11: Some considerations for theoretical replication.

(Note: Ranges are for all possible land-grants without medical schools)

As one may suspect, colleges/schools of engineering with higher levels of research expenditure typically also had higher values in the other categories as well. This resulted in sites that were

generally high, medium, or lower in most if not all characteristics considered. Individual differences among faculty were accounted for by conducting interviews with multiple faculty members at each land-grant site and aggregating the data using the guiding systems framework. The final 3 sites were selected based on the considerations described previously, discussions with university commercialization stakeholders³, and considerations of access to potential participants.

3.3 Recruitment Strategies and Participants

3.3.1 Faculty, Administrator, and Technology Transfer Recruitment

To construct each of the three cases studies, I recruited engineering faculty members with university commercialization experience at the selected land-grant university. Existing professional contacts were used to gain access to a gatekeeper (an engineering or entrepreneurship center administrator) at each institution. Identifying gatekeepers at each institution was important because it supported the identification of potential participants, the distribution of the recruitment survey, and the likelihood of having participants complete the screening survey. After identifying a gatekeeper, one of two strategies was used to recruit faculty participants. At two sites, engineering administrators forwarded my recruitment email (Appendix B) to all faculty within the engineering college or school. At the third site, the gatekeeper helped compile and review a list of potential participants and I emailed each participant directly. The recruitment email included a link to a basic screening survey (Appendix C). The survey served multiple purposes. First, it helped to confirm that participants, in fact, did have university commercialization experience at the relevant site. Second, it provided confirmation that the participant was willing to be interviewed and the necessary contact information needed to schedule the interview session. The screening survey was administered using the Virginia Tech IRB-approved online Qualtrics software platform. I interviewed all individuals who responded to the survey, had commercialization experience, and were willing to be interviewed.

I also recruited an administrator within each engineering college/school (e.g., a Dean or Associate Dean) and an employee of the technology transfer office (TTO) at each institution

³ Elizabeth Tranter (Associate VP for Research Planning – Virginia Tech Office of the Vice President for Research and Innovation)
Anthony Boccanfuso (Executive Director of the University-Industry Demonstration Partnership)
Jack Lesko (Associate Dean for Research and Graduate Studies in the Virginia Tech College of Engineering)

directly via email (see Appendix D). My goal was to recruit a TTO employee that could speak directly to engineering faculty experiences with university commercialization (e.g., an employee that oversaw disclosures from at least one engineering department). In most cases, potential participants were identified at the recommendation of each institution’s gatekeeper. In a few instances, no recruitment email was necessary as the gatekeeper and administrative/TTO participant were one and the same.

3.3.2 Sample

Table 6 provides a breakdown of the total data collected at each institution. At all sites, I was able to successfully recruit at least 5 engineering faculty participants, for a total of 17 faculty participants. I was also able to recruit both a leader within the engineering college or school administration and a TTO employee at each site, resulting in a total of 24 participants.

Table 6:

Total data collected

	<u>Engineering Faculty</u>	<u>Engineering Administrator</u>	<u>Technology Transfer Employee</u>	<u>Documents (web pages, policy documents, guides)</u>
<u>Case 1</u>	6	2	1	~23
<u>Case 2</u>	6	1	1	~14
<u>Case 3</u>	5	1	1	~34
<u>Total</u>	17	4	3	~71

Table 7 provides a demographic breakdown for the total engineering faculty participants in the study by discipline, academic rank, and sex. To protect participants’ anonymity, I have intentionally reported these demographics in the aggregate, rather than by case.

Table 7:

Faculty participant demographics

By Engineering Discipline		By Faculty Rank		By Sex	
	Number of participants		Number of participants		Number of participants
Agricultural/ Biological Eng.	1	Assistant Professor	2	Female	1
Biomedical Eng.	3	Associate Professor	7	Male	16
Chemical Eng.	1	Full Professor	6	Total	17
Civil/Environmental/ Structural Eng.	1	Distinguished Professor	1		
Computer Science	1	Emeritus Professor	1		
Electrical/ Computer Eng.	6	Total	17		
Engineering Education	1				
Fundamental Sciences	1				
Industrial & Systems Eng.	1				
Nuclear Eng.	1				
Total	17				

3.3.3 Participant Protection

Due to the nature of the phenomenon under study and the need for literal and theoretical replication, I have protected participants' anonymity and confidentially in multiple ways. While many of these practices are commonplace in research studies involving human subjects, the combination of a focus on engineering faculty members and the specificity of faculty members' university commercialization activities (e.g., company names, products/technologies described, business partners and mentors, etc.) required additional protection measures developed in consultation with the Virginia Tech Institutional Review Board and more experienced qualitative researchers. Such practices included

- i) The addition of the following item on the study's consent form.
I would like to review my anonymized interview transcript and documentation prior to data analysis. ___ Yes ___ No
- ii) The anonymization of all transcripts to remove names, titles, company names, and the specific details of products or technologies.

- iii) Member checks with participants to ensure that their data accurately portrayed their experiences/insights and they felt adequately protected.
- iv) The disaggregation of participants' demographic information from their university commercialization experiences/insights after analysis.

3.4 Data Collection

As outlined previously, I collected four types of data at each site: 1) interviews with engineering faculty, 2) interviews with administrator, 3) interviews with technology transfer employees, and 4) document/policy data. This section discusses the data collection procedures for each of the four types of data collected.

3.4.1 Interviewing and Interview Protocols

Interviewing was the primary data collection method based on my epistemology, my focus on faculty perceptions, and interviewing's acceptance as an effective technique in qualitative research (Borrego et al., 2009; Case & Light, 2011; Creswell, 2009; Leydens, Moskal, & Pavelich, 2004; Seidman). Rossman and Rallis (2012) provide five rationales for using in-depth interviews:

- To understand individual perspectives.
- To deepen understanding.
- To generate rich, descriptive data.
- To gather insights into participants' thinking.
- To learn more about the context. (p. 17)

These rationales are particularly salient to my proposed research study because I sought to better *understand* engineering faculty members' university commercialization experiences from their *individual perspectives*. Interviews also allowed the participants to both *describe their thinking* in detail and provided *contextual insights* surrounding their experiences with university commercialization. Interviewing also allowed me to prompt for *deeper understanding* and seek clarification when needed.

Data collection required two interview protocols, one for the engineering faculty members and a separate protocol for the engineering administrators/technology transfer employees. The faculty protocol was designed to elicit the participants' perspectives regarding their university commercialization activity systems. As a semi-structured interview with questions and follow-up prompts, the protocol was grounded in activity theory to capture the systems perspective of each participant's commercialization activity, while also allowing for

conversation and insights to emerge throughout the conversation. Table 8 details the faculty interview protocol.

Table 8:

Faculty interview questions and anticipated contribution of the data

<u>Interview Questions and Prompts</u>	<u>Activity System Component</u>	<u>Anticipated Contribution</u>
State your professional title(s) and briefly describe your goal(s) as a faculty member.	AT: Person	Background/Context, RQ 1
Can you give me a short overview of your career timeline and where your university commercialization activities fit in? (sketch?)	AT: Person	Background/Context, RQ 1
Now I'd like to talk in a little more detail about your university commercialization activities. Can you describe them in more detail? [If they have more than one on the timeline, ask which one they want to start with]	None directly	Background/Context
What was your role during your university commercialization experience?	AT: Community AT: Division of Labor	RQ 1
Who else was involved in your university commercialization activity and what roles did they play?	AT: Division of Labor	RQ 1 RQ 2
Why did you decide to engage in university commercialization?	AT: Object	RQ 1
What were the anticipated and actual outcomes of engaging in university commercialization? <ul style="list-style-type: none"> • Would you consider this experience a success or failure? 	AT: Outcome	RQ 1
Did anything impact (positively or negatively) your ability to participate in university commercialization? <ul style="list-style-type: none"> • <i>Documents</i> • <i>Peers/colleagues</i> • <i>References/Trainings</i> • <i>Institutional Resources (TTO)</i> 	AT: Mediating Artifacts AT: Community AT: Division of Labor	RQ 1 RQ 2
What policies, guidelines, rules (official or culturally "accepted") governed your engagement with university commercialization? <ul style="list-style-type: none"> • <i>Institutional</i> • <i>Departmental</i> • <i>Research Lab/Center</i> 	AT: Rules AT: Mediating Artifact	RQ 1 RQ 2
Has your university commercialization experience impacted your professional career? If so, how? <ul style="list-style-type: none"> • <i>Has your research, teaching, service, advising, etc. changed as a result of participating in university commercialization? If so, how?</i> 	AT: Outcomes AT: Person	RQ 1
If you were giving university commercialization advice to another faculty member at [LAND-GRANT], what would you tell them?	AT: Object	RQ 2
Are there any particular stories or anecdotes that stand out in your mind that would help me understand your university commercialization experiences as a faculty member?	Catch-all for additional insights.	All
Are there any particular faculty members at [LAND-GRANT] that I should talk to? Would you be willing to introduce me (via email) or can I use your name when contacting them?	Used to snowball sample additional participants.	

Like the faculty interview protocol, the administrator and technology transfer protocol (shown in Table 9) was semi-structured and grounded in activity theory; however, rather than seeking faculty member's individual university commercialization experiences, this protocol captured the administrator/technology transfer participant's perspective of faculty

commercialization at the institution. I used the data from these interviews for case context and to triangulate the faculty participants' data at each institution.

Table 9:

Administrator/Technology transfer interview questions

Interview Questions/Prompt	Activity System Component
State your name and professional title(s)	None
Have you participated in university commercialization? If so, please describe the university commercialization activity or activities in which you've participated.	None
How would you describe the university commercialization climate within engineering and the institution? Are faculty encouraged to commercialize technology? Are faculty discouraged from commercializing technology?	AT: Rules AT: Person
Why do engineering faculty at your institution commercialize technology?	AT: Object AT: Outcomes AT Person
What are the biggest challenges engineering faculty face when attempting to commercialize technology?	Challenges
How do the P&T and reward systems impact engineering faculty members' participation in university commercialization?	AT: Rules
What tools and people impact participation in university commercialization activities? (positively or negatively) • Documents • Peers/colleagues • References/Trainings • Institutional Resources (TTO)	AT: Tools AT: Community
What policies, guidelines, rules (official or culturally "accepted") govern engagement with university commercialization? • Institutional • Departmental • Research Lab/Center	AT: Rules
How does participating in university commercialization interact with faculty members' other professional activities (positively or negatively)? • Teaching • Research • Service • Advising • Managing Lab	AT: Division of Labor
If you were giving university commercialization advice to a faculty member at [LAND-GRANT], what would you tell them?	Recommendations
Are there any particular stories or anecdotes that stand out in your mind that would help me understand university commercialization experiences for faculty members at [LAND-GRANT]?	Catch-all for additional insights.
Are there any particular faculty members at [LAND-GRANT] that I should talk to? Would you be willing to introduce me (via email) or can I use your name when contacting them?	Used to snowball sample additional participants.

Both protocols began with general questions about participants' background and their experience with university commercialization. Then, the protocols moved into questions about the faculty university commercialization activity/work system at the participant's institution. At this point, the flow of each interview was unique. In some faculty interviews and the majority of the admin/tech transfer interviews, I guided the participant sequentially through the questions, prompting them as needed. In other faculty interviews, participants discussed elements of the

commercialization work system in varying orders as they described their experiences and I dynamically restructured the interview to ensure I addressed all questions. Some participants used specific experiences from the past to discuss university commercialization and others spoke more generally. Finally, I ended all interviews with the advice, anecdotes, and snowball recruitment questions. Overall, the semi-structured and dynamic nature of these protocols supported my collection of both the phenomenon (i.e., direct explanations, meaning, and interpretations from the participants' perspective) and the context of participants' university commercialization experiences.

I piloted both protocols prior to beginning the study's official data collection by interviewing four faculty members at one institution. After these interviews, I solicited feedback from the participants regarding any confusing questions, challenges with the flow of the interview, potential gaps in coverage, and improvements with my interviewing style. Then, I performed a high-level analysis of the interviews to gauge their effectiveness and modified the protocols as needed. The protocols required few changes as they proved effective at capturing relevant data needed to answer the study's research questions. Because these pilot interviews capture usable data, I utilized them to develop one of the study's cases.

3.4.2 University Commercialization Policies and Related Documents

Prior to interviewing participants at each institution, I established an initial case context by reviewing university promotion and tenure policies, university commercialization policy documents, and the technology transfer website. To collect institutional policy documentation, I first collected any data publically available through the institution's and engineering college/school's website by downloading documents or converting webpages into PDF documents. This data was organized and indexed by institution and website location (e.g., Office of Research, Technology Transfer Office, College of Engineering). After interviewing the faculty, administrators, and technology transfer participants, I obtained any missing documentation or documentation that was deemed important by participants and added that documentation to the repository for each site. The counts listed in right-most column of Table 6 represent an approximate number of documents obtained at each site. I used these documents to understand and describe each case's context, but they also served as tools to mediate the

interviews and triangulate other data sources (e.g., confirming insights or identifying discrepancies during analysis).

3.4.3 Data Management

The study received approval from the Virginia Tech Institutional Review Board prior to data collection (VT IRB #15-008). Participant confidentiality and anonymity was maintained using approved research practices: assigning pseudonyms; physically separating data, participant lists, and any keys linking data to participants' identities; password protecting computers and backup disks/accounts; and storing all materials in a locked office or filing cabinet. The interview sessions were audio recorded and transcribed verbatim for analysis. In addition to the interview transcripts, field notes (interview notes and post-interview reflections) were transcribed and used during analysis. These files were added to any policy-related documents and each case was organized and stored individually.

3.5 Data Analysis

My analysis strategy followed Miles, Huberman and Saldaña's (2014) approach to qualitative analysis as outlined in Figure 12. Figure 12 also summarizes the quality measures used throughout my analysis. Though I describe the steps separately and sequentially in the following sections, the process itself is highly iterative (Miles et al., 2014), as highlighted in Figure 12.

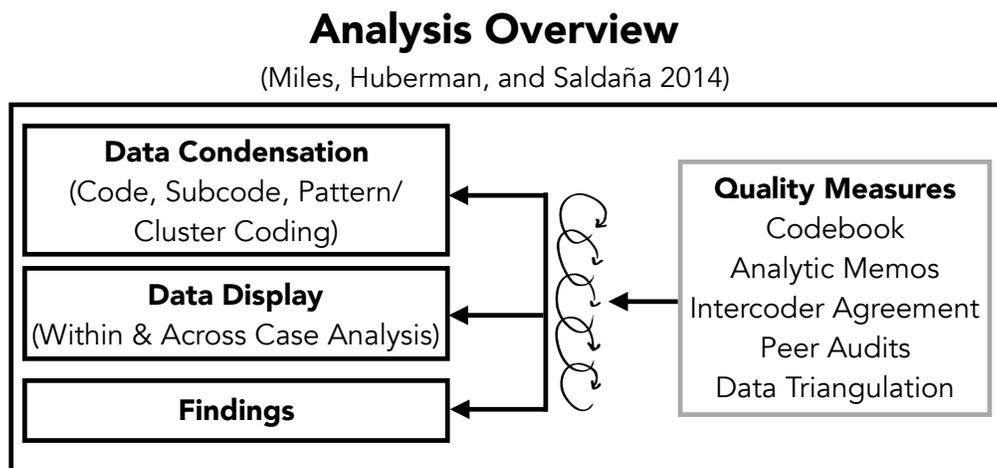


Figure 12: Analysis overview and quality measures

3.5.1 Data Condensation

To condense the verbatim interview transcripts into data relevant to my research questions, I used the qualitative data analysis software package MAXQDA to code both deductively and inductively. My coding process is outlined in Figure 13.

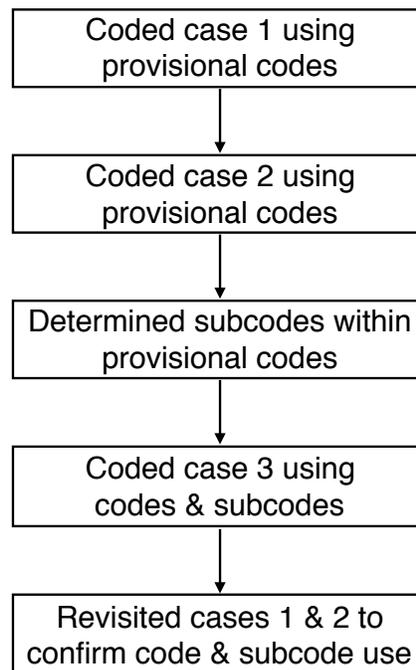


Figure 13: Coding process

I began by deductively coding two of the three cases using the seven activity system elements along with the codes for “Supports,” “Challenges” and “Affect” as my provisional codes (Rossman & Rallis, 2012). A description of these provisional codes is located in Table 10.

Table 10:

Provisional codes

Source	Code	Used to capture insight regarding...
Activity theory	Person	the participant (e.g., having industry experience)
	Object	why faculty are motivated to do university commercialization (e.g., impact and product development)
	Tools/Artifact	tangible items that help participants do university commercialization (e.g., SBIR grants)
	Rules	explicit or implicit norms that regulate action (e.g., promotion and tenure)
	Community	other participants directly or indirectly involved in university commercialization (e.g., tech transfer employees and colleagues)
	Division of Labor	the division of tasks and roles among members of the community (e.g., faculty members file invention disclosures)
	Outcome	the products or results of doing university commercialization (e.g., patents and startup companies)
	Contradiction	a fundamental conflict or situation where faculty must decide between to conflict options (e.g., commit time to university commercialization or to research)
RQ 2	Supports	factors that make doing university commercialization easier (e.g., having tenure)
RQ 2	Challenges	factors that make doing university commercialization harder (e.g., a department culture that doesn't value university commercialization)
Advice from other qualitative researchers	Affect	expressions of affect regarding university commercialization activity (e.g., "I find university commercialization very interesting.")

During deductive coding, I also captured relevant insights that fell outside the initial codes, and coded these data segments as "Other" for further analysis. Following the provisional coding of these cases, I used inductive coding to determine subcodes within each provisional code (Miles et al., 2014). In this step, I analyzed the provisionally coded segments to identify potential groupings that could form subcodes. For example, within the code "Rules" several possible subcodes emerged

- Supported by university leaders
- The technology transfer office controls everything
- Not a "required" academic activity
- General culture
- Partnerships
- Intellectual property and patenting
- Reward system (e.g., promotion and tenure)
- Overhead
- Formal documents/processes
- Conflict of interest & commitment
- Confidentiality
- General

- Must spin out of the university
- Recreating the wheel
- Commercialization terminology

After determining subcodes within each provisional code, I then used the provisional codes and subcodes to code case 3. Finally, I revisited the first two cases to confirm the use and appropriateness of the codes and subcodes.

The combination of deductive and inductive coding supported my analysis in multiple ways. The provisional codes offered a framework to initially anchor the analysis process. The use of provisional codes has been described by other scholars as directed content analysis (Hsieh & Shannon, 2005), and using it enhanced my ability to: (a) discover and describe themes and experiences; and (b) explore the relationships between themes and experiences (Polkinghorne, 1995)—both goals of my study. The inductive techniques (via both the “Other” code and the development of subcodes) helped overcome a deductive approach’s primary limitation—missing relevant insights that the provisional codes fail to capture.

3.5.2 Pattern/Cluster Coding

After condensing the data, I developed pattern codes or code clusters to reduce the number of total subcodes under consideration and refine my analysis into more meaningful categories/themes, causes/explanations, relationships, or theoretical constructs (Miles et al., 2014). To develop pattern codes/themes, I analyzed subcode data within each case to determine consistency, explored relevance, and evaluated the essences of the subcode. Next, similar subcodes were grouped together (or clustered) and analyzed to determine potential patterns/themes. As mentioned previously, this process is highly iterative and often requires coded segments to be iteratively grouped, analyzed, displayed, recoded, and reviewed.

As shown in Table 11, after completing this process for the “Rules” category, I develop three themes from participants’ data: *Attitudes*, *Formal University Rules*, and *Promotion & Tenure*.

Table 11:

Patten Codes/Themes for the provisional “Rules” code

<u>Pattern/Theme</u>	<u>Subcodes</u>
Attitudes	Supported by university leaders
	TTO controls everything
	Not a "required" academic activity
	General culture
Formal University Rules	Partnerships
	IP & Patenting
	Reward System (e.g., P&T)
	Overhead
	Formal documents/processes
	Conflict of interest & commitment
	Confidentiality
Promotion & Tenure	No subcodes, but strongly expressed as both Attitudes and Formal University Rules
No Pattern/Theme*	General
	Must spin out of the university
	Recreating the wheel
	Commercialization terminology
*due to lack of evidence	

The *Attitudes* and *Formal University Rules* these themes are comprised of multiple subcode clusters that provide evidence for a meaningful pattern within the data. For example, coded segments within the *Formal University Rules* theme provide evidence that formal rules are important and impact faculty members’ university commercialization experiences. Notably, *Promotion & Tenure* began as a subcode, but was so strongly expressed by participants as both an attitude and formal rule that it became a theme on its own. I completed this process for each of the activity system elements as well as the *Supports*, *Challenges*, *Affect*, and *Other* categories.

3.5.3 Data Display

After determining the pattern codes or themes within each category (e.g., the activity system elements, Supports, Challenges, Affect), I displayed each case’s themes using a variety of approaches. One approach was developing an activity system diagram for each case (see Appendix E). As with prior analysis steps, this process benefited from being highly iterative and I developed, reviewed, and refined a variety of data displays. Eventually, this within-case analysis process resulted in a set of themes for each case (Miles et al., 2014; Yin, 2014) describing the collective faculty experience with university commercialization at that institution.

Next, I conducted a cross-case analysis to determine similarities and differences between the cases. Again, this process benefited from the iterative display, review, and refinement of data. For example, across cases I displayed how many of the participants at each case discussed a particular theme and explored how they discussed the themes. I used similar analyses to explore both consistencies and inconsistencies across cases. Overall, the within- and across-case analyses provided my study's final results (Chapters 4 and 5).

3.6 Quality Measures

Throughout the design and completion of my study, I enhanced the study's quality by utilizing a range of proven design, credibility⁴, dependability⁵, and trustworthiness⁶ techniques. These techniques included

- developing a qualitative codebook,
- creating an audit trail and analytic memos,
- partnering with other researchers for intercoder agreement and peer audits,
- triangulating data sources, and
- acknowledging my biases.

Collectively, these techniques enhanced the study by increasing confidence regarding the meaning and use of the codes, limiting potential researcher bias, and allowing other researchers to evaluate the data relevant and the study's findings. In the sections that follow, I describe each of the bulleted quality measures in more detail.

3.6.1 Codebook Development

As previously described, Table 10 (along with a general "Other" code) served as my initial codebook. As coding progressed, I developed and refined this codebook using the process illustrated in Figure 14.

⁴ "the relative truth value of qualitative findings and interpretations" (Leydens et al., 2004, p. 70)

⁵ "the consistency of research findings" (Leydens et al., 2004, p. 70)

⁶ "the accurate representations of settings, events, and participants' perspectives" (Leydens et al., 2004, p. 70)

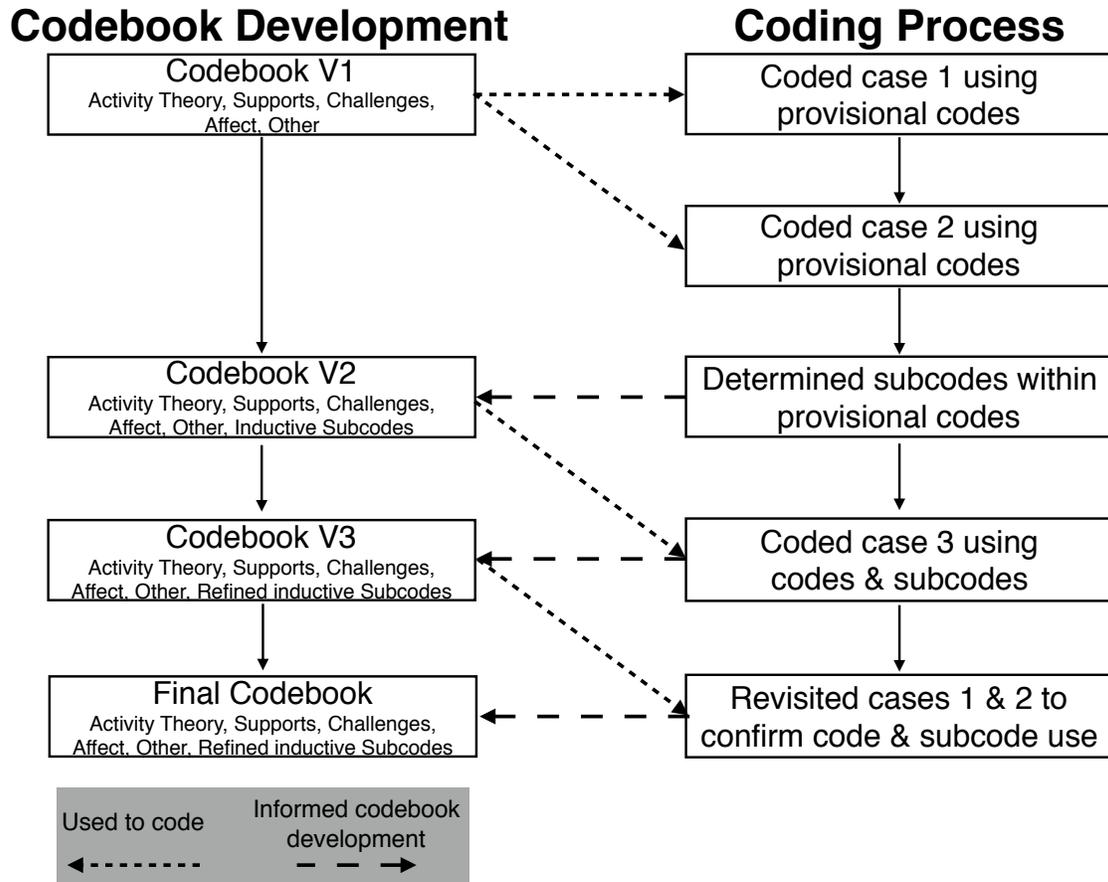


Figure 14: Codebook development process

Starting with two sets of case interview data and the initial codebook (Codebook V1), I completed a round of deductive coding. Next, I revisited the coded data using MAXQDA, grouped similar coded segments, and inductively developed subcodes. This inductive process expanded the codebook to include the newly developed subcodes (Codebook V2). Then, I used this expanded codebook to code the third case, allowing the deductive and inductive coding for this case to refine and further expand my codebook (resulting in Codebook V3). I then revisited cases one and two using Codebook V3 to ensure that my coding was consistent and accurate across all three cases; however, few if any changes were necessary. This process resulted in a final codebook (see Appendix F). I now had both a fully expanded codebook that I used during peer auditing and intercoder agreement quality checks. (Note: As shown in Figure 15, refinements to the codebook were made during peer audits and intercoder agreement, but these refinements were minimal.)

3.6.2 Analytic Memos

My study utilized analytic memos, or short notes capturing “insights, potential themes, methodological questions, and links between themes and theoretical notions” (Rossman & Rallis, 2012, p. 287), because they ensured that my interpretations were not lost over time, supported the development of findings, and enhanced the peer audit process. Overall, these analytic memos serve as an additional source of credibility, dependability, and trustworthiness both for the current study and for follow-up research studies.

3.6.3 Intercoder Agreement and Peer Audits

Throughout this process, I worked with multiple researchers to establish intercoder agreement by coding/displaying a subset of the data and discussing (1) the use of the codes/subcodes, (2) opportunities to add or reduce the overall number of codes/subcodes, and (3) the clarity and accuracy of the codes/subcodes. Figure 15 details when formal quality measure took place during my coding process; however, there were many other less formal audits and opportunities for agreement and feedback throughout the study. On many occasions throughout the study, members of my research group, other engineering education researchers, my doctoral committee members, and my advisor audited my study’s methods, themes, visualizations, and findings. Other researchers also offered critique, provided feedback, and evaluated both the process and the outcomes of the study. As shown in the figure, I performed intercoder agreement activities twice, obtained feedback from my research group twice, and had two update meetings with my doctoral committee.

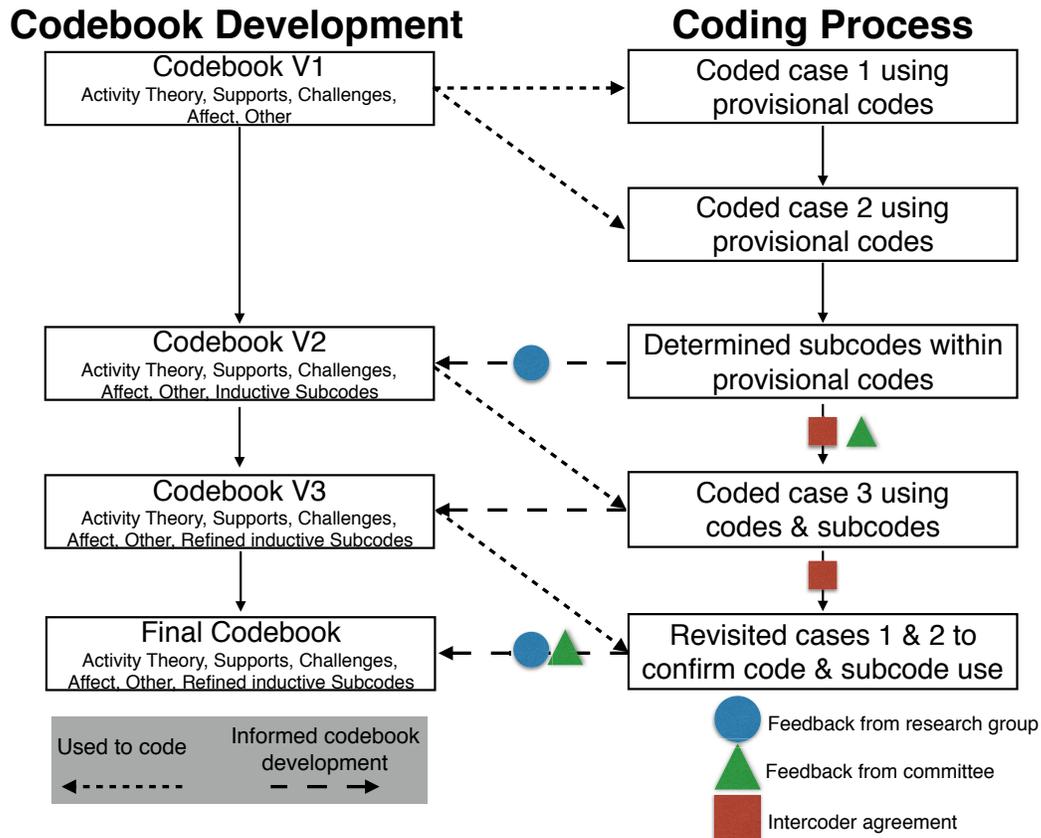


Figure 15: When Intercoder agreement and feedback occurred

3.6.4 Data Triangulation

An important quality measure for this study was comparing the faculty perspective with the administrative/TTO perspective and the university documentation/resources because I was able to triangulate the collective faculty data with other case data at each institution. To complete this triangulation, I analyzed the administrative/TTO interviews after developing my provisional findings. This process enhanced the quality of the study's results and contributions as it confirmed many of the faculty members' insights and revealed instances where beliefs differed. Importantly, this data, particularly the documentation, also provided necessary university context that enhanced the quality and efficacy of the interviews.

3.6.5 Researcher Bias

In addition to the credibility, dependability, and trustworthiness measures described above, protecting against my own bias was also important. A first step toward overcoming potential researcher bias is to acknowledge and communicate my preconceptions associated with the study and research questions. I believe that university commercialization activities represent a necessary, underutilized, and, at times, unsupported set of university activities. These beliefs are especially true in regards to the increase in innovation and entrepreneurship education activities emerging on campuses. While I do not believe that every faculty member “must” or even “should” participate in a university commercialization experience, I do think that faculty members, their graduate students, the undergraduate students taking their courses, and society would benefit from additional university commercialization activities because these activities provide experience managing uncertainty, solving open-ended problems, and thinking in real-world (non-academic) ways. I also believe that there are opportunities for change in the current administrative systems of universities (i.e., cultures, structures, policies, etc.) that would enhance, both in quality and quantity, faculty participation in university commercialization. Finally, a major motivator for designing this study is to illuminate faculty members’ university commercialization participation experiences. Acknowledging and communicating these beliefs is a reflexive action that allows fellow researchers to hold me accountable concerning potential biases.

One of the more likely places for my bias to encroach into my study was during my interviews with faculty. My interest in and perceived value of university commercialization activity allowed me to connect with faculty who also valued participating in university commercialization activities. This helped me establish rapport with faculty and, in turn, collect their honest perspectives regarding their university commercialization experiences. I took great care (e.g., using a semi-structured interview protocol) not to project any biases onto my participants so they would feel comfortable to openly answer my questions and describe their experiences. One approach I used was avoiding the use of leading questions and, instead, asking general question that encouraged participants to provide their own explanations. Piloting my interview protocols helped me recognize places where my biases were likely to emerge or instances during interviews where I needed to pay particular attention not to project my bias onto my participants or lead them when questioning.

During data analysis, I remained open to all possible explanations for how faculty experience university commercialization activities. For example, one finding that I did not anticipate was that some faculty members, even those who frequently participate in university commercialization, do not want to do certain aspects of university commercialization. For example, their motivation for university commercialization participation did not outweigh their need to avoid putting their other academic activities at risk of failure. My data collection and analysis methods were successful in capturing these and other unanticipated points of view.

Finally, my research methods mitigated the influence of my biases. I remained reflexive with my committee and fellow researchers throughout the study and kept an audit trail of my decision making during the entire process (Patton, 2002; Seidman, 2006). Reflexivity and the audit trail made my research process and interpretive thinking explicit, allowing participants and other researchers to question and call out potential sources of bias.

3.7 Strengths and Limitations

In case study design, Yin (2014) recommends cases that allow for both literal replication (predicts similar results) and theoretical replications (predicts anticipated contrasting results). I believe three cases with 5-6 faculty interviews in each case achieved these recommendations. Literal replication was difficult to achieve because faculty university commercialization activity occurs in a dynamic context with individual personalities, other professional activities, and many systemic variables. I bound my study to engineering faculty (one domain) at land-grants universities (one type of institution) and aggregated faculty experiences within each case (as opposed to making each individual their own case). These design decisions strengthened my ability to achieve literal replication. Theoretical replication was also achieved because I acknowledged that although commonalities across land-grant institutions make them a recognizable grouping, the differences in institutional context (i.e., mission/vision, culture, rewards system, and structure), location, and history with university commercialization could have some effect on engineering faculty university commercialization experiences. My decision to select institutions based on the factors previously described allowed for these elements to emerge within the data, if relevant.

Despite these strengths, my research methods had limitations. One limitation of my case study design is only having three cases in my multi-case design. This limitation is largely due to

resource constraints. Yin (2014) recommends 6-10 cases in a multi-case design and completing 6+ cases would support my ability to make stronger recommendations. Another limitation of the study is the fact that only a small subset of the faculty members with university commercialization experience participated at each institution. Although I utilized triangulation measures to help overcome this limitation, my sample may have a skewed perspective if compared to other faculty members who commercialize. Lastly, not all study participants were actively participating in university commercialization at the time of their interview, and my interviews asked participants to reflect on their commercialization experiences. Therefore, the time gap between participants' last commercialization experience and the interview may have impacted their recollection of or beliefs about their experiences.

For these reasons, I am limited to preliminary recommendations and offer my findings to support future, more extensive studies of faculty experience with university commercialization. Considering the little we currently know about faculty members' university commercialization experiences and the limited discussion of individual-level university commercialization experiences in the literature, my study provides a baseline to develop further while still providing useful recommendations for faculty and administration to consider.

Chapter 4: Findings

One purpose of this study is to enhance our understanding of engineering faculty members' experiences with university commercialization. Accordingly, this chapter answers the study's first research question:

RQ 1: How do engineering faculty members at land-grant institutions experience university commercialization?

In order to answer this question, I first provide a contextual description for each institution (Section 4.1). These contextual descriptions situate the findings. In Section 4.2, I describe the findings for RQ 1 using Engström's activity system model and the themes developed during my analysis. Figure 17 uses the activity system framework to summarize my findings by visually aggregating the cross-case similarities of faculty participants' perspectives of the commercialization work system. I then provide in-depth descriptions and examples for each for each theme. Lastly, in Section 4.3, I highlight the cross-case differences between faculty members' descriptions of the university commercialization activity system.

4.1 Commercialization Process and Institutional Contexts

As noted in Chapter 3, the three data collection sites were all land-grant institutions without medical schools, each with a historic focus on outreach and extension. Unsurprisingly, at the time of data collection all sites had dedicated patenting and licensing (technology transfer) offices as well as resources for new venture development activities, and the general commercialization process was similar at each site. As outlined in Figure 16, faculty members begin a university commercialization activity by submitting an invention disclosure.

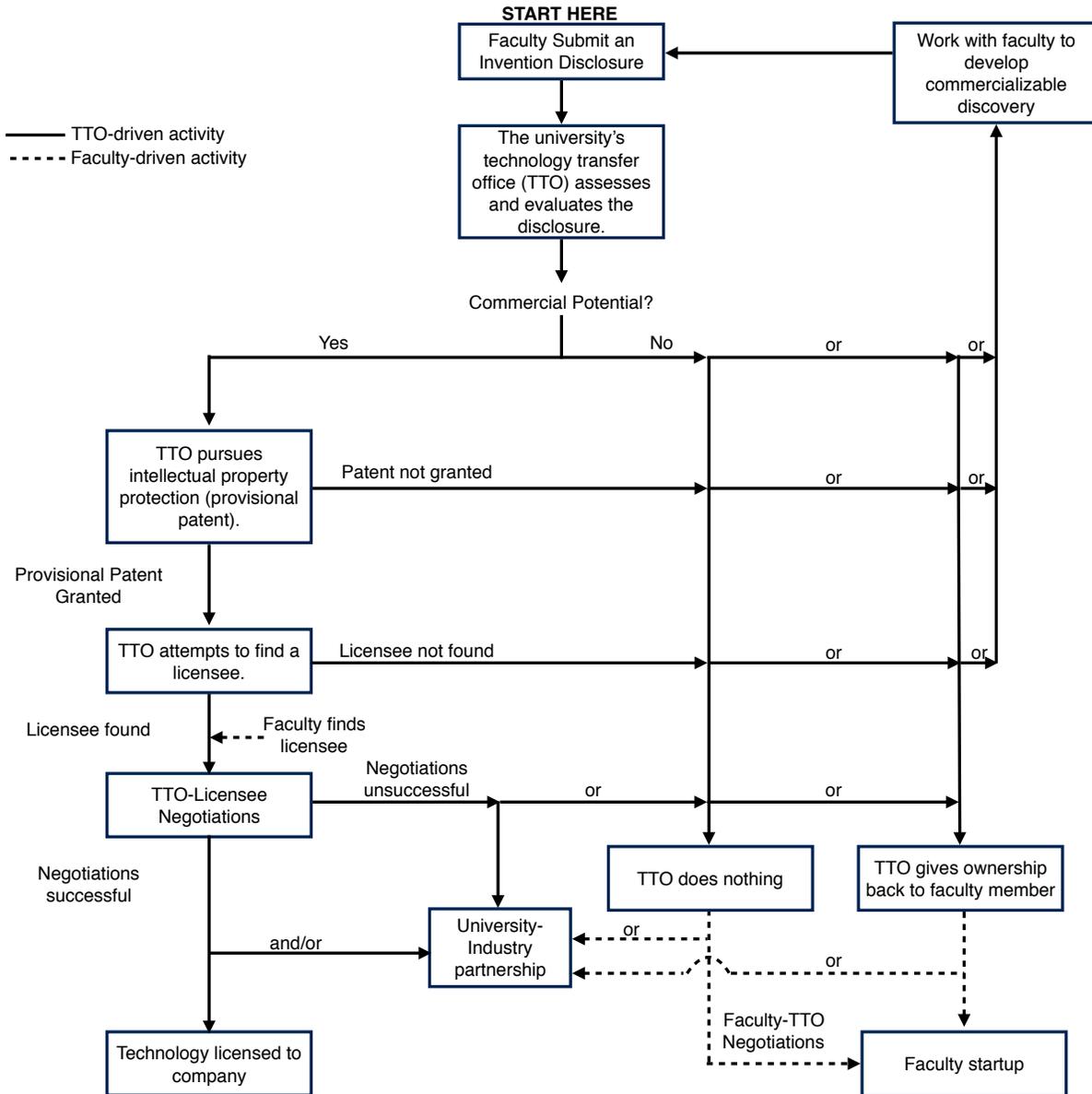


Figure 16: The university commercialization process

Next the university's technology transfer/commercialization office (TTO) reviews the disclosure, reviews the relevant market(s), possibly seeks advice from the faculty member about the potential discovery, and makes a decision about the commercial potential of the discovery. If there is commercial potential, the TTO typically pursues a provisional patent and attempts to license the technology to a company (large or small). If a licensee is found, the TTO negotiates with the potential licensee (e.g., to have the company reimburse the university for provisional

patenting costs, pay for full patent application costs, pay a royalty on the technology, make milestone payments, etc.). After successfully negotiating with the licensee, the first possible commercialization outcome is achieved, titled “Technology licensed to company” in Figure 16. Sometimes, University-Industry (U-I) partnerships are also the product of these negotiations. The details surrounding the identification of and negotiations with partner companies can vary greatly based on the institution, technology, and company.

Conversely, if the discovery lacks commercial potential, is not granted a provisional patent, or a licensee cannot be found, the university typically either a) does nothing with the discovery b) gives ownership back to the faculty member, or c) works with the faculty to develop a technology that is commercializable. Option A places the discovery in limbo because the university has decided not to commit resources toward commercialization (e.g., money or individuals’ time); however, they still retain ownership of the intellectual property. The faculty member still has the option to pursue commercialization (often via finding a licensee on their own, developing a U-I partnership, or starting a company), but they are often acting on their own without the support of the technology transfer office (shown in Figure 16 using the dotted line). Although unlikely, option B allows the faculty member to personally invest funds and/or time to pursue commercialization without the fear that, if successful, the university will claim ownership of the intellectual property and undercut the faculty member. Lastly, option C can utilize what the faculty member and TTO have learned throughout the commercialization process to commercialize a follow-up or modified technology, increasing the likelihood of success in subsequent commercialization attempts.

Despite a common commercialization process and similarities in some contextual details, the sites also differed from one another in a number of ways. In the remainder of Section 4.1, I describe each site in more detail. While two of the three sites granted permission to the release the name of their institution, the third site did not. I have therefore chosen to mask all institutions’ names in order to protect the identity of the participants in the study. To this end, I provide an anonymized site context for each site and describe institutional demographics relative to the other two cases, making broader comments when possible.

4.1.1 Site 1

Located in the Eastern region of the United States, Site 1 is considered a “college town” with the closest metropolitan area over two hours away and the university acting as a primary contributor to the population and local economy. The College of Engineering (CoE) at Site 1 has been consistently ranked among the top 35 graduate engineering schools by US News & World Report. When compared to Sites 2 and 3, Site 1

- has the smallest CoE graduate enrollment,
- is in the middle regarding the number of engineering faculty it employs,
- has CoE research expenditures comparable to Site 2, but significantly lower than Site 3,
- has a ratio of CoE research expenditures to engineering faculty comparable to Site 2, but significantly lower than Site 3, and
- has the least commercial activity.

Based on my analysis of university’s resources and the interviews I conducted, this institution has the least mature entrepreneurial and commercialization ecosystem of the three sites; however, the institution is currently growing its ecosystem and the university leadership is promoting entrepreneurial activity across the university. The technology transfer office and university-affiliated commercial incubator are located a short drive off campus, and the technology transfer office acts as the primary driver for commercialization activity after faculty submit invention disclosures. While Site 1’s technology transfer office acts as a service-oriented organization by providing commercialization services to faculty members and the university, it is also strongly focused on revenue and profitability. According to both faculty and administrative participants, the university has recently established or developed relationships with some sources for private and state commercialization training and funding. Lastly, Site 1’s main source of research funding is from federal, state, and local sources (~85%), with only ~10% of its research dollars coming from industry.

4.1.2 Site 2

Site 2 is also located in the Eastern portion of the United States and resides in the heart of a metropolitan area. The CoE at Site 2 is consistently ranked in the top 35 graduate engineering schools in the country. When compared to Sites 1 and 3, Site 2

- has a larger CoE graduate enrollment than Site 1 and comparable enrollment to Site 3,

- employs the largest number of engineering faculty,
- has CoE research expenditures comparable to Site 1, but significantly lower than Site 3,
- has a ratio of CoE research expenditures to engineering faculty comparable to Site 1, but significantly lower than Site 3, and
- has the highest commercial activity.

Site 2 has a robust entrepreneurial and commercialization ecosystem due to, as the administrator participant explained, early buy-in and resources allocation from the leadership. As an early adopter of university commercialization with a few early successes, the university has gone through entrepreneurial growing pains and now has a network of commercialization-focused programs and faculty who have experience with commercialization. These programs include a source of internal funding for faculty members to explore the commercial potential of their research. Additionally, being located in the metropolitan area enhances the university's connection to industry and a well-resourced external entrepreneurial ecosystem.

As with Site 1, the technology transfer office acts as the primary driver for commercialization activity after faculty submit invention disclosures, but unlike Site 1, Site 2 houses the majority of their patenting, licensing, market analysis, new venture development, mentoring support, and incubation services within the technology transfer office. The technology transfer office is located on Site 2's campus and its focus is on both service to the university and maintaining a self-sufficient financial status. Lastly, Site 2's main source of research funding, like Site 1, is from federal and state sources (~86%) with only ~9% of its research dollars coming from industry.

4.1.3 Site 3

Site 3 is located in the Midwestern region of the United States and, like Site 1, is considered a "college town" with the closest metropolitan area over an hour away. The CoE at Site 3 is consistently ranked in the top 15 graduate engineering schools in the country. Site 3, when compared to Sites 1 and 2,

- has a larger CoE graduate enrollment than Site 1 and comparable enrollment to Site 2,
- employs the least number of engineering faculty,
- has a significantly more CoE research expenditures than Sites 1 and 2,
- has a significantly higher ration of CoE research expenditures to engineering faculty than Sites 1 and 2, and

- has less commercial activity than Site 2, but significantly more than Site 1.

Like Site 2, Site 3 has a robust entrepreneurial and commercialization ecosystem and has developed a network of commercialization-focused programs and faculty who have experience with commercialization. These programs include multiple sources of internal funding and training opportunities for faculty members to explore the commercial potential of their research.

As with Site 1 and 2, the technology transfer office acts as the primary driver for commercialization activity after faculty submit invention disclosures. Similar to Site 1, the technology transfer office and university-affiliated commercial incubator operate as independent organizations and are located a short drive off campus; however, the technology transfer and commercial incubation resources seemed more tightly integrated than Site 1 based on both faculty and administrator interviews at both sites. Unlike, Sites 1 and 2, I was less clear whether the technology transfer office operated via a service-to-the-university or self-sufficiency model. Lastly, Site 3's sources of research funding were more evenly split between government sources (~60%) and industry sources (~35%), indicating a stronger financial connection with industry than Sites 1 and 2.

4.2 Faculty Perceptions of the University Commercialization

The cross-case analysis described in Section 3.5 identified strong thematic similarities across the three research sites. Therefore, to address RQ 1, I begin with these similarities using Engström's activity system framework (Figure 8 in Section 2.5.1) to structure my findings. As described in Chapter 3, I also included an affect code in my analysis to capture participants' mental and emotional states related to university commercialization. Although *Affect* is not part of the activity theory framework, faculty members across institutions clearly expressed the impact that commercialization had on them mentally and emotionally such that affect became an important emergent theme. To this end, Figure 17 summarizes the thematic similarities within each activity system element and visually answers RQ 1. Additionally, Appendix G also summarizes the similarities and provides a brief description for each theme.

Unpacking Figure 17, each underlined header represents the general activity system element, with the key themes listed below. For example, within the "Rules" element of faculty members' university commercialization activity system, "Attitudes," "Formal Rules," and "Promotion & Tenure" each emerged as salient themes across all of the cases. Importantly, all

activity system elements are linked with bidirectional arrows communicating the interactive nature between the elements in any activity system. Also, *Outcomes* and *Affect* are set apart because they impact the system as a whole; thus, an attempt to draw the required bidirectional arrows for these elements risked confusing the visual representation. The remainder of this section unpacks each of the themes in detail with representative quotes. Faculty participants are identified as F_Site#_Participant# (i.e., F_S2_4 is faculty member 4 at Site 2). In addition, because the study included only 1 female, the text uses gender-neutral pronouns when describing participants to protect anonymity.

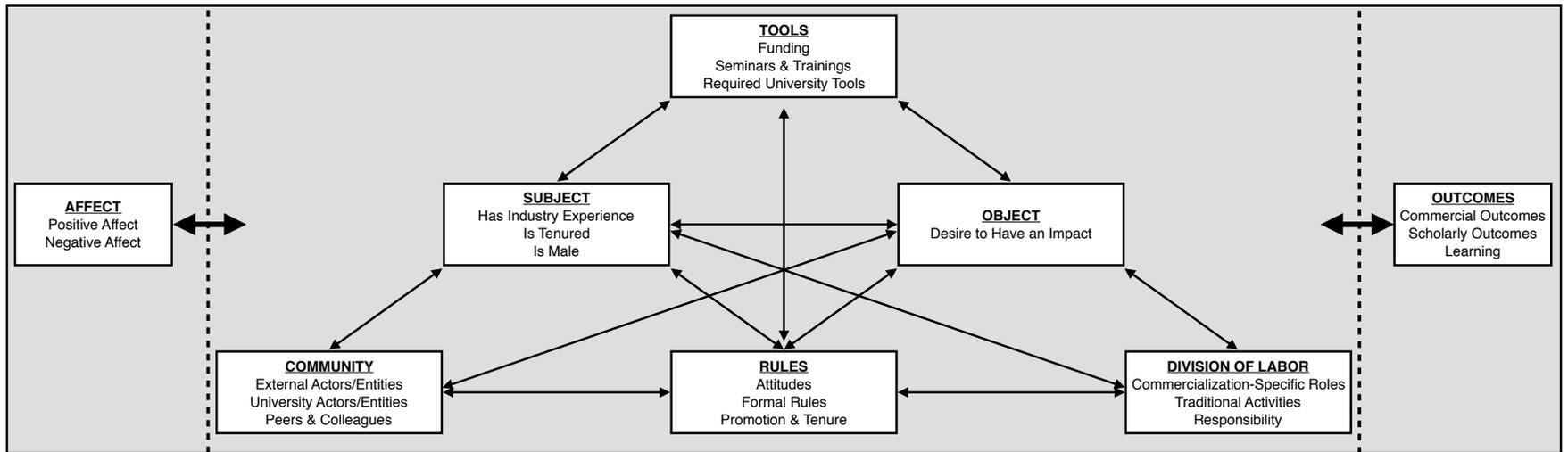


Figure 17: RQ 1 Findings Summary–Common themes in the faculty commercialization activity system

4.2.1 Subject

In Engström's activity system, the *Subject* is the individual or group engaged in the activity under study (Murphy & Rodriguez-Manzanares, 2008). In this study, the faculty interview participants are the subjects, and three subject-based criteria were used to identify these participants (Section 3.3.2); that is, all subjects

- conduct engineering research in academia
- hold or recently held a faculty position at one of the three targeted sites, and
- have participated in commercialization activity *at the targeted site*.

Subsequent data analysis identified three additional themes relative to these subjects: *Has Industry Experience*, *Is Tenured*, and *Is Male*.

Has Industry Experience

The theme *Has Industry Experience* captures the fact that all but one participant described prior experiences working in or closely with industry. These experiences ranged from working in industry for a few years between degrees to working in industry for many years (>30) prior to becoming a faculty member. Some participants worked for large, established companies holding leadership or managerial position. Others worked for small startup companies. Even those participants who did not work as an industry employee described experiences such as serving as expert witnesses for industry clients, consulting with industry, or serving on industry-specific boards and committees. Faculty participants described these connections to industry when they summarized where and how university commercialization fit into their career timelines, discussed their motivation for participating in university commercialization, and identified positive and negative influencers for engagement in commercialization. *Has Industry Experience* is also closely connected with the *External-Actors/Entities & Knowledge & Learning* themes (Sections 4.2.5 and 4.2.7, respectively) because faculty members utilized industrial connections when possible, and their industry experiences frequently informed their university commercialization experiences.

Is Tenured

Is Tenured captures the fact that all but two faculty participants interviewed had earned tenure, and over half were at the level of Full, Emeritus, or Distinguished Professor. Beyond simply revealing the tenure status of participants, however, *Is Tenured* also reflects a strong

consensus across not only faculty participants but also administrators at each site recommending that pre-tenure faculty delay participating in university commercialization until they earn tenure. 7 faculty participants reported that they had engaged in some level of commercialization activity prior to receiving tenure (this includes the two untenured faculty members), and all expressed that, despite being a risky decision, they had either sought feedback from a mentor/administrator or had been very productive regarding traditional metrics prior to participating. Tenure itself, however, is more than a Subject-based theme; it is also a critical element of both the formal and informal rules of each sites' activity system, as explained in more detail in Section 4.2.4.

Is Male

Finally, *Is Male* captures the fact that all but one of participants interviewed, and the majority of the potential participant pool (as reported by institutional data, I-Corps data, and other sources), were male. Unfortunately, this finding is somewhat unsurprising considering the current demographic landscape among science and engineering faculty at U.S. universities as well as in the U.S. entrepreneurship community. Unlike *Has Industry Experience* and *Is Tenured*, however, only one participant explicitly identified gender as a critical factor or characteristic in commercialization activity, and unsurprisingly, this participant was the sole female faculty participant in the study. Instead, gender operated largely as a silent, unacknowledged dimension of subjects' identities. This finding presents opportunities for more in-depth studies exploring female faculty members' experiences with commercialization. It also highlights a potential limitation of the current findings.

4.2.2 Object/Motive

Object/Motive "refers to the 'raw material' or 'problem space' at which the activity is directed and which is molded or transformed into outcomes with the help of physical and symbolic, external and internal tools" (Engeström, 1999, p. 67). More concisely, the *Object/Motive* precedes and motivates activity (Murphy & Rodriguez-Manzanares, 2008). While each participant across the cases worked in a different research domain (i.e., the specific object of their university commercialization activity), two salient *Object/Motive* themes emerged for participants' university commercialization engagement. First, participants expressed the *Desire to Have an Impact* through their university work. For many participants, this theme captures the primary force motivating their commercialization engagement. Second, participants also

described a range of different *Other Individualized Benefits* that spurred their participation, though typically these benefits were secondary to their desire for impact.

Desire to Have an Impact

Desire to Have an Impact captures faculty members' pursuit of commercialization as an opportunity for their traditional university scholarship to make a more direct and immediate impact in society. This theme includes both general statements expressing the need to "have impact" and specific examples of impact such as helping people, solving a real problem, addressing a gap in the existing market, developing intellectual property, advancing the field, and educating students.

At the general level, the following comment illustrates the way many participants described wanting to see their ideas make a difference:

*You know, it is a really cool as a scientist **to see your ideas implemented out there in the world and see other people benefiting from it.** We're very, as you see, we're a moderately high-tech lab, and there are a lot of technologies out there that are in these instruments that come from our lab. **That's part of our discovery and it means that people can do better things.** We have an instrument that's out there that [a major technology company] licensed one of our technologies and they built this cool instrument. It's not cheap, but, you know, it will be successful. – F_S3_1*

In this example, the faculty member described getting "ideas implemented out there in the world" and seeing people benefiting from these ideas – including instruments developed in their lab that support the work of other scientists.

In several cases, faculty specifically contrasted the impact afforded by commercialization with that of more traditional academic publications and presentations. They see commercialization as a way to reach beyond the limitations of these traditional activities. As one participant said,

*The activities that I have in technology commercialization begin from the desire to have an impact in my engineering, in my science. **A part of that impact is a desire to have it filter into the real world, as some would say, and go beyond what might be just journal literature and science literature.** So that's where it begins. – F_S2_6*

Such comments play on stereotypical distinctions between the "academic" and the "real" world, predominantly in terms of faculty members' desire to directly benefit people's lives.

*So that means take [my expertise] and manufacture products that help the quality and quantity of people's lives. **Make the science we do here real. Make it translatable. Make it not just end up in a paper, which is great, but at some point you want that work to do something for someone.** – F_S1_6*

Others went even further, moving from “desire” to “responsibility” and suggesting that while research citations may be metrics important to universities, they are meaningless unless the work in those papers results in concrete changes in the world:

*At the end of the day, **if your patent doesn't get out there to help people, then it's no good. Then it's just something you hang on a wall, right?** It's different from a paper. ... I remember at [a commercialization training I once took], this one guy was like, 'You know, if you can have a paper, a lot of you professors are excited that it's been read by 30 people and cited 30 times versus being able to help some people.' I will say this, it was I think in [year], our technology [significantly positively impacted the lives of multiple people]. I got the phone call that it all worked out. He was absolutely right. **I was crying. It's the most powerful feeling. That's why people should be doing this stuff. It's almost our responsibility to get our stuff out there.** – F_S1_1*

In other cases, the desire to have an impact was linked to specific market needs, as in one participant's description of a need around low-cost environmental gains:

*Turns out, we started doing our research, and lo and behold found out it worked extremely well; at a **relatively low price compared to [other] materials**. Also, [this] industry is well known to have environmental impact issues. They produce a lot of greenhouse gasses. **So they are looking for ways to become more environmentally benign or sensitive**. So they thought: 'Well, gee, if you can make [an environmentally friendly material that makes our product] last longer, and all this stuff, sure, we're interested.' So that led to a series of research projects and developments, which **eventually led up to technology that has since been patented and copyrighted for some other things. Now companies have come along and have licensed that technology. They're in the process of commercializing it.** – F_S3_3*

In this example, impact via patenting, copywriting and commercialization resulted from research that developed a working technology, had a lower price, lasted longer and was more environmentally friendly than existing technologies.

Other Individualized Benefits

While the desire for social impact was prominent across all cases and participants, *Desire to Have an Impact* was not the only *Object/Motive* theme expressed by faculty members. Beyond this theme, participants also described a range of *Other Individualized Benefits* driving their engagement in university commercialization, and this theme aggregates an array of more specific personal reasons to participate. Note that while *Desire to Have an Impact* is a type of *Individualized Benefit*, its prominence across all participants warranted making it a distinct theme. In contrast, *Other Individualized Benefits*, captures the fact that beyond this common motive, participants had other motives that varied by person.

Some participants, for example, also identified a sense of emotional satisfaction as a reason to engage in commercialization:

*For me it's never been a question of doing this or not doing this, because **I love to do it**. I think it works great in the academic environment. – F_S1_3*

*Honestly, **it [commercialization] is just fun**. What interest me in it is that you really you get so caught up in nuts and bolts whenever you're working in the lab of just trying to get something to work. And you have a pretty rudimentary idea of what the commercial aspects are. You make something and you know you can make smaller computer chips, you can make cleaner water, or you're enabling a technology that doesn't exist yet. And you see where it can go, you see where it could go, but really at the end of the day 99% your brain power is going into the nuts and bolts of just getting the stupid thing to work. And what I really like about the whole tech transfer process is you get so many different perspectives of what you're doing. ... [describes the perspectives] ... **So, everyone's looking at what you're doing from different angles and I just love hearing it. I just love... really you walk out of a meeting energized because you suddenly you have a completely different perspective of what you're doing day-to-day.** – F_S2_4*

In these excerpts, faculty describe their desire to participate in commercialization because they find it personally enjoyable and satisfying.

In other cases, *Other Individualized Benefits* encompass more traditional material – and specifically financial – gains, though again, participants generally describe these as secondary, as the following comments suggest.

*I have to tell you the primary one is, and always was, to make a difference. **I do admit that a secondary one is a potential financial gain**. But I think that's not been central to me, number one, and number two, that's actually also pretty*

unlikely—to have a substantial financial gain from any of the IP. It's very rare for, you know, IP from a university to turn out to be a substantial financial benefit to the inventors. – F_S2_6

*I haven't really investigated this very much yet, and so, my initial vision is that it would be something where they [the company] would own it. And basically, I'd like to have my name on the patent. **Potentially, I'd like to have some royalties, but I don't even care if it's a big percentage honestly.** I'd be more interested in seeing it get put into use, and interested to have my name on the patent. I mean those are the two things I would be most interested in. – F_S1_5*

In both cases, as well as comments from other participants who mention financial gain, monetary rewards are positioned as a nice bonus or addition, but desire to achieve public good or social impact remains dominant.

In some cases, the financial gain moved beyond the personal to the gains of the research group as a whole, providing something of a link between personal and social gains. One faculty member explains this process of “sharing the wealth” as follows:

*And we started, I started, really thinking, people in my lab don't get any particular personal benefit. The lab gets all the money: nobody got money, it was the lab. That was my primary goal, my primary goal was raising money for the lab. **Then I started to realize professors get well paid, staff members don't get as well paid. I'm thinking, well, what's the incentive? That's when I started thinking, I have people who are really smart. They're participating in the invention process. They should get benefit from it. So in about [year], we started really looking hard at moving down some new fields. Then we implemented some ideas, we patented it, and you know, people in my lab, several people in my lab, got significant amounts of money from royalties from those things. I think, as being the head of a lab, there is nothing more satisfying—well, there's nothing more satisfying than getting good publications—but the second thing that is most satisfying is when your staff can go buy a house because they got a huge royalty check. I mean, that is really cool when that happens. We really pushed stuff from then on. – F_S3_1***

In this case, while financial gain was a motive, it was financial gain for the participants' research staff, rather than the researchers alone, that acted as a driver. Collectively, statements such as these across the interviews highlight the ways in which personal benefit formed an important secondary driver for commercialization activity.

4.2.3 Mediating Artifacts/Tools (Tools)

Mediating Artifacts/Tools, herein *Tools*, impact the *Subject's* ability to achieve their *Object/Motive*. They can be external and material (e.g., a textbook, a computer) or internal and symbolic (e.g., language). *Tools* also take part in the transformation of the *Object/Motive* into an *Outcome* and can enable or constrain activity (Murphy & Rodriguez-Manzanares, 2008). Notable *Tools* had the fewest commonalities across cases when compared to the other activity system elements; however, it was discussed by all of the participants and three salient themes emerged from the data: *Funding*, *Seminars & Trainings*, and *Required University Tools*. These themes are presented using tables, rather than interview excerpts, because tables allow for the organization and presentation of the numerous examples provided by faculty members, and quotations are less useful and less necessary to capture these tools.

Funding

Funding identifies the mechanisms that faculty members use to fund their commercialization engagement. As shown in the following list, participants identified eight sources of commercialization funding. Because funding is integral to faculty work and the general operation of a university, it is logical that *Funding* emerged as a *Tool* that mediates commercialization engagement.

Commercialization Funding Sources

- Private Foundation Grants
- Matching Support (Company and Government Funding Partnership)
- Joint University-Industry Proposals (SBIR, STTR, IUCRC)
- Venture Capitalists
- Angel Investors
- NSF I-Corps Program
- NSF/NIH (for R&D process before commercialization)
- Engineering Research Centers

Seminars & Trainings

In addition to *Funding*, *Seminars & Trainings* also emerged as a salient *Tools* theme. *Seminars & Trainings* captures events that teach faculty members the commercialization knowledge, skills and attitudes for engaging in university commercialization activities. Like *Funding* faculty members described a range of opportunities to learn about commercialization both at their institution and more broadly. This theme was salient for Cases 1 and 2, however,

faculty at Site 2 did not mention any commercialization-focused seminars and trainings. The following list reveals the *Seminars & Trainings* identified by faculty members.

Commercialization Seminars & Trainings

- Technology transfer office seminars & trainings
- Entrepreneurship center seminars & trainings
- Private Foundation
- NSF I-Corps Program
- NSF/NIH Trainings

Required University Tools

Finally, *Required University Tools* are university-specific tools that mediate commercialization activity such as disclosure forms, contracts, policy documents and handbooks. As seen in Table 12, this theme was discussed with varying levels of specificity at each institution. For example, Case 2 faculty were more specific when describing the forms, contracts, documents and policies that the university required. Case 1 and Case 3 provided some specificity, but were overall more general in their discussion of this theme.

Table 12:

Required university tools

<u>Case 1</u>	<u>Case 2</u>	<u>Case 3</u>
“bunch of forms”	Notice of Intent form	The policy document stating the standard royalty distribution for licensing discoveries
Employee agreement	Conflict of Interest form	Memoranda on the university website
faculty handbook and “policies in it with regard to many things including intellectual property, conflict of interest, and conflict of commitment. And those are the three main things structurally, institutionally that govern these sorts of practices.”	Disclosure Form/Patent Alerts	operating agreements
Specific section in faculty activity report for entrepreneurship – counts toward service	Patents – Provisional, Full (Applications and Issued)	
Provisional patent	Technology Transfer Website/Online Disclosure Portal – Public and Private portions of the system to provide a summary of the technology and its status in the patenting process (marketing and faculty accountability)	
Promotion and Tenure Dossier	Intellectual property agreement between company or startup and the university	
Invention disclosures	Sponsored research agreements	
Sponsored program contract which has an intellectual property and data management plan	Faculty activity report/P&T Dossier	

4.2.4 Rules

Rules are “explicit and implicit norms that regulate actions and interactions within the activity system (Engeström, 1999; Kuutti, 1996)” (Murphy & Rodriguez-Manzanares, 2008 original citation intact). Unlike *Tools*, *Rules* do not represent artifacts, but are the official university policies as well as culturally-accepted ways of thinking that govern university commercialization engagement. For example, faculty members are required to complete an invention disclosure to communicate potentially commercializable discoveries and begin the commercialization process. While the form itself represents a tool that mediates communication

between the faculty member and the technology transfer office, the requirement that faculty members complete this form represents a disclosure *Rule* that faculty should follow. Faculty participants discussed three *Rules* themes within the university commercialization systems: *Attitudes*, *Formal Rules*, and *Promotion & Tenure*. While participants described both the attitudes and the formal rules of *Promotion & Tenure*, its prominence within the data justified it as a distinct theme.

Attitudes

Attitudes describes participants' beliefs regarding the level of acceptance and response to commercialization at their university. Participants discussed university commercialization attitudes both broadly and specifically. At the broad level, the following comment illustrates the “stigma” associated with commercialization and the “mixed messages” entrepreneurial faculty can receive:

I think there is still sort of stigma attached to being an entrepreneurial faculty. People think that your motivations are misplaced. If you are trying to commercialize your research, then you're not a true scientist: you're not a true academic. Because, again, you've let that profit motive creep in there. So there's going to be conflict of interest, there's going to be a premium placed on you personally enriching yourself and you're going to compromise research. You're going to compromise your training and educational responsibilities. I've never had that put in my face, but you always feel like there's a bit of that there. Depending on who you talk to. There are people who are more, sort of, academic purists who would say, 'You should never, ever, ever seek to profit from your research.' But then, you've got things the federal government with a Bayh-Dole Act and programs like the SBIR/STTR programs telling academics to do that stuff. And you've got administrators that have latched on to it and said, 'You know, you guys need to do more of this stuff,' and setting up tech transfer offices and angel investment groups associated with a university Alumni, trying to facilitate all of this stuff. So, you do get mixed messages as a faculty member and just that fundamental decision about, 'Do I really want to do this sort of stuff or do I not?' I think those of the sorts of things people think about. 'Am I going to be stigmatized within my peers or am I going to listen to the strong encouragement that I get from these other sources?' – F_S1_3

Other comments described an overall attitude among participants' peer who do not value or choose not to participate in commercialization activity because it produces outcomes that aren't in the “public domain,” as the following comment suggests:

*I would guess that probably even as a result of that legacy, even to this day **there are certainly faculty colleagues who don't view patenting and entrepreneurship to be an important aspect of a faculty member's activity there. What we should be doing is all should be in the public domain. The objective is to build a science and engineering knowledge base, not to hide it behind IP protection. I think that attitude isn't pervasive, but there's certainly folks that are still around, and certainly [in my current role], when I was trying to convey the message that this was part of our output, there were clearly colleagues who simply said, 'Well, I just don't do that sort of thing, and that's that.'** – F_S3_4*

On the other side of the cultural acceptance spectrum, faculty also described instances where they were being encouraged to start businesses that could impact economic development often by administrators or general university messaging. As one participant explains:

Yes, the university was pushing this [starting businesses]. [Saying,] 'Oh, faculty, please start businesses. We want this to increase the economy and the state...'
– F_S3_1

These attitudes also converged in the degree to which faculty had or lacked power, control, and input within the university commercialization system. In some cases, participants believed they should have “no voice” in the negotiation process, consistent with attitudes about “appropriate” faculty work. The excerpt below, from a participant who is speaking from the perspective of being both a faculty member has developed IP, is a startup founder attempting to license the same IP.

Participant:** So, I guess, either I have **no role**, or the [Technology Transfer Office] may ask me a question, to kind of describe the IP, and help them understand it. **But I certainly have no role in the actual negotiation... on either side.

***Interviewer:** In your opinion, is that good or bad?*

***Participant:** I think it's good, and I think it's necessary.*

***Interviewer:** Can you tell me why you describe it that way?*

***Participant:** Sure. There's a conflict of interest for me in the position of, you know, as inventor, as also being a kind of in the stable of the [university], but then also to have a role in the second party negotiating with them. **So, it's a conflict of interest, and I shouldn't, you know, I should just avoid. In my mind, one way to manage that is to have no voice there at all.** – F_S2_6*

In contrast, another faculty participant describes how having “no real power” can be both “a good thing and a bad thing.” He explains that having no power means that companies are less able to pressure faculty; however, this lack of power limits the faculty member’s participation in the process primarily to advising the technology transfer.

*So technically, **you have no real power. [the TTO] can license things to anybody. And in a way, this is a good thing and a bad thing, because then you can't get persecuted as a faculty member or cornered [by the potential licensee.] 'Hey, give us a good deal on these patents.'***

Finally, one faculty member describes their input as “welcomed, never required” and valued by a technology transfer colleague.

*Participant: I was **not required** to be in the meeting: the contract negotiator was in it. What's interesting is because there was IP, [the TTO] negotiated it which was different than the regular contracts people [negotiating it]. And I would say that **I was welcomed, never required**. I got on the calls because I had my engineering counterpart of the company. We knew what we wanted to do and it was basically trying to get through all the paperwork to make sure the two sides that went together. So I attended, not all, but many of the calls just to, basically, try to be a referee. And so I was part of that. So it was **not required, but I joined it to, hopefully, help things move along**.*

Interviewer: Do you feel as though you were valued in the meeting [with the large company who wanted to give money for research]?

*Participant: I do, but I think that's because of a particular individual I was working with [was]—I won't say junior, but I think she was new to IP licensing and she was **happy to have me there to give her all the background, both on the technology, both on the company, and the people involved**. – F_S2_2*

Such comments reflect an underlying attitude of hesitancy and caution with respect to faculty participation in university commercialization. This attitude includes the belief that faculty members are not essential after the invention disclosure; instead, they are thought of as advisors to the technology transfer staff. This advising role will be discussed further in Section 4.2.6.

Formal Rules

The theme *Formal Rules* identifies the official university rules, processes and policies that govern faculty members' commercialization engagement. Participants discussed policies around conflict of interest, intellectual property ownership, royalties, disclosing, licensing, and faculty time. In general, such policies govern both when faculty can do commercialization work and how much ownership they retain over that work. For example, several faculty described processes for formal leave that enable them to engage in commercial activity while meeting the university's need to be "reimbursed or covered" for faculty time away from the university. As illustrated in the following comment:

*I think there is certainly the possibility of faculty taking leave for entrepreneurial activities. I'm aware of several faculty that have done that. I think there is a possibility of **buying out one's time**, if you will, to do something outside. One of my younger colleagues who started a company some years ago, periodically, when they [the company] grow to the stage of a major update to one of their products, then **he has taken a half year or a summer or a year leave, where his salary would be covered by the company, and the university relieved him from teaching activity or whatever it is for that period of time**. Those things are now feasible.*

*Beyond that, I think that from a faculty perspective it all boils down to time and **how that time will be reimbursed or covered**. Really, I guess I don't believe the university has any mechanism in place where a faculty member can continue to be on the university salary while out doing commercialization or the development of a company. **Typically, that has to be done by taking formal leave and then taking care of yourself when you're out there.** – F_S3_4*

In other cases, these formal rules concern questions of ownership. For example, U.S. law allows 12 months between public disclosure and patenting, and university policies typically control who decides whether to patent and when. If the university chooses not to patent, the faculty member can, but timing is critical because faculty often disclose to the technology transfer office in order to disclose publically (e.g., publish or present at a conference), effectively starting the 12-month clock at the time of invention disclosure. The importance of rules related to ownership and timing is illustrated in the following example:

Participant: ...I asked [the president], could he please set a policy that was like... give the university 270 days, that's nine months, if they are deciding not to make a technology into a full patent or a provisional, that they give it up. They don't have a choice. They agree in nine months or they give it up, and they give it up for free.

A faculty member shouldn't have to pay for it. It's university technology until they patent it and then keep it, or they give it up and they lose it.

Interviewer: Just to be clear, why give it up?

Participant: Because if they're not going to patent it, they should give the faculty member at least three months for the faculty member to pay his own money, file it and own it. Not one month, but three months. [The president] didn't agree to our terms. He made it six months. So he gave it 180 days. [The technology transfer staff] have 180 days after we put in a disclosure to come back to us and tell us, 'We're filing a provisional or a full patent within one year.' Now the faculty member has at least six months to deal with it. This is amazing, this is a good policy. This is a forward-thinking policy. Why? Because the university discovered that out of all the disclosures they get, only a percentage of them go to full patents. The rest get thrown away. All that work gets thrown away. If the faculty member thinks that it's important, and the university doesn't, they should have the right to take it. – F_S3_1

Promotion & Tenure

While formal rules such as those described impact when and how faculty engage in commercialization, the question of if/whether they engage is often tightly linked to the formal and informal rules surrounding promotion and tenure (P&T). As mentioned previously, *Promotion & Tenure* emerged as part of multiple themes within the data, but because of its importance for both faculty and administrators during the interviews, it warranted elevating it to a theme on its own. This importance is linked to two facts: First, all but two of the faculty participants were tenured faculty members. Second, most participants expressly stated that faculty members should wait until they have tenure before attempting a university commercialization activity, unless, as one administrator put it, they are “superhuman.” To better understand why faculty members recommended waiting and the ways the formal and informal rules of P&T impact university commercialization, this section provides examples of how faculty discussed P&T’s impact on university commercialization.

In part, the challenges surrounding P&T center on the conflict between the public dissemination of academic research in traditional venues such as journals and conferences and the secrecy required for patenting, licensing, and commercialization. As one participant explained:

Interviewer: Does participation in a tech transfer and commercialization activity impact that transition or that process of becoming an associate [professor]?

Participant: It could, absolutely. Because they are opposing...they're opposing interests. The interest of achieving associate professor and getting tenure are all about disseminating information and telling people about what you're doing. And the goals of tech transfer are to keep it all quiet and like I'm going to do this here by myself and I'm trying to get this patented before anybody finds out about it. So they're absolutely competing. – F_S1_5

This conflict, in turn, raises significant questions about the degree to which commercialization activities “count” toward tenure – and an overriding sense that disseminations through patenting is not as good as dissemination through academic publication:

The fact is that, especially whenever you're up for tenure, your dossier is going in front of people who are brought up in that time when it was not seen as being... I'm not trying to make it sound like that the university is behind the times, but the reality is that they're going to hold you to the same standards [i.e. of journal publications and grants] that they were brought up with, right? It's going to be really hard to change that proposition, change that, 'No, you really should look at patents.' – F_S1_4

As a result, commercialization activities tend to count only to the extent that they do not detract from or lessen an individual's traditional activities, as another participant explained:

*So I've chatted with faculty members about this [the interaction between commercialization and tenure]. And they told me that if a person would be involved—so in terms of getting patents and software disclosures, and stuff like that—the amount of time involved is not too big and it would only a win. **But in terms of opening companies or doing things like that that are more time consuming, I've chatted with faculty members. And they told me that if there would be a faculty member who is up for tenure, and that faculty member had perhaps been involved in the company, and because of a very significant time involvement their academic contributions had suffered this might work against them.** On the other hand, they told me that if a person had been involved in opening a company and their academic—I mean clearly, their academic...it's likely that their academic pursuits would suffer to some degree. But if they were very—if it was clear that they were good enough, their academic accomplishments were good enough to receive tenure, it would only be viewed as a positive. **The conclusion, and I got this from more than one faculty member, was to be a bit careful pre-tenure.** – F_S1_3 (untenured participant)*

The result of these expectations and the relative value of commercialization in the rules that govern P&T is a consensus among participants that commercialization activities are generally not recommended pre-tenure, and participants were very direct in acknowledging this:

If the faculty member does not have tenure yet, I advise them, "This is going to be extra work on your part because it will not [count] until [the university] says that it really does count and has teeth into it through all the departments [and] all the silos. What you need to do is continue your career as you're doing to get tenure. – F_S3_2

Pre-tenure commercialization is clearly considered an ‘above and beyond’ activity that requires careful and intentional navigation of the rules:

*So, there are also subtle ways in which faculty are discouraged, intentional or not—the system rewards—the people who follow the traditional P&T [promotion & tenure] process if that is your goal. Again, they’re not mutually exclusive. You have to find a way to navigate through them. **It’s doable, but the path of least resistance is typically just fall in step with the P&T process, and you can realize your goals. Or you can jump through all these extra hoops and take on this extra responsibility and work and stress and contrition and do this other thing [commercialization]. It’s doable, but you have to want to do them. – F_S1_3***

There is, however, some recognition that the rules surrounding P&T may be shifting slowly, as evidence by space in relevant documents to record and highlight commercialization work:

*It used to be that there was nowhere on your annual faculty activity report to put entrepreneurship, and therefore it was not viewed as something contributing towards your success as a faculty member. And **now, the paperwork includes a specific section for entrepreneurship. And generally the university, well the College of Engineering anyway, sort of counts it towards professional service in terms of where you would get credit for it in your evaluations. – F_S1_4***

Some participants even noted that commercialization may carry more weight in moving from associate to full professor, where impact plays a key role:

*... Once you become an associate tenured professor, that's a different story, because now, even though they need to keep working towards full professor, the ground rules are different. The ground rules going from associate to full means that you have become mature in your work, and that you can now relate to other full professors you'll be compared with. **Impact counts. Impact is not so***

important trying to get tenure, but impact becomes more important if you're going to go from associate to full. – F_S3_2

However, even as participants acknowledged that commercialization activity is now often formally included in faculty activity reports and P&T dossiers⁷, they expressed that it does not hold the importance of the traditional research, teaching, and service components.

4.2.5 Community

Community refers to the participants of an activity system, who share the same object/motive as the subject (Murphy & Rodriguez-Manzanares, 2008). Within this element, three distinct communities emerged: *External Actors/Entities*, *University Actors/Entities*, and *Peers & Colleagues*. Like the various *Mediating Artifacts/Tools*, the components of these groups are better suited to summary tables as a means to capture the range of individuals and entities that make up the university commercialization community.

External Actors/Entities

External Actors/Entities captures individuals and organizations who do not formally work for the university. Table 13 summarizes the range of external actors/entities that participants discussed during their interviews and the primary contribution(s) those actors/entities play in university commercialization.

⁷ commercialization activity is typically included as a type of “Service” or “Outreach”

Table 13:

External Actors/Entities with primary contribution(s) shaded

	<u>Research Funding</u>	<u>Commercial Funding</u>	<u>Commercial Training</u>	<u>Business Services/ Expertise</u>	<u>Market</u>
<u>Government Agencies (e.g., NSF, NIH, DOD, DOE, NSF I-Corps)</u>					
<u>Private Foundations</u>					
<u>Licensees (Large Companies/Startups)</u>					
<u>Investors</u>					
<u>Alumni</u>					
<u>Family Members</u>					
<u>Connectors/Networkers</u>					
<u>Manufacturers</u>					
<u>Practitioners</u>					
<u>Business Experts/Consultants (e.g., CEO, CFO, legal, HR)</u>					
<u>Competitors</u>					
<u>Customers</u>					

Common external actors across cases were government/funding agencies (e.g., NSF, NIH, DOD, and DOE), company partners (large companies and startups), and individuals with business knowledge and expertise. As shown in the table, these external entities served a variety of roles, but focused primarily on providing funding, training, and business services/expertise needed for commercialization. The market group (competitors, customers), for example, served as a source of information for decision making and the target for commercialization outputs.

University Actors/Entities

University Actors/Entities captures individuals and organizations within the university who share the goal of commercializing university discoveries. Table 14 summarizes the university-affiliated individuals and entities identified by participants along with their primary contribution(s) to commercialization.

Table 14:

Internal Actors/Entities with primary contribution(s) shaded

	<u>Commercial Funding</u>	<u>Commercial Training</u>	<u>Business Services/ Expertise</u>	<u>Governance</u>	<u>Ideation & Workforce</u>
<u>Campus Entrepreneurship Center</u>					
<u>Technology Transfer Office</u>					
<u>University Established Non-profit or Para-University Financial Unit</u>					
<u>Campus Incubators/Accelerators</u>					
<u>Business/Management School</u>					
<u>Industry Relations Office</u>					
<u>Senior University Administration (e.g., the University President, Vice President for Research, and Provost)</u>					
<u>College of Engineering</u>					
<u>Engineering Departments</u>					
<u>Sponsored Programs Office</u>					
<u>Other University Populations (i.e., students, lab technicians)</u>					

Despite the breadth of *University Actors/Entities* reported, the only university entity consistently reported across the three cases was the technology transfer office. The degree to which other entities were involved varied by both individual and site, with no clear patterns. Across the group, however, these actors and entities served roles similar to those played by the *External Actors/Entities* in supporting or enabling commercialization, but some also served gatekeeping functions that governed when and how faculty could engage in commercialization. That is, these entities often developed and oversaw the *Rules* discussed in Section 4.2.4. Lastly, other university populations such as students and lab technicians served as sources of ideation and a workforce for research and development leading to commercialization.

Peers & Colleagues

While *External Actors* and *University Actors* capture the primary groups that shape faculty members’ university commercialization activities, participants in this study also

described individuals within both of those groups who move from peripheral to central actors; these are individuals who were not merely necessary or loosely supportive, but were closely connected with and important to the participants' commercialization engagement. Thus many of the actors and entities in this group also appear in the two previous groups; the distinction rests on the degree of involvement and support. For example, if a participant generally described an external type of business mentor, I classified that community member in the theme *External Actors/Entities*; however, if participants described a strong supportive, collaborative, or recurring relationship with a business mentor, I captured that individual as a *Peer & Colleague* due to the relationship being closer and more collegial. Table 15 lists all of the *Peers & Colleagues* participants identified within the system and their primary contribution(s).

Table 15:

Peers & Colleagues with primary contribution(s) shaded

	<u>Research Collaborators</u>	<u>Mentors & Advisors</u>	<u>Industry Experts</u>	<u>Governance</u>	<u>Ideation & Workforce</u>
<u>Another Professor</u>					
<u>Department Head</u>					
<u>Mentors</u>					
<u>Students (interested in commercialization or working in the lab)</u>					
<u>Industry Partners</u>					
<u>Post-Docs</u>					
<u>Research Scientists</u>					

Generally, participants across cases identified fellow professors in both their department and at their university as well as student colleagues as important *Peers & Colleagues* within their commercialization communities. In considering the types of individuals who moved from peripheral external or university actors to colleagues, it is worth noting that the *Peers & Colleagues* group includes research collaborators (students, post-docs, co-researchers), commercialization mentors/advisors, and individuals who collaborated through idea generation and actually engaged in commercialization. The list did not, however, include more distant university administrators or entities such as TTOs, nor did it include individuals from the various external agencies supporting and governing commercialization.

4.2.6 Division of Labor

Division of Labor involves the division of tasks and roles among members of the community. It also identifies the divisions of power and status (Murphy & Rodriguez-Manzanares, 2008). Given the complexity of the work involved in commercialization, for the purposes of this study I focus on participants' discussion of their own role in the process. The emergent themes within this activity system element are *Commercialization-Specific Activities*, *Traditional Roles*, and *Responsibility*. The first two themes capture the ways in which faculty members' commercialization activities do and do not overlap with traditional conceptions of faculty work; the third theme, *Responsibility*, addresses participants' perceptions about the types of activities they should (and should not) be responsible for within the system.

Commercialization-Specific Activities

Commercialization-Specific Activities capture activities directly related to commercialization such as disclosing IP, patenting, evaluating market potential, and starting companies, that are clearly different and independent from more traditional faculty work such as advising, publishing, or securing funding. Typically, these activities are often performed in addition to faculty members' traditional roles, although, as I describe in the next section, they can sometimes yield both commercial and traditional academic outcomes. For example, for commercialization to proceed, faculty members are formally required to file invention disclosures, an activity that falls outside the things the university requires of faculty generally. That is, all tenure-track and tenured faculty are required to publish; no faculty are required to file invention disclosures, but as many faculty note, filing such disclosures is essential to their commercialization engagement:

*I pretty much understand that I have to write **invention reports**. – F_S1_6*

*...there were **three invention disclosures that we submitted** on three different topics, and they were submitted to the office of technology transfer at [University]. – F_S2_6*

*Because we knew ahead of time it was very applied research, so we knew that there was a commercial potential, we of course **filed patent disclosures** as soon as we had enough information to be able to clearly state what the idea was and what the potential was in terms of doing that. – F_S3_3*

Similarly, commercialization requires faculty members to evaluate potential licensees, an activity that again does not fall under traditional expectations. Yet participants discussed this activity as important when attempting to commercialize. To this end, one faculty member expresses the importance of the individual researcher (the faculty member) in understanding the impact of a discovery.

*Well, the individual researcher **has more understanding of the impact**, it would seem to me and should be included in all of that [finding a company to license the technology]. And then the fact that they are not, is a big mistake, and may harm the whole project as a result. – F_S2_5*

Another faculty member highlights the separation between traditional faculty roles and the need to be able to evaluate market potential of a discovery and write a subsequent business plan, stating

*I think that writing a business plan is very different than doing academic research, and we, I think, [those in my field], are not really prepared for that. I had wonderful mentoring. I had a financial person who worked with me, someone else who had worked as a co-founder on another business, and they were with me step by step, so **looking at projections, the marketing plan**, that was really interesting, but I think it was somewhat difficult for me to go from writing abstracts and just justifying the research— from, ‘Oh, here's a grant, and here's the [relevant] outcome,’ to **looking at the very succinct marketing aspects of the tool. Why would someone invest in this?** – F_S3_5*

As these examples illustrate, commercialization requires faculty to undertake specific activities that fall outside the types of tasks required of university faculty generally.

Traditional Activities

At the same time, a number of the activities linked to commercialization do resemble activities performed by tenured and tenure-track faculty generally, as captured by the *Traditional Activities* theme. For example, securing funding is both a traditional and commercialization-specific activity, because securing funding can be done as a strictly traditional activity (an NSF-sponsored research grant), as a strictly commercialization activity (venture capital), or as a hybrid of traditional and commercialization (a university-industry partnership). The theme *Traditional Activities* thus captures work that, while resembling traditional faculty activities, can

serve both traditional and commercialization-specific faculty roles. Such activities include not only the funding and research itself that leads to commercialization, but also serving as an advisor or consultant and building and mediating relationships.

For example, part of faculty service work often includes advising the general public as well as companies or agencies through consulting and expert witnessing, often in non-commercial capacities. Faculty participants described similarly acting as an advisor or consultant to a startup that is attempting to commercialize (or has successfully commercialized) their technology, as the following comment suggests:

I'm [serving in an advisory role]. My activity in there [at the startup] is actually fairly low key now, just a few hours a week. Providing advice, showing them [the leaders of the startup] to meetings. – F_S1_2

One faculty participant even stated that this advisory role is the most they are willing to do while still performing traditional faculty activities.

I think that [serving as an advisor] probably to my mind is about all you can do as a faculty member unless you remove yourself from a faculty role for a couple years, which I guess I wasn't prepared to do at that time. – F_S3_4

Faculty also discussed advising the technology transfer staff and external partners about the specifics of a disclosed technology. In the following example, the faculty member describes that their advising role is “to explain the technology” and be “the expert in the room.”

The first role is, obviously, just to explain the technology. A lot of times, the patent guy you're dealing with or the person you're working with in the tech transfer office is not an expert in [my area of expertise] for example. We've had people working in [another expertise]. We've had people working in [another expertise] and had people working in pretty much anything but [my area of expertise], right? So the first thing is you've got to explain the technology to someone who hasn't worked in the field. So, a main role is technical, it's basically tech support. And then, not only for tech transfer, but whenever they bring companies in who are interested in licensing it. They want the expert in the room. So really they want me there from a technical standpoint. ... My role is to—that's one of those cases where they don't necessarily want me thinking outside the box—they want me pretty much answering the questions and let them take care of the commercialization and licensing aspects. – F_S2_4

In addition to advising, faculty described another common *Traditional Activity*: building and mediating relationship. Traditionally, faculty members need to network with potential research collaborators, develop relationships with funding agencies, and manage relationships with graduate student researchers. Such relationship management is equally important in commercialization engagement, as one participant illustrated describing the importance of relationships and their role as the “intermediary between the student, who is learning how to do fundamental things and is here for a PhD, and this company who wants a product tomorrow.”

One of the most important things, I think, in my career is the word relationships. You need to visit the company. They have to know you, trust you. You’ve got to understand what they want and what you want. How do we make this a win-win situation? A company is just not going to come and say, ‘Oh, here’s \$200,000, go and have fun.’ No way. No way. For them, what’s their return on the investment. They need to understand that. And for me, I understand that need, but I also understand the fact that I’m educating students. So my role is to serve as that intermediary between the student, who is learning how to do fundamental things and is here for a PhD, and this company who wants a product tomorrow. My job is to say, ‘Look, this is how we need to do it.’ Sometimes keeping a company at bay, otherwise they may be calling everyday or emailing my students or even texting them everyday. No way. No. My students are here to get an education. Once a month is enough. I don’t want to do no more than once a month, and believe me I had that conversation with a lot of industrial scientists. – F_SI_6

Another faculty member also discussed their need to manage existing relationships with potential partner companies and the relationship between the technology transfer staff and a technical representative at a potential partner company. This faculty member describes informing the technology transfer staff when companies visit their lab and behaviors that might “scare off” potential industry partners.

Participant: They find people and I find people. I know the companies who might be interested. ... they’ve brought in about three companies and I’ve brought in two companies; through my own—just people, just companies I know from working in the field.

Interviewer: It’s a pretty... is it fair to describe it as a pretty dynamic relationship to where you’re talking with them, they’re talking with you about who’s coming in or who potentially could do something with the technology?

Participant: Oh yeah. I mean I’m talking with those guys [the technology transfer staff] pretty regularly. Anytime there’s a company who’s interested or someone who’s going to be on campus, I contact them [the technology transfer

*staff] and they come out. And they want to make sure that they meet the companies. Usually when the companies come out here, if they're reaching out to me, it's because they have a technical interest. So what they do is they come in and they can introduce themselves as the commercialization/licensing guy and kind leave it at that. **You don't want to scare the technology guys off** with having someone come in who kind of says, "Well if you're interested, here's the card." Because, there's another process to this. The technology guys don't want to hear that. They just want to hear the technology. They come in and they're kind of, 'Oh, yeah we're working with [interviewee] on this.' Especially if we know there's a lot of interest from companies. **And they give a good nonthreatening segway into the relationship that doesn't make it sound like we're here to make a buck or whatever, but that the university's interested in keeping up with how the companies are using our technology.** – F_S2_4*

Lastly, faculty members also described building and mediating relationships with potential business partners. In the following example, the participant describes the activity clearly as “relationship building” and expresses some of the thinking that goes into developing a relationship with a business partner who has a complimentary skillset.

*The thing that's really interesting is that the guy that I'm thinking of working with could be a potential CEO for my company, and **we are just kind of feeling each other out**, so to speak, seeing how we work. We've briefly talked about [the technology] in the past, but his thing is that he's not an academician, but he has networking resources, he has the tech background, and I am in academia, and I've gotten grant funding, ... We are thinking about coming together so that we can leverage the strengths that the other brings to the table. **It's like that relationship building, but it's just very, very different, trying to figure out if this is someone I want to work with.** – F_S3_5*

In each of the cases described here, the work faculty members are doing relative to commercialization happens within the context of their traditional research, teaching, and service work; while in some cases the focus may be different (e.g., building relationships with a company rather than a government agency), the underlying processes and activities faculty describe appear to be aligned with general faculty work. Therefore, in contrast to *Commercialization-Specific Activities* that are largely independent from traditional university work, faculty can more easily apply expertise developed through research, teaching, and service to these important commercialization activities.

Responsibility

The final *Division of Labor* theme, *Responsibility*, describes participants' beliefs about faculty members' broader set of responsibilities with respect to commercialization, along with what types of things faculty should explicitly not be responsible for.

First, and perhaps most importantly, participants see themselves as responsible for launching and driving university commercialization:

A lot of what I see that happens here [with regards to commercialization activity], it really has to be professor-driven. They have to find the company and they have to do a lot of the legwork. – F_S1_1

Another participant drew a harder line expressing that the transfer of intellectual property should be faculty members' decision and not a decision made by a "bureaucrats," stating

.. intellectual property is transferred from the faculty member to the university. It is faculty-driven. The process of transferring it to the university should be a faculty-driven decision. Shouldn't be bureaucrat decision, should be done by faculty. – F_S3_1

Still another faculty member expressed that, despite the university culture, faculty are responsible for driving the commercialization process forward and should stay "proactive" throughout the process.

And I would tell them [other faculty], probably, to be very proactive. If they go into a provisional patent period to not just sit around and let it go by. To be proactive. They need to be in there trying to get people to buy it. So if it goes into a provisional patent period, they need to be out there getting licensees not just letting [the TTO] try to do it. – F_S1_5

At the same time, while participants believe faculty are responsible for driving the process at a very fundamental level, they also believe that there a number of commercialization activities they would rather not or should not do. As demonstrated by the following excerpt, one faculty membered enjoyed licensing to big companies because their focus could remain on research and the company would handle all of the commercial development activities.

Well, it's the time. Again, I really liked how I was able, even though it was a bad royalty rate and all that stuff, I really liked my experienced licensing it to the big company. That was a great experience because then the big company wanted,

they would even sponsor some research to just pushed the envelope, but they ran with all the hard stuff. The stuff that I don't want to deal with. There's a lot of development issues, there's [discipline specific challenges], all these things that they can go with. – F_S1_1

Another faculty member described running a startup as too time intensive and potentially harmful for meeting traditional university metrics.

So, the other scenarios where I've seen it go poorly is where you actually start a mentor-backed startup, but you as a faculty member are doing it full time. And that is a huge suck on your time, and then that's when you begin to see major performance issues with sort of traditional academic metrics. So I think what has enabled me to avoid both of those issues, is to find sources of capital that I can get a big investment. I know that there's investment there for the whole long term. And I don't need to go run it [the startup] as a full time job. – F_S1_4

Such comments point to the ways in which participants did not want responsibility for commercialization activities that would take them too far away from or interfere with their traditional teaching and research work.

In other cases, this shifting of responsibility was linked more towards faculty members' expertise; that is, faculty do not need to be responsible for areas of commercialization that are beyond their domain:

I'm not fluent in legalese and most of the documents are—I get half a page into it and it just starts to hurt the eyes and the brain. So I read as much of it as I can. I understand most of it. But a lot of it also just I have no reason not to trust my tech transfer office. And if they tell me that that's written into the license, that's fair enough for me. I'm not worried about it. They have a lot more at stake than I do. The worst thing that happens to me is that someone else starts using the technology, which is all I ever wanted in the first place anyways. And I still get to keep doing my work and I still get a paycheck. I'm not worried about it. The tech transfer office is going to make sure that they are covered on all levels because if someone comes back and finds out that someone swooped the technology that they didn't protect, they're going to be out of a job. So, if they tell me it's covered, oh, I'm sure that they have a much more vested interest in making things work than I do. I'm just a technology guy. I just want to see the technology work and see someone use it. – F_S2_4

Elsewhere in the same interview, this participant further justified why they believe they should not have control over each part of the commercialization process, especially negotiations with company partners.

***Participant:** They want the expert in the room. So really they want me there from a technical standpoint. **They take care of the rest. And that's exactly how I want it too. I would stumble all over myself trying to figure one of these things out [the tech transfer process].** My role is to—that's one of those cases where they don't necessarily want me thinking outside the box—they want me pretty much answering the questions and let them take care of the commercialization and licensing aspects.*

***Interviewer:** From a negotiation standpoint are you involved in any of those conversations?*

***Participant:** No. **Honestly nor should I be. I don't bring anything to the table that would help those negotiations.** – F_S2_4*

Thus as the comments of these themes suggest, participants recognize the centrality of their work in initiating and driving commercialization. Moreover, they also recognize the limits of both their time and expertise as university researchers, and argue for a division of labor that recognizes these differing facets.

4.2.7 Outcomes

Outcomes are the realized outputs, tangible or intangible, that result from participating in human activity systems. As shown in the summary visualization, *Outcomes* both impact and are impacted by each element in the activity system. The participants of this study identified three university commercialization *Outcomes* themes—*Commercial Outcomes*, *Scholarly Outcomes*, and *Learning*.

Commercial Outcomes

Commercial Outcomes are outcomes directly related to the process of commercialization itself. While patents, startups, and licenses were the most frequently discussed *Commercial Outcomes*, participants also noted a range of other outcomes such as

- Patents
- Startups
- Licenses
- Publicity/Reputation (from commercialization activity such as a new product)

- Equity in Startups
- Economic Development
- Revenue
- Products

Importantly, these outcomes can be realized by the faculty member, department, university, and local economy as is often the case with a university spinoff that creates jobs in the region.

Scholarly Outcomes

In addition to *Commercial Outcomes*, participants also reported that their commercial activities produced more scholarly outcomes associated with research. For example, licensing a technology to a partner company can lead to additional research, funding, collaborations, and publications, as well as the possibility for service through consulting. In this sense, faculty members' engagement in university commercialization complemented their ability to produce the kinds of "products" historically needed for tenure, promotion, or other university advancement.

This complementarity is evident in the following excerpt, in which a participant describes the outcomes that resulted from an ongoing research and development partnership between academia, private companies, private organizations, and the state government.

*Participant: From that [partnership] and the results that evolved from that, then **further research was done** focused on finer details if you will. Different types of [products], different conditions, different methods of application, and so on. As well as developing and working, for example, we're working with [a product for a specific purpose], so then [a specific government organization] said, 'Well, why don't you go and test this [using our existing infrastructure]?' **So we tested on several [sites belonging to the government], where we would go apply [our technology] and over the next couple years we'd go take [samples] and do measurements and demonstrate, 'Yeah, it works very well.'***

...

*From all those things, eventually then, [we] work with the sponsoring agency **who then worked to get a license to commercialize this**. ... So we help those agencies try to find outside groups who would manufacture the [technology] and so on.*

Interviewer: If I understand correctly, you've worked with both companies, private organizations, and you've worked with state agencies in partnership with the research that you're doing.

*Participant: That is correct. My colleague who is [an expert in this] area obviously works and **publishes in the [relevant] journals** and the manufacturing people, who are the professional societies in [related to the technology]. So as he*

would **present papers and information** there, other people would contact him and get involved in the project. **Being an academic, normally we publish information, publish research results.** As those results become public, interested parties would contact us to say, 'Oh, I'm interested in that research. Can you come talk to me, or present this information in my company or some place?' **Then, as commercial developments or interest gets closer, they say, 'Well, look, we'd like to do some work with you. Maybe we can fund some research, or give you a site or have you work with our people or our [technologies].'** So we worked through all those types of things. – F_S3_3

This participant identifies a mixture of both traditional (publications, presentations, research collaborations) and commercialization-specific (licenses and product development) outcomes. Moreover, the description highlights the ways in which the two types of outcomes worked synergistically to benefit each other, with publication generating collaboration that leads to licensing, which in turn generates new research questions.

In addition to linking commercialization to publication, faculty members also reported using commercial activities to secure additional funding. In the following excerpts, for example, one participant describes securing funding through commercialization activity as “one of the best mechanisms to keep your lab going.”

They [a private organization] want you to do... basically how they reward you is if you got an SBIR grant or an STTR grant, they'll give you a supplemental grant. Let's you got 200k to do X. Then you can get another 100k to say, 'Hey, we might be able to use this base concept, but try something different over here. Do something.' So we got the award. – F_S1_1

There's one time I got 25k and they [a startup company] got a 150k. I'm using it. That's something that people don't realize. This is one of the best mechanisms to keep your lab going too. – F_S1_1

As with *Commercial Outcomes*, faculty members described a range of other *Scholarly Outcomes*. For example, publicity or enhanced reputation can result from commercialization activity and can lead to industry-sponsored research studies (e.g., a follow-up study to advance the technology) or, larger, formal university-industry partnerships. Faculty members can also win awards based on their commercialization activity and which can increase their reputation in the field, an important consideration for promotion into higher faculty ranks. As previously

discussed, publications and patents resulting from commercialization activity or follow-up research can be added to P&T dossiers and faculty activity reports, providing evidence of a faculty members' excellence and impact in their field. Finally, engagement with university commercialization, when students are invited into the process, can help students find jobs upon graduation, and can be a valuable teaching tool for students.

Learning

The third key outcome that emerged from the data analysis was university commercialization's ability to support further learning, not only for the faculty members themselves, but for their colleagues and their students. While this theme could be considered part of *Scholarly Outcomes*, the value it was given and frequency it was discussed by faculty members warranted making it a separate theme. At the most obvious level, faculty described learning from prior commercialization experiences in ways that benefited their engagement with subsequent commercialization efforts.

*I was just going to say, but even that **what's been good is when I'm learning stuff, just lessons learned from one experience doing the tech transfer, has been very useful for the others.** Like 'Oh, should we go to this big company? No, no, I remember when these guys did it. They didn't... It was too early. Maybe we can... Let's not talk to venture capitalists yet. We're way too early.'* – F_S1_1

Another faculty member describes how their commercialization activity has resulted in a senior research engineer's decision to participate in a university commercialization workshop in order to help learn how to start a company. As described in the quote that follows, this learning is important because the research engineer will be the individual launching the university-based startup company.

*One of those [provisional patents] is currently in the process of being filed as a patent. It has to do with [describes technology.] We've put in a few, of course, follow-on proposals. **One of the senior research engineers is interested in starting a company on this and is in the process of participating in an entrepreneurship program that the university has established, which involves a [detail redacted] series of workshops. I'm assuming that once that they're all done, he'll be the key person in launching that activity.*** – F_S3_3

Once trained the research engineering will also bring this new knowledge back into the lab. This example illustrates how a faculty member's engagement in university commercialization can help their colleagues learn about commercialization.

At the same time, participants also discussed the ways in which their commercialization experiences supported student learning. In the following excerpt, for example, one participant describes using commercialization experiences in the classroom to teach technical concepts.

It [having commercialization experience] helps a lot because in a classroom, I can tell them stories. I tell them stories about the things that I've done wearing my industry hat. And stories are the best way that you can teach someone. We're programmed to convey information by stories. Before there was a written language, people conveyed information from stories. And these industry experiences are great for being able to tell those stories about technical concepts that you want them to remember. – F_S1_3

Elsewhere in the interview, this faculty member elaborates on the impact of commercialization on their students' learning.

But to me it's [commercialization] an absolutely wonderful training environment for a variety of different students. I don't think you can do a good job on the technology development piece of it unless you understand fundamental science. So there's lots of stuff there for students who are interested in the more basic aspect of what we do to benefit from and to do their research and to publish papers and write a great thesis and get themselves into a great post doc. And I've had students go to some of the best labs in the country based on the work that they did for me. I've had students go to industry. I've had students go to venture capital firms that start startups based on the work that they've done for me, because I've got a whole continuum of different types of research funded in a variety of different ways from the very basic to the very entrepreneurial. And I can tailor that to a specific student and expose them to many things that are going to be of benefit to them. So it's all about filling out their CV with those experiences and being able to convey that experience to somebody else who's interesting in hiring them to do something similar in their lab or in their company. And it's worked out really well, I mean, I've had I think a lot of... I've benefited from a lot really great students that have done really good scientific work. They, in turn, have benefited from some of these experiences and been able to leverage those into some really nice opportunities to start their careers. So, I think it's a great way to teach students. – F_S1_3

In a final student-learning example, another faculty member describes commercialization engagement as a mechanism to teach students about communication, the "IP process," and

leadership skills within the R&D process. This participant sees commercialization knowledge and learning as a way to help students “be successful” and avoid mediocrity.

I think that this [commercialization engagement] is educational. In my view, a person with a PhD in Engineering should be a, well, if they go to academia that's a different story, but if they go to industry, they should probably be some type of leader in the R&D process at some company. And if they have a leadership position, then they should have the skills, not just the skills to let's say write software or something like that. They should have the skills to make presentations to other people at the company. They should have the skills to explain things to people in other groups. Like, they maybe worked on a prototype and now the other group needs to implement something related to that prototype. They need to be able to understand the IP process as part of being in a leadership position in the design process. So I think that I'm trying to train them to be—I want them to be successful, I don't want them to be mediocre. So, I'm trying to train them with a variety of skills. – F_S2_3

Comments such as these highlight the ways in which faculty see their commercialization experiences enhancing teaching and learning, particularly for graduate students. These comments also illustrate how commercialization can help these students build a range of critical professional skills that are essential to contemporary engineering practice.

4.2.8 Affect

The final aspect of the faculty commercialization activity system was *Affect*. *Affect* was operationalized as participants' expression of emotion or the acknowledgement that commercialization engagement had an effect on the faculty member's mental or emotional state. As indicated in Figure 17, *Affect* both precedes and results from faculty members' participation in university commercialization. As a precedent, faculty member brought an emotional or attitudinal state to their commercialization experiences; therefore, participants' affect often impacted multiple elements of the activity system. At the same time, engaging in commercialization (and any specific element of the activity system) impacted faculty members' affect toward commercialization.

Generally, participants described experiencing a range of affective states throughout the process, as illustrated by the following comment.

My role is actually fairly small in the company, and I've gone through being pessimistic to being euphoric about it. Right now I'm euphoric. I think it's going to do very, very well as it stands now. – F_S1_2

While not all participants always expressed moving between these two extremes, discussions typically included both *Positive* and *Negative Affect*.

Positive Affect

Positive Affect identifies emotions and mental states indicating positive motives or evaluations of the university commercialization system (e.g., positive feelings toward university commercialization, interest in commercialization, or lack of discomfort or stress). In some cases, positive affect was linked to elements of the system that govern the commercialization process, as when one faculty member, describing a favorable change to the university patent policy, happily says,

“This is amazing. This is a good policy. This is a forward-thinking policy.” – F_S3_1

More often, however, positive affect was linked to *Object/Motive* or *Outcomes*. One faculty member excitedly describes their desire to have more impact through commercialization, comparing their feelings to those experienced after winning a championship.

And just to have that level of impact, obviously you just want to see that...you want to do it again. You talk to most faculty who don't go through the entrepreneurship or the tech transfer process and their biggest regret in their careers, especially the ones that are lifelong academics, is that they never got to see something go to that point [in which it has a significant impact on society]. And I've gotten to do it and it's just kind of like when you win a championship or something. You spend about two days celebrating it and all of a sudden you're just thinking about the next one. – F_S2_4

While these examples represent only a few ways that faculty members illustrated *Positive Affect*, *Positive Affect* expressions also included attitudes towards colleagues (developing trusting relationships and interesting partnerships), positive comments from outcomes (celebrating and satisfied with the experience), and desire to participate because of an enjoyment of the process itself (interested, excited, and appreciative).

Negative Affect

However, not all expressions of affect were positive. *Negative Affect* identifies emotions and mental states that result in negative evaluations of the university commercialization system (e.g., negative feelings toward university commercialization, disinterest in commercialization, discomfort or stress). Notably, these negative emotions were most often connected to the *Rules*, *Tools*, *Community*, and *Division of Labor* and less frequently associated with participants' *Object/Motive* or commercialization *Outcomes*. That is, where innate interest and successful commercialization experiences often led to positive feelings of satisfaction, failures (products or ideas that were not successful in the market) did not necessarily lead to negative feelings. Instead, across cases, participants' strongest negative affect was frustration with the process. One faculty member admitted during their interview that they were "venting" about policies and norms that they did not agree with. As illustrated in the following excerpt, this participant stated that they have had to fight with the university over the clarification of a policy, ultimately turning away work because of the policy.

*And I have **fought continually** to actually try to get [University] to say, "The statement of work you've presented does not overlap with any of your work here." And I've been mildly successful in that. And so, **I have given work away. I've had other people doing work that I couldn't do because of that.** – F_S2_2*

Similarly, during a discussion about university commercialization procedures, another faculty member described their frustration with the amount of paperwork and the timeline required to complete it. The participant stated:

***That's a horrible thing. That form almost makes you not want to do anything. That's been a disgusting thing.** I had a grant that I got in July. [specific date removed]. We finally got awarded [in January of the following year] because of that paperwork. Again, if there's something they could improve on is to make that all electronic. I kind of understand it, why you need some of that paperwork, but **it shouldn't take 7 months.** I spent every day working on it. – F_S1_1*

While the previous excerpts highlight frustrations with specific rules, in other cases the frustration was more generally directed at *University Actors/Entities*. For example, one faculty member expressed their belief regarding why most faculty are frustrated with the technology transfer office.

Faculty hate that [being told that [the TTO] isn't willing to go out on a limb without company backing], and faculty resent tech transfer office because of it. Because basically, what the tech transfer office's saying is your baby's ugly and nobody like to hear that their baby's ugly. – F_S1_3

Here the participant explains that some faculty get personally offended when the technology transfer office is unwilling to commit resources without company remuneration.

Beyond expressions of frustration, faculty participants also described being uncertain about aspects of the university commercialization system. For example, the following quote illustrates one faculty member's uncertainty about the rules associated with faculty time commitment.

*Participant: I think one of issues for entrepreneurship, particularly within our department, is time commitment and how you interpret the rules regarding time with outside activities. **I still actually, after all these years, don't have a clear interpretation of the real university position on time commitment.** It varies depending on who you asked. If you ask some, they will say that, 'You should not work more than 8 hours on external activities per week, during the school year, and none in the summer if you're charging in the summer.' None. That's one extreme of it. The other extreme is, 'Eh. Just as long as you get your work done, I don't care.' I have heard different stories from different people in the university.*

Interviewer: At the department level or more broadly or both?

*Participant: College and department level. **So yeah this leaves you in an uncomfortable position, obviously. When there's not uniformity in this issue.** – F_S1_2*

Similar to *Positive Affect*, the examples provided here represent only a small subset of the data captured within the theme *Negative Affect*. Participants expressed negative feelings associated with being stigmatized by their peers, disappointed with the outcome of a negotiation, and, most commonly, frustrated with the way commercialization process operates at their university.

4.3 Differences Between Cases.

Because the data revealed such strong similarities across faculty members' experiences, as noted earlier, the results focus on themes aggregated across the cases. However, several potential differences among the cases also emerged from the data. Given the limited evidence for these difference, they are presented here as potential areas for future exploration rather than

definitive markers. These differences may be suggestive of future explanations and will inform future research including additional interviews, cases, and analyses.

4.3.1 The University Commercialization Ecosystems

The first difference identified among cases is the existing university commercialization ecosystem at each university. Two of the three case sites have more robust commercialization ecosystems than that of third; the third is in a transition period in which the emphasis on innovation and entrepreneurship is growing across the campus. The two sites with robust ecosystems offered a wide range of established entrepreneurial programs dedicated to supporting both faculty and students' ability to commercialize ideas and technologies. As one an administrative participant explained, their university was an "early adopter" of commercialization, is a commercialization "leader" among engineering-focused schools, has supported the evolution of its commercialization ecosystem, and has established a "clear-cut way of doing" commercialization.

Well, it's [the commercialization ecosystem] certainly has evolved as technology transfer at all universities with the Bayh-Dole Act back in the early 80s. And of course, there was something called inventions, spin-outs, and everything before that, but certainly, Bayh-Dole helped crystallized that and make it clear who owned what, and who was in charge, and what you had to do in order to protect your intellectual property; who had the ownership, and then what you did it, and the requirements to do what you needed to do at that time. So we were one of the early adopters I think, [our university], to getting that done through our [senior leadership] at that time. And we're one of probably the leaders, I guess you could say, in the country in terms of doing that, especially, at an Engineering-type school. Perhaps, not the first, but –because previously I think a lot of the inventions and things related to this kind of activity came from the agricultural side, and from life sciences, and food—Gatorade if you will. And then before that drugs were from University of Wisconsin and all that. And it still is to a large extent, that's really where the money tends to be. So it's somewhat new for Engineering, even though there –you would think that there would be a lot of inventions and biomedical devices, and things like that. So we have evolved with that whole process, and the climate has always been encouraged here at [our university] to go through the process; do inventions, disclosures, patent applications, patents, licenses, spin-out companies, seeking funding for all those things. I think it's always been encouraged,

...

So I think it's evolved over time—much more accepted and encouraged now, virtually in every department. I don't know of one department that does not

encourage the process or –and it’s a pretty clear-cut way of doing –going through the process now. – A_S2_1

The robustness of this university’s ecosystem was also acknowledged by at least one faculty participant as evidenced in the following excerpt.

Participant: And it does seem like that [our university] is much more organized, and has policies about IP much better than - well, yeah, every other university I've been a part of, and then, from what I hear from others. Other universities, I guess the hearsay that I hear is that that they are understaffed, they are disorganized, they don't know what's going on, they do things last minute. That kind of a crisis mode is not helpful in IP.

Interviewer: And that experience is not true in [your institution]. They are organized, and they don't operate in that crisis mode?

Participant: Yes. Yes. Definitely. – F_S2_6

These robust, established commercialization ecosystems are also evidenced by the organization of both universities’ commercialization documentation. Each has a central website that provides an organized range of resources for faculty and students (e.g., policy documents, guides, and links to additional resources).

These robust ecosystems contrast sharply with the developing ecosystem at third site. Over the past few years, and especially with changes in leadership, this institution has placed a greater emphasis on commercialization by developing new programs, changing intellectual property policies, and establishing partnerships between the relevant university commercialization community members. This institution is also in the midst of testing and refining its commercialization support mechanisms; therefore, programs and services, like a recently defunct university-affiliated incubator/accelerator, are still in flux. Like the two robust universities, the third institution has recently created a centralized repository for university commercialization information, but it is in much more nascent form.

Notably, these contextual differences also coincided with two of the three other differences noted among the cases, *Community Entrepreneurship Centers* and *Negative Affect*.

4.3.2 Acknowledging the Community: Entrepreneurship Centers & Individuals

One of the key differences among the cases was the way in which the participants discussed the campus units linked to innovation and entrepreneurship. First, while participants

across all cases frequently discussed the institution's technology transfer office (TTO) as an important member of the commercialization *Community*, only faculty participants at the site with the robust entrepreneurship and commercialization ecosystem consistently discussed their university's formal center for entrepreneurship, a center with a mission to train and support both students' and faculty members' entrepreneurial endeavors. At the other institutions, only a single participant at each institution mentioned either the university's entrepreneurship center or an "entrepreneurial programs" within the College of Engineering.

Second, case participants differed in the ways in which they discussed the individuals within the innovation and entrepreneurship communities. Participants at the institution still developing its commercialization ecosystem frequently mentioned specific individuals within their commercialization activity system by name. Conversely, participants at the two institutions with robust commercialization ecosystems spoke generally about the types of people in their university commercialization communities (e.g., tech transfer staff, an investor, an administrator, etc.). I hypothesize that this difference could be related to the robustness of the existing ecosystem. Because two of the sites had robust ecosystems with a range of established resources and university-level sources of support, specific individuals at these universities may be less likely to be called upon for support or touted as stand-out entrepreneurial faculty/administrators. At the developing site, the ecosystem may be more dependent on the specific individuals driving these new efforts, and faculty may see them as key players rather than trusting units or programs generally. However, additional study is needed to fully understand these differences.

4.3.3 Negative Affect

Another difference among cases is the amount of *Negative Affect* expressed by faculty participants at the non-robust site. While *Negative Affect* was present within each case, all participants at the site with the growing ecosystem had negative thoughts or emotions related to their commercialization experiences. These participants represent the only case where negative affect was universal. In fact, approximately two-thirds of the segments coded for *Negative Affect* are from this case, with only 15-20% of the segments from each of the other cases respectively. I hypothesize that the abundance of negative thoughts and emotions can be linked to the fact that the university is early in the development of their commercialization ecosystem and, understandably, faculty are experiencing growing pains normal to any broad institutional change.

4.3.4 Wide Variation of Possible Tools

The final difference among cases seems to have no link to the robustness of the commercialization ecosystem. After coding and refining the *Tools* category for all three cases, it became clear that faculty at each site utilize very different *Tools* to engage in commercialization. Interestingly, faculty participants in one of the cases I previously deemed as having a robust ecosystem did not mention any *Commercialization Trainings & Seminars*, though this tool was mentioned by participants at the second robust site. I believe the range of *Tools* and discrepancy within the data may be to multiple factors including a combination of the breadth of possible *Tools* relevant to university commercialization; the uniqueness of each faculty member's current and past commercialization experiences; and the contextual differences between institutions and disciplines. The lack of similarity in the *Tools* activity system element represents an important contribution of this study and an outcome that should be explored further in future studies.

Chapter 5: Commercialization Supports and Challenges

In this chapter, I turn to the study's second research question:

RQ 2: How do elements of the university system support or challenge engineering faculty members' commercialization experiences?

My analysis identified factors supporting and challenging faculty members' engagement in university commercialization that were common across cases. As with the description of the commercialization system itself, faculty interviews represent the primary source for the findings in this chapter, but university commercialization documentation and the engineering administrator interviews clarified and confirmed these findings.

In order to describe supports and challenges that are meaningful and actionable, I organized the findings utilizing four supports/challenges categories, *Individual Attributes*, *Commercialization Resources*, *Formal and Informal Rules*, and *Time Commitment*, as summarized in Table 16 and described in detail in the remainder of the chapter. While this chapter reports the supporting and challenging characteristics of faculty members' commercialization experiences, the limited number of cases in the study makes it premature to make claims such as, "A supportive/challenging university commercialization system has X characteristics, organized in the following way." Instead, the results highlight *some* characteristics of supportive and challenging university commercialization systems, and further research should be conducted to determine additional characteristics as well as possible interconnections between these characteristics.

Table 16:

Provisional Faculty Commercialization Supports and Challenges

	<u>Individual Attributes</u>	<u>Commercialization Resources</u>	<u>Formal and Informal Rules</u>	<u>Time Commitment</u>
<u>Supporting Characteristics</u>	<ul style="list-style-type: none"> • Prior Experience • Knowledge/Expertise • Building Relationships 	<ul style="list-style-type: none"> • The Technology Transfer Office • Funding • Seminars and Trainings • Access to Knowledgeable Colleagues 	<ul style="list-style-type: none"> • Attitudes among university leaders 	None
<u>Challenging Characteristics</u>	<ul style="list-style-type: none"> • Prior Experience • Knowledge/Expertise • Building Relationships 	<ul style="list-style-type: none"> • The Technology Transfer Office • Funding • Seminars and Trainings 	<ul style="list-style-type: none"> • Intellectual Property and Patenting • Company Partnership • Attitudes among individual faculty • Promotion and Tenure 	Spanned all challenge categories

5.1 University Commercialization Supports

As highlighted in Table 16, participants identified supports for 3 of the 4 categories, and Section 5.1 illustrates the ways participants discussed these supports.

5.1.1 Individual Attributes

As detailed in Table 16, *Individual Attributes* aggregates the supports that pertain to characteristics of the faculty engaging in commercialization. Across the data, participants described two key attributes: 1) prior commercialization experience and/or an understanding of commercialization, and 2) the ability to build relationships.

Prior Commercialization Experience and Commercialization Knowledge/Expertise

Prior university commercialization experience and commercialization knowledge and expertise are linked concepts within the data, both supporting faculty members' commercialization experiences. While prior commercialization experiences were not the only mechanisms to increase knowledge and expertise, they were quite common and many participants described using what they learned from participating in prior commercialization

efforts as a key support in subsequent activities. In general, faculty participants expressed the positive impact that prior commercialization experience had, regardless of whether those experiences were in university or industrial settings.

For example, one participant described their prior experiences as beneficial for overcoming the “daunting,” “challenging,” and the potentially “costly” nature of university commercialization.

*...I can see where for people who haven't had prior experience, it's very daunting and it's very challenging and it's very easy to make mistakes that are very costly later on. **I benefited tremendously from having been through those situations before...** – F_S1_3*

As another participant's comment illustrates, their prior commercialization experience and learning things “along the way” taught them about the industry norms important for university commercialization. In this example, the participant describes a lack of knowledge prior to engaging in university commercialization, but after a few years of engagement they are now more knowledgeable about potentially challenging and unfamiliar startup-related business practices (such as using revenue multipliers to value a company).

*Participant: So if you're making let's say 50 million dollars in revenue and you're in a market that has a 3.2x multiplier on revenue for evaluation, then you're worth about 170 million dollars. **So those are the sorts of industry norms that go into those dollar figures.***

Interviewer: And where did you learn about those industry norms or where did those become part of your attitudes, part of your every day speak?

*Participant: This is all stuff **I've learned along the way. I knew none of this going into it. It's just been the last 3 years of being a part of this environment. I've sort of picked these things up along the way.** – F_S1_4*

While some participants gathered their experiences after become faculty members, others described previous settings. For example, one participant described feeling fortunate that their graduate advisor had an interest in university commercialization because this interest resulted in their ability to learn about university commercialization as a graduate student. Interestingly, although this participant also had industry-based commercialization experience prior to becoming a faculty member, they highlighted these graduate school experiences to demonstrate “how [university commercialization] can work in an academic context.”

One thing I would add is that I was fortunate in graduate school to have an advisor [who was interested in university commercialization] and [to] experience the process of thinking through what's new and what might be a good idea, writing it down in an invention disclosure, and then beginning that process. So I had two examples early on in my graduate training of how [university commercialization] can work in an academic context... – F_S2_6

Similarly, many participants had industry experience prior to becoming faculty members. This industry experience helped them gain knowledge and expertise they could easily translate to university commercialization (e.g., determining the patentability and potential value of their research findings). One of these sentiments is captured in the following excerpt:

When I became a professor here at the university—because I had a business background, or industrial background, prior to becoming a professor— in addition to normal duties of teaching tech research, I was always very applications oriented. As I worked through projects, I would look through projects I would look through and say, ‘Oh, you know, this might have some patentability.’ Because I knew how to file patent disclosures, those types of information, it was very easy for me to send those forward and say, ‘Hey, here's something that might have some value.’ – F_S3_3

As this section illustrates, these prior experiences supported participants in their commercialization activities by helping them understand the process, orienting them towards market applicability, and preparing them for the types of challenges that inevitably occur.

Building Relationships

In addition to evaluating the patentability and potential value of research findings, prior industry experience also supported faculty members as they built and mediated relationships with industry partners. Of the various roles that faculty described (Section 4.2.6), building relationships was the one most consistently identified as a critical support. Participants described relationships not only with industry partners, but also with staff in the technology transfer office, other faculty, business-oriented individuals outside the university, and specific mentors/advisors. In the following example, a faculty member describes their belief that having “a really good relationship with an industrial partner” based on “trust” has supported their ability to successfully license multiple patents. Specifically, the faculty member stresses accountability and appreciation of the industrial climate in building a trusting relationship:

*...we have three more patents that are going to be licensed by a company. So very successful at that. **That all relies on the fact that you need to have a really good relationship with the industrial partner.** They have to **trust** you, and they have to know that you're going to deliver, and they have to know that you appreciate the industrial climate. – F_S1_6*

Another faculty member also emphasizes trust when developing relationships with business people, because establishing a trusting relationship can lower faculty members' burden with respect to the business aspects of university commercialization, an area in which they feel less competent:

*One of the things I've learned in my entrepreneurship activity is that **it's good to marry business people with technical people.** Don't expect technical people like myself to be good business people. **You need to find someone that you can trust and who is capable of handling the business issues.** – F_S1_2*

Participants also emphasized the importance of developing good relationships with technology transfer offices (TTOs). For example, one faculty member described knowing a large portion of the “friendly” TTO staff and how the TTO staff is excited to work with them. Interestingly, the participant describes a belief that not enough faculty make the effort to utilize (or build a relationship with) the TTO staff.

*I can easily tell you if it's patentable. I'm very well versed in figuring that out. Whether it's worth patenting, that's where they [the technology transfer office] come in. That's where they're extremely valuable. But they're very accessible. **At this point, I know half that office and they're just friendly.** They're really excited to get—I don't think enough of the faculty—you almost get the **impression that not enough of the faculty utilize them.** They love it because **no one should be that excited to see me walk in the door.** They like being part of this stuff. – F_S2_4*

Considering the TTO's role in the commercialization process (see Chapter 4), it is logical that building a relationship with staff in the TTO supports university commercialization activity.

Finally, participants also described building relationships with other knowledgeable individuals (faculty, business people, mentors) who could help answer the many questions that arise during any university commercialization experience. One participant explained that these relationships go beyond information, which is needed but can be obtained through other

resources, and, instead, described the value of the relationships as having someone to “walk you through, and to help you.”

I think that you have to have really good people who you work with and connect with, so that you can get your questions answered, because you're going to have a lot of question. You need a relationship. I think that a collaboration is really important, more so than just reading documents and going through a program. I think they need to know, yes, the program is great, yes, the information is okay, but if you don't have someone to walk you through, and to help you, then this may be a little bit problematic. – F_S3_5

Across participants, then, this awareness of the importance of relationships coupled with the ability to successfully build relationships grounded in trust played a key role in supporting faculty members’ commercialization efforts in terms of navigating the intricacies and challenges of system.

5.1.2 Commercialization Resources

Moving beyond the individual, participants also identified multiple resource-based supports within their commercialization activity systems, including technology transfer offices (TTOs), funding for commercial activities, commercialization-focused seminars and trainings, and access to knowledgeable colleagues.

The Technology Transfer Office (TTO)

University technology transfer offices were developed as a result of the Bayh-Dole Act of 1980 and 1983 to support and govern university technology transfer and commercialization activities, and therefore logically they should be a source of support. Faculty confirmed this support in two primary ways. First, TTOs can provide knowledge and expertise, as the follow excerpt illustrates:

Interviewer: So how do you know that information [info about the university and intellectual property rules/regulations at a land-grant institution]?

Participant: Oh, just conversations with [the technology transfer office] and with the university lawyers. Since I have a lot of patent experience, we just kind of talk shop. That’s one of the things you know especially, I think it was well understood that even though I understood the whole patent filing process better than some that I didn’t necessarily understand the nuances of tech transfer in a university. So all of these guys were coaching me. They were readjusting my understanding so that I was more inline with how academics works. – F_S2_4

Second, participants described the TTO as a resource that performs a range of university *Commercialization-Specific Roles* (Section 4.2.6), including market analysis, evaluating potential value, legal activities, and helping to manage relationships with partner companies. As one faculty member explains, the TTO can support commercialization activity by conducting market analysis, evaluating potential value, and giving discoveries an “honest vetting.”

And so this is the one thing, this is where I really come to trust my tech transfer office, if I have ideas. Because I can go to them and they will give it an honest vetting, and it's a commercialization analysis and the type of stuff that I can't do. I don't run the necessarily market analysis and that's kind of stuff that I'm not good at or I can't put numbers on it. I can easily tell you if it's patentable. I'm very well versed in figuring that out. Whether it's worth patenting, that's where they come in. That's where they're extremely valuable. – F_S2_4

Another participant discussed the TTO as a resource that can make sure “everything is legal,” stating,

Well, they [faculty interested in university commercialization] would probably need to go chat with people like [the TTO] to make sure that everything is legal. They definitely don't want to do anything illegal. – F_S2_3

Lastly, participants described TTOs as playing a key role in helping to mediate partnerships with external companies, as illustrated in the following quote:

Similarly, when it came to contracts for grants and things, when industry would support that, of course they would come in with having to work through the intellectual property rights for anything that was created or developed during patenting. So I would normally work with them [industry], and of course [my university's] intellectual property group [the TTO] in regards to who do I need to report stuff to and what information is necessary. – F_S3_3

As demonstrated, TTOs serve as key resources to not only offer expertise, but also step in and undertake activities faculty are not typically equipped for, and at the same time help faculty protect their own (and the university's) legal and financial interests.

Funding

As with traditional research activities, funding is an important support mechanism for university commercialization because funding reduces the burden on the faculty member and provides tangible resources for R&D. Generally, both the TTO and individual faculty members are supported from funds dedicated to pursuing patent protection on university intellectual property (IP). Without these funds, individual faculty members would be required to self-fund the process of protecting their commercializable discoveries. One faculty member describes the benefits of having this “pot of money” set aside for pursuing IP protection because it reduces the need to ensure funds are available for such purposes.

*If the tech transfer office, or some other entity within the university, **doesn't have a pot of money for pursuing protection of your inventions, you as an investigator will have to take the lead on figuring out how to make that work.** – F_S1_3*

Commercialization-related funds also provide R&D resources, such as the means to develop commercial prototypes, renovate lab space, and develop startup companies. As one participant describes in the following excerpt, they used grant funds to develop a “commercial prototype” of their technology, an activity that can significantly advance their ability to attract and retain licensing partners.

*.. **the grant would actually pay for building a commercial prototype, so we have a bigger version that has been run over the last several years.** – F_S3_4*

Another faculty member used commercialization-related funds from an industrial partner to renovate their lab space. As the faculty member states, their renovated lab space “influences all aspects of IP and research” because they are now able to do things better and more quickly.

*Until the end of last year my lab space was ultimately too dirty, and too small. So **I lobbied with one of my industrial partners to get a gift to upgrade and renovate my lab, and that was that was done [in the past year]. And so, now I can do more things, I can do them better, and do them more quickly. And that influences all aspects of IP and research.** – F_S2_6*

Funding thus supports both the legal costs associated with commercialization and the physical and personnel resources needed to develop tangible products with commercialization potential.

Seminars & Trainings

In addition to the TTO and funding, participants identified commercialization-focused seminars and trainings as a resource that supports their engagement in commercialization. Interestingly, the training provider was less relevant than the content itself in that participants described effective training led by government agencies, private foundations, and their own universities. The following examples highlight the collective impact of these various training opportunities on their university commercialization engagement.

Concerning government training, for example, one participant mentioned how they benefited from the National Science Foundation's I-Corps program as a support.

*And with the [National Science Foundation's] I-Corps program, some of the stuff we were looking at was like minimum viable product. **And so right from the start we're thinking about that here and trying to gear our proposal efforts towards that minimum viable product for [the potential product/technology].***

... [later in the interview] ...

*Obviously one of the big parts of the I-Corps program is the interviews and the calling and finding out what people actually want and **just that mode of thinking was really interesting. And I bought the books and read the books and it was just really interesting, and so I have a new...at least a concept for if I wanted to starts a business someday kind of what maybe some of the first steps may look like. So I'd say it was a success...that I would consider a success. I learned a lot from that.** – F_S1_5*

From this interview and my exploration of the I-Corps program, I-Corps seems particularly beneficial for faculty who want to 1) evaluate the potential value of a technology, 2) determine if and how their research discoveries can become a technology, and 3) learn about starting a company.

In another example, a faculty participant highlighted training from a private foundation, stating

*I took this training from [a private] foundation. I guess it should go in there. **They had this really cool tech transfer training for me.** – F_S1_1*

This participant later described how this training helped shift and reinforce their mindset toward valuing the real-world impact of their university work and the possibility of creating technologies that can help people.

Another participant described how a new university-sponsored commercialization training helped them learn about commercialization.

*I was able to engage with a new program in our [technology transfer office]. It was something called [X], and **they take faculty through this process of commercializing a product.** – F_S3_5*

In this case, the participant described the way the training taught them how to write a business plan and evaluate the value of research discoveries, both critical activities in the commercialization process.

Notably, these trainings were not necessarily limited to faculty, and that, too, served as a support by broadening the base of people within the university who could collaborate on commercialization. For example, one participant described the ways a commercialization training program run by the university would likely help a senior research engineer launch a company based on university technology.

*One of the senior research engineers is interested in starting a company on this and is in the process of participating in **an entrepreneurship program that the university has established**, which involves a [X] series of workshops. **I'm assuming that once that they're all done, he'll be the key person in launching that activity.** – F_S3_4*

By enabling non-tenure-track personnel to assume commercialization-specific roles like starting a company, such trainings free up faculty members' already limited time and thus enhance their ability to succeed in both their traditional and commercialization-related roles. This same participant later elaborated on the changes at the university regarding the growth in programs and resources for faculty that highlight an overall increase in support through training:

*I think that at the present time **we do have programs that help bring people up to speed in terms of the kinds of things, such as developing a business plan and putting together a group just to advise and support, and the kind of commercialization activity that go along with trying to raise money and convince investors and give elevator speeches and those kinds of things.** At the time [in the past] we really didn't have it, and so people were winging it. I think right now, though, we do have resources, in fact, entrepreneurs in residence and all that sort of thing, which **I think makes it a lot more feasible for someone like the senior research engineer I was talking about whose experience really is confined to the university.** He's interacted a lot with industry on projects, but*

hasn't really actually worked in industry or attempted to build a company before.
– F_S3_4

Importantly, these excerpts demonstrate that training programs can play a key role in addressing gaps in individual attributes and make university commercialization “more feasible” for individuals who lack industry or prior commercialization experience.

Access to Knowledgeable Colleagues

The final resource-related support participants discussed was access to knowledgeable colleagues inside and outside the university. One participant described the benefits they experienced through their relationships with an entrepreneur external to the university as follows:

[The entrepreneur I've worked with] is very good about knowing how to raise money, for one. Also managing—he understood the business aspects. He's been through the product development cycle before. And he knew a lot of people too. He knew a team and that was very important. He had a team, a team of people that he could call on, for instance, for administrative or financial. So he could call these people together, build the organization very quickly and know that you have good people. Very important. – F_S1_2

In this example, this entrepreneurial colleague was not only knowledgeable, but also had access to a team of people who could provide additional expertise in commercialization-related domains such as product development and finance.

In many respects, this access is closely linked to the ability to build relationships described earlier: building relationships requires being able to identify and meet individuals who can provide the necessary support. In some cases, access to these individuals is fortuitous; faculty may know individuals through their prior experiences, through a friend of a friend, or through professional networks. In other cases, however, TTOs or training programs such as the NSF I-Corps program can serve as conduits to help initiate the relationship. Faculty still need to be able to build and leverage those relationships, as noted in Section 5.1.1, but access to potential relationships can be facilitated from within the system. The same participant who noted the importance of developing relationships with people who can answer questions and “walk you through” the university commercialization process highlighted the centrality of this access:

I think that you have to have really good people who you work with and connect with, so that you can get your questions answered, because you're going to have

a lot of question. You need a relationship. I think that a collaboration is really important, more so than just reading documents and going through a program. I think they need to know, yes, the program is great, yes, the information is okay, but if you don't have someone to walk you through, and to help you, then this may be a little bit problematic. – F_S3_5

Commercialization resources, then, in the form of services, funds, and support, collectively provide key tools to enable faculty to engage in university commercialization.

5.1.3 Formal and Informal Rules

Commercialization Attitudes

Commercialization Attitudes, or the views and opinions regarding commercialization within the university also supported faculty who sought to commercialize. Faculty members described *Commercialization Attitudes* as supportive when there was a general acceptance for university commercialization at the university and/or college-levels of the work system. As illustrated in the following excerpt, one participant believed that their institution's acceptance of entrepreneurial activity was a key benefit of working at the university. Since this faculty member had prior experience working outside academia, the flexibility of faculty work combined with the institution's acceptance of entrepreneurial activity impacted their decision to remain an employee at the university.

I think the ability for me to do the entrepreneurship is a major benefit of staying at the university. So, an alternate reality where I wouldn't be able to do any entrepreneurship at all, might be a reality in which I'm not a Professor at [the university]! – F_S1_4

In another example, a faculty member identified specific ways that their university has accepted university commercialization, valued university commercialization, and sought to encourage its value among its employees. As detailed below, the faculty member identifies supportive attitudes as demonstrated by overall support for existing commercialization activities, leadership that values commercialization, commercialization-friendly rules, and opportunities for commercialization-related funding:

.. I think, my university has been overall fairly supportive of IP generation and transfer. So I credit them for that. But they've been supportive in the sense of

talking about it, saying that we value it, encouraging department heads and faculty to also value it in terms of dossier and tenure and evaluation obviously. And I do credit the university that they have at least one funding program where proposals can be submitted for an initial seed funding for [amount redacted] a year. – F_S2_6

Participants also identified supportive attitudes by describing supportive college-level administrators and department heads, as illustrated in the following examples (one at each of the three sites).

*Interviewer: So **thinking about the current climate in your department**, right? Let's say someone who just became an associate professor, right? Goes to the department meeting or the promotion committee and says, "You know I have this really good opportunity to do [university commercialization] ..."*

*Participant: Look, look, look... **the department head has his own company. It's just not an issue here anymore.***

*Interviewer: Would you say that that's **true across the university or within engineering** across the university?*

Participant: I'll tell you it's certainly true within engineering. – F_S2_1

*And we found nothing but **support from the Department Head**, and before we launched both of the companies we went and talked to the **Department Head about it and they were generally supportive of it.** – F_S1_4*

*Certainly, I think the university has made **entrepreneurship more visible, and certainly describes successful activities of the faculty in the commercialization area.** – F_S3_4*

Interestingly, at two of the three sites, participants acknowledged that attitudes toward commercialization are in flux due to leadership changes. After describing leadership changes and programs that have effectively enhanced the university commercialization attitudes, the participant explained:

*Hey, **this is the environment [now] that will help transform faculty, staff, and students into thinking, oh, what we discover in the university could and should and can be taken out into the community.** I don't care whether it's a new wheel that makes things work better or it's a blood test that saves lives. – F_S3_1*

Therefore, even when attitudes among individual faculty members may vary (see Section 4.2.4), visible university endorsement of commercialization and positive attitudes from administrators can create an important space in which faculty are able to engage in commercialization.

5.2 University Commercialization Challenges

Many of the categories that provided sources of support for faculty engagement in university commercialization also emerged as sources of challenges. In general, when the presence of a characteristic acted as a support, the absence of the same characteristic also acted as a challenge. However, additional challenges also emerged, specifically associated with *Formal and Informal Rules* and *Time Commitment*. Although a few faculty noted some changes in *Rules* that had created a slightly more favorable or flexible commercialization environment, in general, these two categories both represented hurdles faculty had to overcome or work around in order to engage in commercialization.

5.2.1 Individual Attributes

Even as certain individual experiences, knowledge, and skills support faculty engagement in commercialization, gaps in these areas pose challenges. In particular, both lack of knowledge and inability to build relationships, particularly with industry partners, emerged as key challenges.

Lack of Commercialization Knowledge

As noted above, prior commercialization experiences often provided the knowledge and skills participants needed for subsequent efforts. In the same way, lack of knowledge and expertise are considered challenges. As one participant stated regarding the kinds of communication practices needed in commercialization, most faculty “are not really prepared for [writing a business plan].” The participant described making the switch between traditional faculty work and university commercialization as challenging.

*Sure. I think that **writing a business plan is very different than doing academic research, and we, I think, [those in my field], are not really prepared for [writing a business plan].** I had wonderful mentoring. I had a financial person who worked with me, someone else who had worked as a co-founder on another business, and they were with me step by step, so looking at projections, the marketing plan, that was really interesting, but **I think it was somewhat difficult for me to go from writing abstracts and just justifying the research from, "Oh,***

here's a grant, and here's the [relevant] outcome," to looking at the very succinct marketing aspects of the tool. Why would someone invest in this? – F_S3_5

While the participants in this study, given their experiences, often had such knowledge, they frequently cited a general lack of knowledge regarding commercialization as a primary gap for their peers, as in the following comment.

*When I've talked to people at the university who are not familiar with the patenting process who say: "Hey, I've got this great idea. I've done research and I've found out Y correlates really well to X. I'm going to become a multimillionaire. All I have to do is find a company who will pay me to do this, and I'll be a multimillionaire!" **They don't really understand the process of developing a business, or how to get money or sell a product, how to even produce a product.** They're basically academics that said: "Oh, this idea is worth millions of dollars," which it generally isn't. Implementation of the idea is worth a million dollars, but to get there you generally have to invest a lot of money. **Faculty members generally don't think about that process, they think about the output that we produce, which is the knowledge or the creation of the idea, or the demonstration of the principles of the idea, not actually the implementation or creation of a product or service, and the sales of a product or service.** – F_S3_3*

As this participant noted, faculty seem to focus on “the output that we produce” and not the “implementation or creation of a product or service, and the sale of a product or service”; the participant thus perceived a general gap in faculty knowledge about commercialization process broadly. Another example of faculty members’ general lack of commercialization knowledge, is illustrated by one participant’s statement that faculty members lack knowledge marketing knowledge, an essential skill for commercialization.

*Most faculty member are... they're ambitious but **oftentimes they really don't know how to market. I love my colleagues but many of them, many of them, don't know how to market.** – F_S1_2*

This fact challenges faculty members as they attempt to promote their university discoveries and engage with potential company partners because, as I previously showed in Figure 16, the technology transfer office often requires a company partner in order to file a full patent application and move forward in the university commercialization process. As a result, an

inability to successfully market your discovery can hinder a commercializable discover early in the university commercialization process.

Other participants went even further, characterizing the knowledge gap as an institutional characteristic. A participant with extensive industry experience clearly expressed the fact that universities, and the individuals employed by them, “don’t have a clue about business.” This participant described the lack of knowledge/expertise in business as “tragic” and, later in their interview, goes on to describe how this lack of understanding is causing universities to miss out on an opportunity to fill a nationally-important gap in the R&D/economic development cycle.

*Universities don't have a clue about business. Any of them. MIT has no clue. Harvard has no clue. Berkeley has no clue. Stanford. Where I am, they have no clue. What happens is **they don't have people that know anything about business.** They have people who come to the university because they can't hold down a job in business somewhere. It's true for [Site 3]. **It's really tragic...** – F_S3_2*

In summary, participants highlighted not only their own initial knowledge gaps that made commercialization challenging, but also the gaps in their colleagues and in their universities broadly.

Building Relationships

While acting as a support, building relationships can also act as a challenge for commercialization engagement. One participant stressed that the commercialization process can be challenging to move forward because finding a company partner drives the university patenting process and faculty members typically don’t have existing relationships with company partners/licensees.

*And the U.S. patent has been filed for it. **It has been filed because this was done in collaboration with a company, and the company is paying for the filing. So, you see, everything is driven by if you have a company that's interested.** Now, you can imagine that unless a faculty member is the company interested, it's very unlikely that they're [the faculty member] ever going to know what company is interested. They may have a general idea of what is valued, but it's going to be very difficult to go forward. **So [the TTO] won't go forward, unless you have a company. And typically, a faculty member is not going to know the company.** – F_S2_2*

Faculty also described a general lack of support for building relationships with companies. For example, one participant described that they, not the TTO, are primarily responsible for connecting with potential company partners and that most of their success in this area is due to having prior industry networks.

Interviewer: How much of that negotiation with finding that big company do you do vs. [the TTO]?

*Participant: I've done almost all of that. That's kind of where the problem is too... I don't think it's [the TTO's] fault. They've done some things... so that lady that I told you that was really good, she would organize these expos [around the region], these convention centers where people would have IP and stuff out there. And she hooked me up with that company that lost IP and then got it back. **But the big company I had found and the two startups are from me, basically. And even this other company, they would not have been involved if it wasn't that they liked my students and they liked our work. It wasn't really [the TTO]. And that's one of the things that makes it hard and I think it's a lot to do with just being [where we're located], to be honest.***

... (later in the interview)

Interviewer: What do you use help you with finding those big companies and finding those partnerships?

*Participant: It's just networks. A lot of people I knew from when I was as [my former company]. It's really that. **It's really almost solely on stuff that I did before I was here.** – F_SI_1*

Interestingly, the participant also expresses how the university's location represents an additional challenge for connecting with companies/licenseses.

These examples illustrate the challenges associated with lacking commercialization knowledge and building relationships with company partners, especially for faculty members who don't have prior industry experience or existing industry networks.

5.2.2 Commercialization Resources

All but one of the *Commercialization Resources* that was identified as being a support was also identified as being a challenge to faculty commercialization activity. The technology transfer office, commercialization funding, commercialization seminars and trainings all emerged as challenges as well as supports.

The Technology Transfer Office (TTO)

While the technology transfer office acted as a support, participants also described challenges associated with the TTO. For example, participants described the challenges associated with placing the control and responsibility in the hands of the TTO. As one participant explained.

*I disclosed this to [the TTO] as a possible new something that could be commercialized. They put in a provision patent, filed a provision patent on it and **through the course of a year I really didn't hear from them [the TTO] ...at all. I presumed they were supposed to be looking to see if there's somebody willing to license it. I don't know if they looked out there or what they did. I'm not sure what they did. I just found out at the end, after the one year had passed, that the provisional patent has expired essentially meaning that it is not in that form not patentable.** – F_S1_5*

The lack of information from the TTO made giving up control challenging, and left the faculty member with no recourse for pursuing the technology themselves. This same participant believed that, although the TTO maintains control, they actually care less about whether a disclosure succeeds than the individual faculty member:

*...we do the disclosure, the invention disclosure. It gets into the system. And I feel like it's kind of treated just as like—**it was just one more thing in a long list of disclosures to them.** And it's kind of... It's much more important to me than it is to them, and so, yeah... so following that through on my own or like some hypothetical other person that I'd be giving advice to, [I'd tell them,] **'They're [the faculty members] going to care a lot more to keep track of and make sure it succeeds than say [the TTO] will.'** – F_S1_5*

This difference, as the comment suggests, results in faculty members needing to work to “make sure [the project] succeeds” even when they have ceded control.

A related challenge posed by TTOs is the time and detail required for some offices to negotiate and complete the partnership paperwork. One participant, for example, described the process as “horrible” because of what seemed like an unnecessary volume of legal material required by the TTO, even though the partnership seemed very straightforward and had less potential for windfall commercial gains:

Interviewer: Okay. Can you give me a little detail on why it's [developing contracts with industry] a horrible process? You don't have to go ...

*Participant: Takes so long. They want to dot every "i" and cross every "t," even if it probably won't make any difference, right? You know, I mean, who owns the patent and if it's joint ownership of patent, it's joint ownership, right? **But they'll put fifty-seven pages of material in there, and it's always a legal thing, we have to do this.** Okay, great, but this is not Gatorade, so it's not going to be a billion-dollar thing, it might be a few hundred thousand dollars. It's changing how a company builds a technology, it's a practical consideration. It's not an intellectual consideration. We published a couple of papers on it, you know. – F_S3_1*

TTOs, then, even as they provide expertise and take on roles faculty may be ill-equipped for, can also pose challenges in terms of poor communication, inattention (at least perceived inattention), time, and paperwork.

Funding

Participants also identified a lack of funding as a *Commercialization Resource* challenge. Lack of university commercialization resources can, for example, increase faculty members' role in marketing their research and finding partner companies.

A lot of what I see that happens here, it [university commercialization] really has to be professor-driven. They have to find the company and they have to do a lot of the legwork. A part of that is because [the TTO] is really strapped. They don't quite have the resources that they should have. – F_S1_1

Here the barrier is not the TTO itself, as in the cases above, but rather the lack of resources that leave the TTO “strapped” and without the necessary personnel to support commercialization. As a result, university commercialization engagement requires more of a faculty member's time and attention and, in most cases, is subsequently more challenging for the faculty member.

Additionally, participants explicitly identify company partners, and the funding they are required to contribute, as a critical factor in obtaining advanced patent protection (i.e., a full patent) and moving forward in the university commercialization process. This importance is due to the fact that universities often require the licensee to pay for the costs associated with patenting university discoveries (a Formal Rules challenge that will be discussed later). In the following example, the participant was told by the TTO that if they couldn't find a licensee, their limited budget would force them to stop their pursuit of a full patent.

*I'm sure you'll run into them, people who had those experiences where **the tech transfer office said, 'We'll fund the U.S. provisional application, but if we can't***

find somebody to license this thing, that's as far as will take it. We don't have an unlimited budget...'- F_S1_3

Therefore, a lack of funding can pose significant challenges for university commercialization and faculty members' experiences with the process.

Seminars & Trainings

The last *Commercialization Resource* challenge identified by participants involved the dearth of commercialization-focused training; as one faculty member put it,

*There are certainly **no trainings. Zero trainings.** – F_S2_2.*

While participants at the other two sites acknowledged the existence of some university commercialization trainings, even there, participants as well as data from TTO and administrator interviews and university documents highlighted the scarcity of trainings dedicated to helping faculty members commercialize their research. This scarcity presents a challenge to entrepreneurial faculty, not only contributing to a lack of knowledge but also creating frustration, as the following comment illustrates:

***Participant:** So I do think that tech transfer here and at other universities is doing a very poor job of explaining to the faculty members, like what the rules are. OK? So I think that we are not aware of the rules and regulations. For example, when I was informed of this software disclosure thing, I was completely unaware of it. After hearing about it, I understood that. ... I think it would be fair to say that probably every serious research university, there are a ton of regulations that faculty and graduate students receive minimal –they have minimal knowledge about all these things. And I'm sure that, like a lot of us inadvertently break a lot of rules. OK. I'll give you an example. When I joined this university, I had an orientation. Nobody –I don't remember anything about intellectual property. I don't remember one – like ten minutes, definitely not an hour. Now, I understand that when there's stuff –when the orientation is basically designed primarily for staff members. So I believe that maybe 20% of the people in the room are faculty members, incoming faculty. With that in mind, staff members, they are very unlikely to contribute to tech transfer, right? They're very –so, maybe this is reasonable. But how come we don't have a –how come we don't have anything on IP? Like, nothing. So, something here doesn't make sense. – F_S2_3*

As this participant notes, because faculty and graduate students are provided little opportunity to learn about the rules and regulations of university commercialization, not only are they less likely to engage, but those that do engage may even “inadvertently break a lot of rules.”

As noted earlier, however, commercialization seminars and trainings offer the potential to overcome other challenges and leverage other supports; namely, they could provide commercialization knowledge and access to knowledgeable colleagues. That being said, some participants stated that while they were unaware of any commercialization trainings at their university, they aren't sure they would have or take the time to participate in them if they were available.

5.2.3 Formal and Informal Rules

Participants identified a range of formal rules related to university commercialization, and with very few exceptions, described these rules as a challenge. In particular, rules governing intellectual property and patenting and rules governing company partnerships were common hindrances.

Intellectual Property and Patenting Policy

Intellectual property rules pose two major challenges to faculty: the timing of patenting versus publishing and decisions regarding whether to disclose ideas as potentially patentable. With respect to the patenting/publishing challenge, obtaining intellectual property protection and the university patenting process is a support to university commercialization because it allows faculty members and their students to publish potentially commercializable findings. Once a patent has been filed on a discovery, faculty members can then meet the outcomes required in traditional faculty roles by publicizing their findings via conferences and journal publications. However, certain types public disclosures (e.g., enabling disclosures) *prior* to obtaining intellectual property protection places the intellectual property in the public domain, and starts a one-year clock for filing a U.S. patent application. This one-year grace period does not however apply in most non-U.S. countries, thus risking or destroying international patentability. As one faculty participant explained, publicizing prior to patenting can destroy the critical “profit motive” that is needed for potential licensees to justify their investment. But the processes and timing are complex because often funding is required to get a process or product to the point where it has commercial value. As the participant explained, failure to properly protect

intellectual property (i.e. by publishing too early) “may have completely destroyed the potential profitability,” and this failure is one reason many potential technologies will never make it out of university labs.

*And if you're going to be successful in getting beyond just that [small applied trial] to an actual commercial product, you're going to have to do more advanced [applied] studies. It takes more money than you can raise by grant funding and angel investors, I'll tell you that. I know that from first hand experience. **And in order to get somebody to invest those resources, the physical resource, the expertise, and the money, there has to be a profit motive there.** ... You have to be able to capture that potential profitability, so you have to do your research and keeping with that end goal. If your goal is only to get to [small scale, limited applied], you can do that as an academic. Find a collaborator and you can get there, in [my specific field] you could do those one off [applied] studies. **You may have completely destroyed the potential profitability in the process and there's a bunch of different ways that you can do that. Not protecting your intellectual property for example, is one way. If you destroyed that potential, then that small [applied] studies are probably as far as you ever will get. And what the general population doesn't realize is that there's a lot of potential technology sitting in laboratories across this country, across the world, that would be a benefit to a large number of people with differing conditions that will never see the light of day because the profit motive has been sucked out of them.** So like it or not consider it a necessary evil or however you want to characterize it, the profit motive has to be there. My long winded definition is it needs to be successful in the marketplace and those are the reasons why. – F_S1_3*

In addition to potentially destroying the profit motive by publishing/presenting, faculty members also face challenges in terms of university requirements regarding disclosure of any potentially commercializable discoveries from their university work. In short, faculty may experience uncertainty and stress regarding whether or not something is “worth” disclosing. This uncertainty adds to questions about the need to publish and the timeline differences between publishing and patenting. To alleviate this uncertainty and stress, faculty adopt different approaches for their intellectual property disclosures. Some faculty will submit disclosures on everything, regardless of its potential value. This approach means excess disclosures enter into the university commercialization system and can cause undue work for both faculty and the TTO. Other faculty submit no disclosures and instead widely disseminate their discoveries, which, as noted above, can destroy the value and reach of potentially impactful/profitable discoveries and technologies. Some, but not all, faculty have established relationships with the

TTO to help them determine when they need to disclosure and when they can proceed directly to publications.

Company Partnerships

Another set of formal rules that challenge commercialization concern partnerships with companies. In this long but revealing excerpt, a participant describes losing an existing partnership with a company (potentially worth millions of dollars to the university) due to a disconnect between the university and industry partnership processes. The participant described the ways the TTO sought to “own everything” while asking the company to pay for all of the intellectual property protection and pay additional royalties. Such an unequal approach made partnership negotiations difficult because 1) industry partners were not willing to take the risk required by the university’s partnership rules or 2) as described in this example, industry partners had different rules for university-industry collaborations.

*A real company wants to come and work with me. They've already contracted with me at a previous university to do work. They want to continue it here. They give up to millions of dollars to some universities. Okay. We bring them in. **We're going through the negotiations. In the end, due to contractual reasons, they decided not to engage with the university due to a liability clause issue.** But throughout the process, the dialogue that came about was that the university wanted to have ownership of everything that the university invented. But they were offering an upfront licensing fee that a company could pay. And if they paid that, they'd get a non-exclusive license. And this was sort of to encourage industry to come in. Well what fell out in the industry partner, that wanted to engage, actually pointed out in a conversation, in a very cynical manner, is the stance of [my university] is that the faculty should invent. The faculty should disclose. The faculty should articulate with the value is. And then the company should pay all costs for the patents. And once it's awarded, then they will have their nonexclusive right that they've already paid for to use the patent. And if, and oh by the way, there will probably be a royalty that will have to pay on the patent they just paid for. And the company basically said, “Look, we've got a rule. You invent something. You patent it. And then you come to us and pitch it to us and we'll see if we want it or not. And then we'll talk about the licensing fee. If we pay for the patent, we have a standard university clause saying, ‘We'll pay for the patent, we automatically have rights to the patent, no licensing fees; that's our policy.’ And OTT said, ‘No, we don't do that. You need to not only pay for the patent, you basically need to pay for the right - sorry - you need to pay all the work to have the technology owned by [my university]. And once it's owned by [my university], then you need to pay a licensing fee.’ And this is really the model that [the TTO] here uses, is - you've got to find a company that's interested; the company has to pay all costs to make the patent real; and then a*

*company has to pay a licensing fee, or a royalty. Most industry people have the same impression that this Fortune 100 company was - was, if you want to try to sell us on the open market licensing deal, you patent what you think is interesting. **But the way it's set up is, there's this minefield of 'we own everything' until you show interest. And as soon as you show interest, we want you to pay for everything, and then pay us royalties on top. And that's was the first of many hurdles that eventually broke the relationship of the company and they went away.** – F_S2_2*

Thus the internal university rules and expectations worked directly against the participant's ability to successfully engage in a company partnership that would lead to commercialization.

While some of these rules regarding partnerships are university specific, one participant noted that the Bayh-Dole Act itself, which served as a catalyst for university commercialization, simultaneously makes company partnerships too risky for industry partners and licensees to invest meaningful sums of research and development money into university discoveries. As the participant explained, this is due to the fact that companies are unable to guarantee that these discoveries will remain exclusive:

***What you don't know is there's this small print hidden back door [of the Bayh-Dole Act] that allows the government to have a royalty-free license to anything that's done under contract with federal facilities.** If you do it off-campus, that's another story. And that's part of my life, because I learned the hazards of the Bayh-Dole, ... **The point is the Bayh-Dole is inhibiting to companies from working on real things.** That means that the whole thing about Obama trying to get manufacturing out there – everything else is going to fail because no one is taking care of the Bayh-Dole Act problem. They've skirted it and it's a tragedy. What happens is, if you have a friendly company you would like to work with, there's just no way of doing it. What happens is they shove this stuff under the carpet and say, 'Well, we will give the company the right of first refusal to have exclusive right to the IP that comes out.' That doesn't negate the power of the ideas or the covenants of the Bayh-Dole Act so the Bayh-Dole can still give, say to [another company] any proprietary information that comes out of the contract, and that is a serious inhibitor.*

... (a little bit later in the interview) ...

***The truth of the matter is, the Bayh-Dole is killing the American economy as far as encouraging faculty to get out there and do stuff.** It's just going to ruin the country if something isn't done about it. You didn't want me to do a survey or discussion about this, but you need to add this somewhere in your study, because once you uncover all this- I have kept track of this diligently. What happened is, they've tried to make a sweeter deal for companies to be able to own IP as of the last four or five years. That's been happening in the government, but it still*

doesn't eliminate the fact of the Bayh-Dole on IP. It's a hazard, and the truth of the matter is, when you do your due diligence, you'll find if you talk to people who are in the technology transfer office, any place at [university name], doesn't matter, they'll say, "Oh, we don't worry about it, because if we have to, we can always get a waiver." That waiver is a hard thing to get. – F_S3_2

As this section suggest then, federal rules regarding intellectual property and university-industry partnerships, as well as university rules in these same areas, create a myriad of challenges that faculty must navigate if they hope to pursue commercialization activities.

Commercialization Attitudes

While attitudes among university leaders provide a significant source of support for commercialization, as described previously, attitudes among many faculty members within and across departments acts as a marked hindrance. This duality of attitudes toward commercialization was clearly captured by one participant, stating

*I do feel like here it's a very interesting thing where **you have certain people that really want you to do tech transfer, and certain people that almost find it offensive.** And it's sort of this weird thing. – F_S1_1*

Another participant described this attitudinal challenge by discussing the “stigma” associated with being an entrepreneurial faculty member, stating

*I think **there is still sort of stigma attached to being an entrepreneurial faculty. People think that your motivations are misplaced.** If you are trying to commercialize your research, then **you're not a true scientist, you're not a true academic because again, you've let that profit motive creep in there.** So there's going to be conflict of interest, there's going to be a premium placed on you personally enriching yourself and you're going to compromise research, you're going to compromise your training and educational responsibilities. I've never had that put in my face, but **you always feel like there's a bit of that there. Depending on who you talk to.** – F_S1_3*

This excerpt captures the ways in which participants recognized that many of their peers may think that entrepreneurial faculty members' motivations are misplaced (too financially motivated) or that they are not a “true scientist” or “true academic.” And as this participant notes, even when peers do not make those claims directly, the perceptions form a recognizable undercurrent that poses a real challenge for entrepreneurial faculty members.

In some cases, attitudes about the inappropriateness of commercialization may be discipline-specific. One faculty member describes a lack of publicity and visibility for university commercialization in their field as follows:

*I don't hear a lot about tech transfer in [my field of] engineering. I don't know. **I don't hear people talking about patenting things in [my field of] engineering.** I'm sure people are. I'm sure people are doing stuff but I just don't hear about it a lot. **So I don't think it's part of the attitudes as much as it is in [my department] or some of the other departments.** – F_S1_5*

Thus while there is a supportive attitude toward commercialization generally at the university level, there is relatively little support at the department level because the field is not one commonly linked to commercialization.

For other participants, these negative attitudes can arise in the context of the historic mission of land-grant universities. In the following example, the participant discusses the tension between the “selfish” perception of university commercialization and the mission of helping the region economically.

*So I feel to a certain extent the land grant kind of mission held back a little bit of the, “Go start your own company,” because **that sounds like a selfish thing to do as opposed to help this region be economically**—I think it's somewhat of a tension. – F_S1_6*

Here, personal profit, that is, seems to conflict with the idea of land grant institutions serving the public good.

Attitudes regarding industrial sources of funding for commercialization projects can also be a challenge because such funding, according to “purest academics,” is not considered equal to awards obtained from government funding agencies like the National Science Foundation:

*...you know these purest academics, they're going say to themselves, ‘Industrial money. That's not the National Science Foundation. **It's like a second class citizen of award.** Absolutely false. **Right? It's all money. It's all overhead. It all creates scholarship.** I still publish in [journal name] and the high-impact journals... – F_S1_6*

This participant, like most faculty in the study, clearly disagreed with colleagues about the differential value of different kinds of funding, and explicitly noted that all funding is a support

and it all contributes to the mission of the university by creating scholarships. These “purest” beliefs about funding can hinder a faculty members’ ability to engage in commercially-oriented activities.

As seen from these example, *Commercialization Attitudes*, specifically from faculty members’ peers challenged entrepreneurial faculty members by stigmatizing, isolating, and devaluing engagement in university commercialization.

Promotion and Tenure (P&T)

Among the formal and informal rules that present challenges to commercialization, perhaps the most significant is the promotion and tenure (P&T) process; there was near universal acknowledgement among participants and administrators that untenured faculty should not undertake commercialization. Participants described P&T as a challenge for university commercialization engagement largely because P&T is driven by traditional faculty outcomes (e.g., publications, grant funding, and service to the university/field) that are different than those common with university commercialization engagement (e.g., patents, startups, and products). They acknowledged a few exceptions, such as when commercialization serves to increase someone’s impact and reputation later in their career or when outcomes such as patenting can be reported in P&T dossiers; however, these exceptions were scant within the data.

The following example captures a common sentiment among participants describing the ways in which commercialization is “extra work” for pre-tenure faculty and “will not count” in tenure evaluations.

If the faculty member does not have tenure yet, I advise them, "This is going to be extra work on your part because it will not count, until [Case 3] says that it really does count and has teeth into it through all the departments, all the silos. What you need to do is continue your career as you're doing to get tenure, but you need to start now on looking at stuff that you're familiar with that if you change it, reformat it, it would reformat in such a way that you could train students to actually work on stuff that has a chance to lead to a company." That would be my advice to the faculty person. They need to be warned, there are two answers, that answer they need to be warned that it's going to be extra work, even though they're busy already. If you really want to make an impact or start something, you should start thinking about it now. – F_S3_2

This particular participant went on to acknowledge that commercialization could support associate professors as a way to demonstrate the impact of their work and help them become “more mature” in their work and relatable to the full professors they’ll be compared to.

*Once you become an associate tenured professor, that's a different story, because now, even though they need to keep working towards full professor, the ground rules are different. **The ground rules going from associate to full means that you have become mature in your work, and that you can now relate to people who other full professors you'll be compared with – [now] impact counts. Impact is not so important trying to get tenure, but impact becomes more important if you're going to go from associate to full. One way to get impact is to be able to start a successful company or work for a large cap company, like HP or something like that and help develop their next generation technology. I would say you would do that either via a sabbatical, so you don't have to worry about the IP issue, or start having students show up at HP and start working for them, so that your students will be well-known to them. There's nothing like getting a strong letter from an industry on your reference letters when you're being considered for being promoted from associate to full. That's my advice. – F_S3_2***

In most cases, however, participants’ discussions of P&T centered on the ways P&T does not “count” in the dossier. In part, this lack of value is connected to the attitudes described earlier. One participant highlighted the challenges involved in shifting long-standing expectations:

*This [university commercialization] is a relatively new—the idea of entrepreneurship being part of the engineering curriculum is relatively new. And the fact is that, especially whenever you're up for tenure, is your dossier is going in front of people who are brought up and if that time when it was not seen as being...like anything else... I'm not trying to make it sound like that the university is behind the times, but **the reality is that they're going to hold you to the same standards that they were brought up with, right? It's going to be really hard to change that proposition. – F_S2_4***

In some cases, participants positioned commercialization as something “not valued” and suggested that it could even be used against the faculty member being evaluated.

*Because I don't think it's [university commercialization activity] valued. **It wouldn't be valued. In fact, depending on who reads [the dossier], I could be a negative. – F_S1_2***

Interestingly, an underlying and revealing challenge expressed in this excerpt is the uncertainty embedded within the P&T process (e.g., “depending who reads it”). Another participant went even further in describing the potential negative impact, explaining that they would ask that their university commercialization activity not be mentioned during the P&T review and “if anybody brings it up, try to get the subject changed, right away.” This participant elaborates on their reasoning stating that both general university commercialization engagement as well as potential university commercialization successes could result in jealousy among other faculty or being accused of having a lack of focus on more traditional academic roles.

***Participant:** I would ask the person presenting my case. Let's say I started a company and sold it for 500 million dollars. I would say, “Please, please, please don't mention it. And if anybody brings it up, try to get the subject changed, right away.” Because, it's seen from a pure academic point as that's not what we're here for. We're here for scholarship. So people are either jealous, or — I mean, I know people that have started companies and sold for 100 million dollars, and I'm like, “Hey, I wish I got a cut of that.” — Or, it's [doing university commercialization is] a lack of focus on academic pursuits. ... So, if you can't show an impact on society, people will not be interested. It [showing an impact] wouldn't be a negative in any case. — F_S2_2*

These concerns over the place of commercialization in promotion and tenure highlight the ways in which, regardless of the attitudes among university leaders and administrators attempting make space for commercialization, attitudes and expectations among faculty broadly about the kinds of faculty work that merit tenure and promotion form a critical challenge for untenured faculty.

5.2.4 Time Commitment

As discussed in Chapter 2, faculty members have many roles and responsibilities in their daily activities. Accordingly, faculty members identified *Time Commitment* as an important factor challenging their university commercialization engagement. In many respects, *Time Commitment* undergirds each of the other three support/challenge categories. That is, for example, it takes time to acquire the knowledge and expertise required for commercialization, to build the necessary individual and industry relationships, to acquire the funding and work with TTOs, to complete the necessary paperwork and carefully think through decisions regarding disclosure versus publication – and as the discussion of promotion and tenure policies and practices suggests, time spent on these activities is often time not spent on traditionally

“tenurable” activities. These conflicts were evident across the interviews as participants positioned commercialization as something done “in addition to” traditional faculty work, and in turn limits participants’ degree of involvement in commercialization. One faculty member described not being willing to step away from their traditional faculty role in order to give university commercialization the time and attention needed.

I think that probably to my mind [serving as an advisor to a startup or company partner] is about all you can do as a faculty member unless you remove yourself from a faculty role for a couple years, which I guess I wasn't prepared to do at that time. I'm still not. – F_S3_4

Similarly, a participant found the time required to complete the necessary university paperwork too burdensome to make it worthwhile to pursue a personal stake in a startup company. As the participants explains, the decision not to take an ownership stake in a startup based on their discoveries was a personal sacrifice, but that the paperwork process was bad enough to justify the decision.

*That's a horrible thing. That form almost makes you not want to do anything. That's been a disgusting thing. I had a grant that I got in July [day]. We finally got awarded [in January of the following year] because of that paperwork. Again, if there's something they could improve on is to make that all electronic. I kind of understand it, why you need some of that paperwork, **but it shouldn't take 7 months. I spent every day working on it.***

... (later in the interview) ...

*So, I'll put it this way. **I could've had shares at that one startup company that licensed my stuff. And they asked me and I said no just because I didn't want to deal with their [the university's] paperwork.** Now that's kind of stupid, on my side, but it's also...that's how bad that paperwork is. – F_S1_1*

The *Time Commitment* required for commercialization also intersected with discussions of formal university policies, procedures, and rules like conflict of commitment, conflict of interest, and whether or not commercial outcomes are counted in faculty members’ promotion and tenure evaluations. The primary exception to time as a challenge to university commercialization is when faculty chose to use a sabbatical to intentionally dedicate time for university commercialization engagement. In these instances, participants used existing university rules to pursue commercialization interests within the boundaries of their faculty

work; however, the university and departmental attitudes/acceptance of using sabbatical time in this way very greatly based on the culture of the university and department.

5.3 Summary

This chapter illustrated how participants describe the activity system characteristics that supported and challenged their university commercialization activities. To this end, my analysis identified four supports/challenges categories (*Individual Attributes*, *Commercialization Resources*, *Formal and Informal Rules*, and *Time Commitment*) that emerged as an effective way to communicate participants' experiences. *Individual Attributes* and *Commercialization Resources* operated largely as both supports and challenges with *Access to Knowledgeable Colleagues* only identified as a support. On the other hand, *Rules* and *Time Commitment* primarily acted as challenges with *Commercialization Attitudes* being the only *Rules* factor to be identified as a support and challenge. These results, when combined with prior research, enhance the recommendations provided in the next chapter.

Chapter 6

Using case data from three land-grant universities, I developed a working model of faculty members' university commercialization work system (Chapter 4) and identified provisional supports and challenges present within this system (Chapter 5). Beyond these contributions, my study also adds to the broader conversations within the university commercialization literature. In this chapter, I situate my findings within the literature, provide provisional recommendations for faculty members and administrators interested in enhancing their university commercialization work system, discuss the limitations of my study, and offer opportunities for future work.

6.1. Discussion

Situating the findings (Chapters 4 and 5) within the broader scope of university commercialization research, I focus on four key areas: demographics, motives, roles, and the place of commercialization within the land-grant university's landscape.

6.1.1 Participant Demographics: Tenured Males with Commercialization Experience

Because of the exploratory nature of this study, I intentionally avoided excluding or oversampling for any faculty demographic characteristics (e.g., age, sex, tenure status, discipline) and worked with the institutional gatekeepers to recruit a sample of engineering faculty members with commercialization experience. As summarized in Chapter 3, my final sample of 17 participants included only one female and two untenured faculty participants, but an almost even split between associate and full professors across a range of engineering disciplines. Moreover, most participants had previous commercialization experience. Overall, these characteristics align with existing literature describing the typical faculty demographics for university commercialization as tenured or highly productive (e.g., Marion, Dunlap, & Friar, 2012; Perkmann et al., 2013; Renault, 2006), male (e.g., Lam, 2011; Perkmann et al., 2013), and experienced with commercialization (Hindle & Yencken, 2004).

With respect to tenure and productivity, my participants spoke directly about the benefits of having tenure prior to attempting university commercialization, citing the ability to more easily justify the time commitment and align commercialization with building a post-tenure

reputation and demonstrating impact. Being tenured also typically indicates productivity (Marion et al., 2012), and Perkmann et al. (2013) found existing evidence that productivity positively impacted commercialization activity. In my data set, some participants discussed productivity directly when they explained that commercialization could be done pre-tenure provided the faculty member remained productive with respect to traditional faculty expectations (publications and funding). One engineering administrator described this link between productivity and pre-tenure commercialization activity by referring to successful faculty as “super-human” and admitting that these faculty “probably work more than they should.”

*I would say that the people that do it successfully [commercialize pre-tenure] are some of those folks that are super-human. Really, really bright folks. They're good citizens. They are successful at multiple things. **They probably work more than they should.** They probably have a less of a family life, or they may not have kids. And that they, they love what they're doing. – A_S1_1*

These findings align with previous work that link productivity and tenure to university commercialization.

In terms of gender, prior studies have demonstrated strong links between being male and engaging in commercialization activity (Perkmann et al., 2013). Other research studies have also reported on the gender gap between male and female faculty members' commercialization activity (see (de Melo-Martín, 2013) for a thorough analysis of this discrepancy). While this study's male participants did not specifically mention any benefits associated with being male, the female participant did note that the university commercialization system at her institution felt like a “good old boys club” and she struggled to find mentors with whom she could connect – struggles that did not come up in conversations with any of the male participants. At the same time, the potential pool of female faculty with commercialization experience was relatively small at site 3, the only site for which data was available. Less than 10% of the possible participants were female. Because the gatekeepers sent the recruitment emails directly at the sites 1 and 2, I was unable to calculate the percentage of women in the overall pool; however, more general studies of the demographics of entrepreneurship point to a significant gender imbalance (Fairlie, Morelix, Reedy, & Russell, 2015). This lack of possible female participants also aligns with the general disparity between the numbers of male and female engineering faculty nationally, with women making up only 15.7% of all tenure/tenure-track engineering faculty in the U.S (Yoder,

2016). Although speculative at this time, activity theory and prior work on faculty gender and underrepresented minorities suggest several possible explanations for the gender imbalance of university commercialization. These explanations include female faculty members' increased service workload, which could limit time available for commercialization; the lack of acceptance of female entrepreneurial engagement within academia that might increase the potential negative promotion and tenure implications for women who choose to take on these activities; discouraging or discriminatory attitudes towards women within the predominantly male entrepreneurship community that could make establishing and maintaining relationships more challenging; and increased familial obligations for women that may further limit available time. Such challenges have been well-documented in the literature broadly and thus merit further exploration in the context of university commercialization specifically. With only one female participant in the pool, however, I can only note alignment with larger studies, but not substantiate additional claims about male versus female faculty experiences. At a minimum, this imbalance in sex demographic (both in actual participants and possible participants) and the comments from the female participant reveal that additional research is needed to understand the possible causes and impacts of university commercialization being a largely male activity. There is also an opportunity to explore if and how female faculty members' commercialization experiences differ from males.

Lastly, most of this study's participants also had prior commercialization experience via industry, a non-academic research lab, or previous university commercialization activities (including experiences as graduate students). Participants described how prior experience benefited their present or future commercialization experiences in terms of both helping them navigate and understand the process and establishing connections to business experts or other mentors and partners. My findings also suggest that less experienced academics are constrained by their lack of knowledge and expertise as well as their limited network. Similarly, Mosey and Wright (2007) (as cited in Markman et al., 2008) found that "less experienced academic entrepreneurs are constrained in their ability to create and develop new ventures because they lack corporate experience and industry networks" (p. 1413). Hindle & Yencken (2004), citing other studies, determined that faculty members need prior entrepreneurial experience, in addition to being the "initial technology champion," in order to move university commercialization toward the development of a new spinoff firm. Dietz and Bozeman (2005) in their curriculum

vitae analysis of technical human capital determined that patent productivity was supported by higher levels of industry experience. This demographic characteristic offers additional evidence that having commercialization experience positively impacts faculty members' future commercialization experiences, further supporting Perkmann et al.'s (2013) similar conclusion. However, as several of the participants in this study noted, various forms of training can help address these gaps by introducing participants to the processes and market orientations that support commercialization and by helping participants begin to create networks of mentors and partners. Recalling one faculty participant's background, graduate education represents a promising venue for providing these important commercialization experiences and trainings.

6.1.2 Motive: Faculty Members' Desire to Have Impact

While the demographics and background of the study participants largely aligns with prior work, faculty members' motivations seem more nuanced. These participants engaged in commercialization activities primarily because of their desire to have an impact. Detailed descriptions of this theme support, enhance, and challenge prior work on faculty motivation. For example, Lam (2011), expanding on the work of Stephan and Levin (1992), identified four faculty orientations and linked these orientations to three motivations for entrepreneurial activity, as summarized in Table 17. Lam found that *Entrepreneurial* faculty, when compared to the *Hybrid* faculty were more motivated by the *Gold* than the *Puzzle*. *Hybrid* faculty members primarily commercialize their research because they are motivated by the *Puzzle* and, less importantly, the *Gold*. And *Pragmatic* and *Pure Traditionalist* faculty are largely motivated by the *Ribbon* and thus favor traditional university activities.

Table 17:

Faculty orientations and motivators for academic entrepreneurship (Lam, 2011 p. 1360)

<u>Faculty Orientations</u>		<u>Motivators</u>	
Entrepreneurial	“believes in the fundamental importance of science-business collaboration for knowledge application/exploitation”	Puzzle	seek knowledge and are curious – (e.g., desire to apply and exploit research results or create opportunities for knowledge exchange/transfer)
Hybrid	“believes in the fundamental importance of science-business collaboration for scientific advancement, but also recognises need to maintain boundary”	Ribbon	seek funding and reputation – (e.g., desire to increase research resources, build networks, and place students)
Pragmatic traditionalist	“believes academia and industry should be distinct, but also recognises need to collaborate for pragmatic reasons”	Gold	seek to increase personal income
Pure traditionalist	“believes academia and industry should be distinct and pursue success strictly in academic arena”		

Lee (1996) offers two additional theories that may influence faculty members’ motivation to participate in commercialization: social responsibility theory and utility maximization theory. The former theory, when applied to universities, suggests that academics (especially those at land-grant institutions) produce a public good and have a social responsibility to make that good accessible to the public, which may underlie faculty members’ desire to use commercialization as a way to have an impact and complement traditional outlets like publications and presentations. The latter theory as applied to universities implies that academics participate in commercialization activity because it offers another mechanism to obtain funding and maximize possible sources of university revenue; which intersects with Lam’s “ribbon” category.

Using Lam’s and Lee’s frameworks, my faculty participants could be classified largely as either *Entrepreneurial* or *Hybrid* according to Lam’s definitions, and their choice to engage in commercialization in order to have an impact aligns with aspects of both Lam’s *Puzzle* category and Lee’s social responsibility theory. Despite this alignment, *Desire to Have an Impact* offers a broader conception of knowledge transfer and curiosity than Lam’s existing conception. When faculty members described “having an impact,” they described a broad set of impacts that

includes helping others, solving a real problem, addressing a gap in the existing market, developing intellectual property, advancing the field, and educating students, all of which go beyond curiosity and seek to have a tangible impact. At the same time, *Desire to Have an Impact* differed slightly from Lee's social responsibility theory in that commercialization may not lead to freely accessible public good. Profit motive is often necessary to attract the investors and industry partners needed to successfully commercialize university discoveries; opportunity for public good and limited accessibility are not enough. This tension between exclusive, profitable good and freely accessible public good is discussed in more detail within the context of the overall mission of land-grant universities (Section 6.1.4).

Thus my findings suggest that Lam's and Lee's existing motivation categories may not adequately describe all of the factors faculty members consider before engaging in commercialization. While my participants had personal motivations that align with both Lam and Lee's prior work (including increasing their reputations, securing funds for their lab, and profiting financially, as discussed in Section 4.2.2) these factors were secondary and appreciated, but *impact* remained the primary driver for engaging in university commercialization. The affective component of participants' experiences echoes this driver in that participants frequently expressed feelings of accomplishment and satisfaction in seeing their work "in use" in the world. Consequently, these findings point to additional social and affective dimensions of participants' motivation for engaging in university commercialization; specifically, dimensions that aggregate desires to solve a puzzle, tangibly contribute back to society, and secure commercialization resources. Moreover, the emergence of both primary and secondary motives and a range of positive emotional responses suggests that faculty do not engage in university commercialization for a single reason, but have a multitude of nuanced reasons for their engagement.

Perhaps most importantly, in contrast to Lam's findings, my study's participants did not favor *Gold* as a motivator. A few of participants acknowledged that they would not mind benefiting financially from their commercialization efforts, but these participants quickly followed up these statements describing money as a secondary motivator or an unrealistic outcome. This lack of financial motivation extends the results of other university commercialization research that found money to be a secondary motivating factor (Markman, Gianiodis, Phan, & Balkin, 2004; Siegel, Waldman, & Link, 2003; Siegel et al., 2004; Standish-Kuon & Rice, 2002). In fact, Markman, Gianiodis, Phan, and Balkin (2004) showed an inverse

relationship between financial incentives and entrepreneurial activity for faculty. For example, when revenue sharing increased, entrepreneurial activity went down. Not only does their study reinforce the limits of financial for faculty, it also possibly highlights the fact that the stigma of perceived profit motive within the faculty culture causes faculty to avoid doing entrepreneurial activity when revenue sharing is high. In other words, faculty may not want to be seen engaging in commercialization when profits are high because of existing attitudes toward commercialization as not “pure” or “appropriate” scholarly work.

Lastly, in addition to the absence of money as a motivator, my *Object/Motive* findings also complement the findings from a 2012 multi-case study focused on student and faculty university spinoff activity at Harvard, MIT, Stanford, Arizona, California-Berkeley, Maryland, North Carolina, and Utah⁸. Their study found that “most of the *universities* in [the] research [study] focused on the potential impact of their faculty research rather than on financial gains, seeking primarily to optimize the application of the technologies developed at their universities.” (Boh et al., 2012, p. 9) What they found at the university level, my study echoed at the faculty level. While it is impossible to tease out the top-down versus bottom-up interactions between individual faculty motives and institutional motives, my findings indicate that in this respect, faculty and institutional foci overlap in important ways that are consistent with, rather than adversarial to, traditional conceptions of the university’s mission.

6.1.3 Faculty Members’ Roles in University Commercialization

In exploring the university commercialization system from the faculty perspective, the findings from this study also contribute to our understanding of the roles of various members within that university commercialization system. Prior research has suggested that faculty represent the essential human capital in the university commercialization work system (based upon Agrawal, 2006; Boh et al., 2012; Siegel et al., 2004). However, while the activity system described in Chapter 4 certainly includes faculty in key roles, this study also highlights the ways in which this “essential human capital” is in fact made up of a community of commercially-minded individuals, not just faculty members. Moreover, this community includes individuals who are both internal and external to the university, and, importantly, one of a faculty member’s

⁸ Note: There is no overlap in institutions between the Boh et al 2012 study and my study.

key roles throughout the commercialization process is building and managing relationships with and among members of this community.

Because research activities start the university commercialization process and university commercialization is often based on a technological discovery, faculty members serve as the initial investors, inventors, and technical specialists; as participants' desire to have an impact demonstrate, commercialization is the process of bringing their own research results into the marketplace. These roles make faculty essential in that if they do not conduct commercializable research, submit invention disclosures, and support and advise their technology transfer office throughout the process, it is unlikely that university-based discoveries will be commercialized into products and services. Further, because faculty members have a strong desire to make an impact and most technology transfer offices have limited resources, participants reported that they are often responsible to "drive" the commercialization process forward. These facts keep faculty members central to the university commercialization activity system; however, this study clearly identified several other essential groups of individuals.

First, my analysis revealed that employees of the technology transfer office (TTO) are essential because they are officially in control of and responsible for commercialization activity after faculty members submit the disclosures. Although faculty reported that it helps, and is sometimes necessary, for them to remain vigilant with respect to the progress of these activities, the commercialization process can permanently stop if the TTO decides not to pursue a patent, not to license a technology, or misplaces a disclosure. TTOs also perform essential commercialization roles such as conducting market research, evaluating the commercial potential, and coordinating licensing agreements; again, faculty may be involved and advisory, but as many participants noted, these are tasks and domains outside the expertise of most university faculty and they are dependent on TTOs to fill these critical roles.

Beyond TTOs, participants listed a breadth of additional sources of essential human capital within the commercialization community, including industry partners, mentors, consultants, investors, lawyers, and experienced business leaders. Link, Siegel, and Bozeman (2007) identified the importance of academic and industry communities in commercialization processes, and my data supports their belief that participants need a community of knowledgeable commercialization experts around them. This need for a commercially-oriented community was also identified by a previous multiple case study project (Boh et al., 2012, p. 7),

which concluded: “It is important to note that experts, business people, entrepreneurs, and other alumni volunteers play a vital role in many of the programs listed above [commercially-focused training/networking programs] and make important contributions to the university’s entrepreneurial ecosystems.” Additionally, in the present study, participants highlighted faculty peers as an important part of their commercialization communities, especially those who can collaborate to conduct research, develop technologies, and pursue commercial outcomes. Perkmann et al. (2013) also identified prior research that demonstrates the importance of “peer effects” and their positive impact on faculty members’ entrepreneurial engagement. As these studies allude and both Chapters 4 and 5 note, it is important for faculty members to access and build relationships with a range of individuals inside and outside the university who provide essential knowledge, skills, funding, advice, and encouragement throughout the commercialization process. While such knowledge, expertise, and resources may not necessarily make any one individual essential, the unique nature of each commercialization activity makes developing clear-cut definitions of essential versus supporting roles ambiguous at best. Participants in this study clearly saw their commercialization activities immersed in a complex network of people and organizations.

This network complexity may also help to explain faculty members’ shifting roles across the commercialization process. In Chapter 2, I also showed that faculty engagement declines later in the commercialization cycle (Boh et al., 2012). The current study partially confirms these findings, as some faculty expressed roles in which they would preferred not to engage, and these roles were typically later in the university commercialization process. My analysis can offer multiple suggestions for possible causes of this decline in engagement. First, as described in Section 4.2.6 (*Responsibility*), there are some commercialization activities that faculty members simply do not want or do not feel equipped to do, such as the legal aspects of commercialization or starting a company full-time.

The reasons for not wanting to perform these activities vary and can include lacking knowledge and expertise, a time commitment that is too large, and a preference for research and discovery. Lack of knowledge and expertise is linked, as noted in Chapter 5, to lack of prior commercialization experience as well as lack of training, and in some cases, lack of time and desire to learn about the nuances of commercialization. Blismas, McCoy, and Lingard (2009, p. 485) credit these gaps to academics’ training and the habits formed by “following research

protocols and writing formulaic reports and papers,” but they can also be credited to the current faculty incentive system at most universities (Perkmann et al., 2013) which may not reward time spent on such work. Overall, this lack of experience and expertise matters more in the later stages of commercialization because activities such as marketing to companies, negotiating licenses, manufacturing products, and launching businesses require specific knowledge and skillsets not included in typical faculty training programs (e.g., graduate school).

Time commitment and the transition of control to the TTO could also be causes for a decline in faculty participation in the latter stages of commercialization. Some faculty members described the time needed to properly start and run a company as too much of a commitment in the context of their faculty work. This time commitment is especially pertinent given the current promotion and tenure policies at most universities, and is compounded by conflict of interest policies that may limit time spent on certain types of activities. Additionally, the control exercised by TTOs, in which faculty primarily serve as advisors when called upon instead of proactive leaders, may impact commercialization engagement. These factors, coupled with the overall complexity of commercialization, highlight the ways in which, while faculty may play an essential role in *initiating* commercialization, the essential human capital required for successful university commercialization includes individuals with a range of skills, backgrounds, and roles.

6.1.4 The University’s Mission

Both faculty members’ motives for commercialization and their roles in the process are embedded in larger discussions of the overall mission of the university, and the mission of land grant universities in particular. In Chapter 2, I described a general shift in the faculty work system in the U.S. to include more commercialization activity, as evidenced by numerical growth in the amount of commercial activity over the ten-year period from 2004-2013 (AUTM, 2014), changes in faculty evaluation language (Sanberg et al., 2014), changes in faculty demographics/governance (Schuster & Finkelstein, 2008), and an increase in entrepreneurial education within today’s universities (e.g., Gilmartin et al., 2014). Despite this shift in activity, the literature is mixed on whether the universities “third mission” is an appropriate use of resources and whether commercialization impedes universities’ (especially land-grants’) historic mission for public good and outreach/extension (Larsen, 2011; Powers & Campbell, 2011). This

debate is further complicated by the potential benefits of university commercialization (see Table 2).

Evidence for this debate about the mission of the university and the appropriateness of faculty engagement in commercialization was apparent throughout my data. Across all cases participants consistently reported that they desired to increase the impact of their research beyond academia and that commercialization represents a natural mechanism to do so. Although not all participants expressly stated it, this use of commercialization in many respects aligns with the outreach and extension mission of land-grant universities. It represents a method for faculty to enable their research to have an impact beyond the walls of the academy and to fulfill their social responsibility to give back to the public (Lee, 1996).

However, despite this intersection between commercialization and public good, faculty reported that attitudes and rules surrounding university commercialization were mixed at best, often conflicting with participants' desires to broaden the impact of their work through commercialization. As described in Chapter 4, participants reported receiving mixed messages regarding the acceptance of their commercialization activity and perceived a stigma attached to commercial activity. Two additional interconnected conflicts discussed by the present study's participants compounded these mixed messages: time commitment and the promotion and tenure system. Participants reported that the time commitment required for commercialization can become a conflict because it prevents faculty members from engaging in other activities that are part of their work responsibilities, including activities counted toward promotion and tenure (e.g., publications & presentations). Sanberg and colleagues (2014, p. 6544) state that current faculty evaluation policies "at best, mostly tolerate commercialization efforts," referencing Lach and Schankerman's (2008) survey of the incentive system at over 100 universities. Importantly, the tenured faculty and administrator participants in this study consistently cautioned pre-tenure faculty against commercialization engagement because of the risk that it could jeopardize their chances at receiving tenure. And while Renault's (2006) work calls for the recognition of patents and spin-off companies in promotion and tenure evaluations to help address this issue, debate continues as to whether such recognition is appropriate.

This debate, in many ways, is rooted in the links between commercialization and profit. It is clear from both the data and the literature that a foundational tenant of university commercialization activity is the existence of a profit motive (e.g., (Slaughter & Rhoades,

2004)). That profit motive points to the fact that, in order to commercialize a university discovery, most investors or company partners expect to return a profit. While non-profit options exist in some areas, in general, bringing a product to market, especially university discoveries that typically emerge early in the commercial development cycle, requires a substantial financial investment. Those who provide that investment expect a return on their investment. One faculty member I interviewed touched on this idea of profit motive during their interview. In the following example, the participant explained that in order for some discoveries to have an impact or get out of the research laboratory, there must be a potential profit or many of these beneficial technologies will “never see the light of day.” Later in this interview, the participant explained that since universities aren’t equipped to manufacture and distribute products, they must obtain company partners, who require a return on their investment. This fact means that an ability to profit from the discovery is a must in order for most companies to engage in university commercialization.

*And what the general population doesn’t realize is that **there’s a lot of potential technology sitting in laboratories across this country, across the world, that would be a benefit to a large number of people with differing conditions that will never see the light of day because the profit motive has been sucked out of them.** So like it or not, consider it a necessary evil or however you want to characterize it, the profit motive has to be there. – F_S1_3*

This profit motive leads to an understandable level of secrecy and exclusivity, which in turn leads to an understanding of what it means to contribute to the “public good” that differs from the traditionally understood contributions in the form of journal publication and presentations. For example, is failing to enable the transition of publically beneficial commercial discoveries/technologies beyond the wall of the academy undermining universities’ mission of delivering public good? Additionally, with universities’ continued struggle to remain financially viable, any opportunity for the institution itself to profit, be it via profits from any form of academic capitalism (e.g., selling curricula, hosting conferences, or commercializing research) (Slaughter & Rhoades, 2004) is important to the survival of the academic organization and its ability to deliver all forms of public good. At the same time, if universities or individual faculty profit from work supported by public research dollars, do these activities represent an inappropriate use of tax dollars and a violation of the public trust. This tension raises the

question, ‘As a land-grant institution, does the profit motive required to successfully have an impact through university commercialization compromise or enable the historical mission of universities (i.e., to educate and freely contribute back to the public good)?’ While the outputs of university commercialization may not be “free,” commercialization processes can enable technologies to move beyond academic journals and into the public in ways that published research results may not.

This study sheds light on the fact that the issue of profit and public good is not a simple either/or topic. That is, the public good and profit motives are not inherently exclusive, and faculty desires for impact point to the border between them. Participants in this study sought commercialization precisely because they did not believe traditional publication sufficiently served the public good or allowed their research to become used and meaningful in the world. Their desire to move research discoveries into the public domain is thus not clearly either within or beyond the present mission of the university; rather, it seeks to mediate between the two.

As the findings here demonstrate, for these participants, commercialization is not primarily about making money, it is about having an impact beyond publications and presentations. This goal doesn’t fit neatly into the traditional university conceptualization of promotion and tenure or the way faculty work systems have historically operated. Moreover, the findings show that traditional faculty activities and commercialization-specific activities are, in fact, often tightly integrated. Faculty members described consciously considering how they could engage in commercialization activities while simultaneously meeting their other traditional faculty expectations (e.g., funding their lab via commercialization). Faculty members discussed engaging in commercialization only when it would not interfere with more traditional faculty activities such as ensuring that students can still publish their work. In her review, Larsen (2011) found that faculty who commercialize also successfully pursue the traditional goals of the university: “Our review indicates that, despite some inconsistencies in empirical findings, enterprise [i.e., commercialization] appears, by and large, to be positively related to traditional academic endeavors as indicated by the performance of scientists who engage in commercially oriented activities.” (p. 7). This study’s finding regarding the intersection of traditional and non-traditional activities represents an opportunity for additional exploration of the nature of the faculty work system.

Importantly, considering the general tensions surrounding the appropriateness of the university's third mission and the fact that faculty who commercialize are still stigmatized, how do policies and university work systems ensure that the commercialization ecosystem is an inclusive environment for all faculty members and students? As an activity undertaken predominately by males, how are historically marginalized groups limited in their participation and ability to have broader impacts through commercialization? Additionally, how does a lack of diversity and potentially exclusionary culture limit university commercialization's opportunity for public good, delivery of societal benefit, and development of a diverse science and engineering workforce? Answers to these questions are important not only because universities need to develop inclusive commercialization supports and limit challenges, but also because our society needs solutions that innovate broadly and across borders.

Overall, it is not the intention of this study to offer resolutions to the conflicts between commercialization and the mission of the university, but the by-products of this overarching conflict are felt by faculty members who engage or consider engaging in commercialization and warrant a much richer discussion within and beyond the academy.

6.1.5 Activity Theory: An Individual and Systems Perspective

In Chapter 2, I discussed the need to better understand university commercialization from the individual faculty perspective. I also discussed faculty members as part of a larger, dynamic university commercialization system and, thus, a need to also explore commercialization from a systematic perspective. Base on my literature search, however, I found no prior studies that have attempted to simultaneously analyze university commercialization at both the systems and individual levels. Instead, university commercialization activities were often explored at either the systems level (case study in which the university bounds the cases) or the individual level (attempting to correlate commercial activity with research productivity).

As a result, I designed this study to capture and analyze data at both levels. Essential to this design was the activity theory framework because it enabled me to focus on an individual's (one faculty member) perspective of an activity (university commercialization) and, importantly, the contextual details of the activity (obtained via the activity system elements). Moreover, activity theory also supported the development and analysis of a targeted cases because it enabled me to aggregate multiple faculty members' perspectives into a single picture for each

institution, analyze for similarities and differences across the cases, and report the findings in a coherent, structured way. Overall, this approach expands on the methodologies applied to studies of university commercialization and faculty work systems.

Beyond being a methodological addition to the university commercialization and systems analysis literatures, this study also adds to the limited, but promising, research demonstrating activity theory's applicability in educational contexts. As demonstrated by this study's ability to produce meaningful recommendations, activity theory can contribute to both our understanding and improvement of the university commercialization work system. To my knowledge, this study represents the first time activity theory has been applied to the study of university commercialization and, more generally, one of the few instances in which it has been applied to faculty work making it a possible example for future studies.

6.1.6 Implications for Engineering Education

With the previously described increases in university entrepreneurial ecosystem and the links between commercialization activity and faculty and student learning, it is clear to see that this study has implications for the field of engineering education. As the number and quality of entrepreneurial education programs and centers increases, it will become increasingly important that faculty are able to contribute to these initiatives. Contributions to the university entrepreneurship ecosystem can take the form of formal majors, minor, courses, or educational modules at both the graduate and undergraduate levels, along with informal learning opportunities such as mentoring and advising graduate students, entrepreneurship clubs, class projects, or similar activities. Engagement in university commercialization provides faculty members with the knowledge, skills, and experiences needed to teaching students about product development, commercialization, and entrepreneurship, and to help shape learning outcomes and curricula that address student needs and goals. These concepts are especially important for students who take jobs in industry and for those who are likely to develop products and services in the commercial sector. Additionally, by engaging graduate and undergraduate students in the process of university commercialization, faculty members can support future commercial engagement within and outside of academia by providing students with experience, knowledge, expertise, and access to knowledgeable colleagues.

In addition to the impact on teaching and learning, faculty members' experiences with commercialization and, in particular, experiences mentoring student inventors and researchers also helps inform discussions about student ownership of intellectual property and students' persistence within the academy. Accordingly, determining policies and approaches to support and protect student rights and learning is an increasingly important topic within academia. However, faculty may experience tensions between realizing commercializable results from their labs and student rights – e.g., a faculty member facing an ethical dilemma between the timely delivery of a product to market and respecting students as university learners and not company employees. It is important that universities proactively safeguard students' rights and address such tensions by welcoming faculty members into these important commercialization-focused conversations.

6.2 Recommendations for Faculty and Administrators

One of the purposes of this study was to provide provisional recommendations to administrators and faculty members interested in enhancing university commercialization and the university's third mission. Importantly, these recommendations are intended for those who have already weighed the pros and cons of university commercialization and seek to engage or enhance others' engagement in such activity. These recommendations are grounded in the findings presented here, and thus actionable, but because of the small data set and the need for a broader, more diverse set of faculty perspectives, they should be considered provisional pending an expansion of the study.

Recommendation 1 – Cultivate a Commercialization Community

Given the importance of the internal and external commercialization community and community members' ability to address challenges such as lack of experience/expertise and commercialization time commitment, I recommend the following

Both administrators and faculty members should cultivate a university commercialization ecosystem that fosters and connects a broad community of commercialization experts who are dedicated to having an impact through commercialization.

Recommendation 2 – Consider Mission, Rules, and Attitudes

Based on the supportive and challenges aspects of formal and informal rules and the attitudes of both university administration and peers/colleagues, I developed separate recommendations for administrators and faculty members regarding the university's mission, rules, and attitudes related to commercialization.

Administrators should seek to establish and clearly communicate how commercialization fits into their university's mission. This includes why the institution values commercialization and how the potential benefits of commercialization outweigh the associated challenges.

Faculty members should clearly understand the rules and attitudes at their university before engaging in commercialization and consider the pros and cons of their decision to engage. Faculty members will benefit from seeking advice from other faculty members and administrators about their experiences engaging in commercialization at the university.

Recommendation 3 – Gain Commercialization Experience

Because faculty participants clearly described the benefits of having prior industry and commercialization experience, I recommend that

Both administrators and faculty members should foster opportunities to gain commercialization experience. This may mean considering (faculty) or supporting (administrators) non-traditional sabbaticals or other industry opportunities that complement a traditional faculty member's career. At a minimum, explore opportunities in which faculty members with prior commercialization experience can share their knowledge and expertise with less experienced faculty members.

Recommendation 4 – Leverage Tenure

Due to the importance faculty members' placed on promotion and tenure and its identification as a significant challenge for pre-tenure faculty, I make separate recommendations to administrators and faculty members.

Administrators should engage tenured, productive faculty members in the university commercialization system. Increase their awareness of commercialization, encourage them to consider how their academic work could be commercialized, and develop opportunities for academic "purists" to understand/appreciate the potential benefits of commercialization.

Faculty members, if pre-tenure, should clearly understand the promotion and tenure-related pros and cons of commercial engagement. They should start with

small activities that are less time intensive (e.g., advising the technology transfer office or sitting in on market analysis presentations). If tenured, faculty members can explore how commercialization can increase their ability to have an impact, increase their reputation in the field, or fund research and improve lab spaces.

Recommendation 5 – Support Female Faculty Participation

This study found that, like engineering in general, faculty who commercialize are primarily male. This limitation in community demographic may impact supportive factors such as access to knowledge colleagues and be caused by challenging factors such as unsupportive attitudes toward entrepreneurial female faculty and increased time commitment for female faculty member in their traditional faculty roles. As a result, I recommend the following

Administrators should look for and break down barriers that challenge female participation in university commercialization. For example, actively seek and respond to feedback from female faculty members who currently engage in commercialization, develop more diverse mentor networks for commercialization activities, and identify whether increased service obligations are limiting female faculty participation and, if so, appropriately modify actual and expected female workloads. Importantly, identify and challenge any university unsupportive attitudes and biases female faculty members experience.

Faculty should support female faculty engagement by inviting and encouraging their participation in the university commercialization community. They should also directly acknowledge and discourage attitudes that are unwelcoming or detrimental to female faculty participation.

Recommendation 6 – Integrate Traditional and Commercial Activities When Possible

Based on faculty participants' division of labor being split between commercial and traditional roles as well as their limited time for commercial activities, recommendation 6 is directed toward faculty members as a means to successfully pursue traditional and commercial roles.

Faculty members should attempt to integrate their traditional scholarly activities with commercial activities, remembering that most university incentive system still strongly value traditional metrics like publications, presentations, and grant funding. Also, seek out programs like the NSF I-Corp or opportunities from private foundations that can enable you to meet traditional metrics (e.g., funding) while still exploring the commercial potential of your discoveries.

Recommendation 7 – Review Faculty Evaluation Systems

Because of the value and importance placed on promotion and tenure, the range of commercialization-related attitudes, and the fundamental tensions between the historical mission of land-grants and university commercialization, I recommend that

Both administrators and faculty members should review and, if necessary, adjust faculty evaluation systems according to the mission of their university, ensuring that commercialization activities are valued accordingly during the promotion and tenure process.

Although provisional due to the limitations of the study, these 7 recommendations are intended enhance the entrepreneurial and commercialization ecosystems within academic institutions. Future studies will allow for these recommendations to be revised and new recommendations to be put forth further supporting this goal.

6.3 Limitations and Future Work

Several limitations in this study point to the need for additional research. First, in balancing depth, breadth, and pragmatics, the study was limited in terms of number of cases, institution type, and academic disciplines. Three cases, with 17 engineering faculty interviews as the primary data source, limits my ability to generalize the findings, and situates my study as more exploratory than explanatory. This exploratory nature does not lessen the contribution of the study, but it does mean that my recommendations regarding engineering faculty members' commercialization experiences should be considered provisional and will require confirmation through a more robust dataset. Accordingly, a key opportunity for future work includes conducting additional interviews at the three existing sites, increasing the number of cases, incorporating a more diverse set of institutions (e.g., more land-grants, private, teaching-focused), and expanding into other disciplines.

Within these constraints, the sample itself represents another limitation. First, because all participants self-selected to participate, and most had significant university commercialization experience (with varying levels of positive, negative, and indifferent experiences), the results exclude those who may wish to participate but have chosen not to. Participants' background and eagerness to participate may have resulted in a sample that provided an edge-case perspective, and the broader population of faculty who participate in university commercialization may have

differing perspectives. The potential for differing experiences may be particularly true in the case of those individuals who attempted university commercialization, but were unsuccessful in navigating the process. The majority of this study's participants had some level of success (e.g., granted a patent, licensed at least one technology, or started a list one spinoff), and even those who had not considered their attempts to be successful learning experiences. Second, the relatively extensive commercialization experience among my study's participants may also limit these findings as faculty members who are new to university commercialization may have different experiences. Third, the time gap between participants' commercialization experience(s) and the interview may have resulted in changes in participants' beliefs or an inability to accurately recall their experiences, which could limit the impact of my study's contributions. In most cases, these were retrospective interviews in which faculty described commercialization activities that had occurred as recently as the same year as the interview, but also as distant as 20 years prior to the interview. Lastly, the fact that almost all participants were male and tenured limits the data because female and/or untenured faculty may have different experiences and perspectives. These sample limitations provide opportunities for addition studies that focus on specific populations within the university community, such as first time-commercializers, faculty who started but intentionally stopped a commercialization effort, and faculty with very strongly positive or very strongly negative experiences.

The sample may also be limited by a potential self-reporting bias as faculty described their experiences in a personal interview rather than responding to an anonymous survey. The face-to-face nature of this data collection technique may skew participants' descriptions toward motives and explanations that are more noble than realistic. I took steps to overcome this limitation by asking general, non-leading questions (e.g., 'Why did you decide to engage in university commercialization?'), remaining neutral (e.g., avoiding positive or negative reactions to participants' responses), establishing a rapport with faculty prior to asking such questions, and clearly explaining that the study's focus was on gathering and understanding participants' experiences and the supports and challenges rather than praising or condemning anything in particular. Nonetheless, the possibilities for such bias point to the need for mixed methods approaches in future studies to allow triangulation of findings.

The study is also limited by its focus on faculty members' perspectives as the case boundary. There are, however, other important perspectives of the university commercialization

system that should also be understood. Rasmussen, Moen, and Gulbrandsen 2006 (2006), through their multiple case analysis of commercialization in European institutions, concluded that “the numbers of actors involved is large, partly with interfering and unclear roles.” (p. 528) The breadth of community members reported in this study echoes Rasmussen et al.’s conclusion, and identifies an opportunity for future research. By exploring the university commercialization system from multiple perspectives in the commercialization community, additional supports and challenges can be identified and a more robust set of actionable recommendations can be developed.

Beyond these limitations, the findings of the study also point to additional important directions for future work. First, activity theory and the activity system offer multiple opportunities to build on the present study. For example, activity theory’s concept of contradictions represents a particularly interesting opportunity for future research. The existing case data could be analyzed to explore potential contradictions within faculty members’ commercialization work system such as contradictions between publications and invention disclosures, contradictions across faculty roles, and even contradictions between profit and public good motives. By identifying these core contradictions, a follow-up study could seek to understand why these contradictions exist, how these contradictions protect and challenge the mission of the university, how commercially-friendly universities can overcome them, and whether or not universities, in general, should overcome them.

In addition, as suggested earlier, there is an opportunity to better understand the motivations underlying faculty members’ decision to engage and the reason why faculty members consider but decide not to engage in commercialization. Markman et al. (2008) call for additional research on the precursors of commercialization, and my study supports this need for additional understanding. While my participants clearly expressed their motive as a desire to have an impact through commercialization, a straightforward follow-up question could be, ‘How do non-commercially oriented faculty members decide whether or not to engage in university commercialization?’ When this study’s findings are considered alongside Lam’s findings, it is logical to conclude that there may be other possible reasons, or at least more nuanced explanations, for engaging in academic entrepreneurship.

A final opportunity for future work includes additional research into the faculty training and the educational implications of university commercialization. For example, understanding

the existing types of commercialization trainings, the “best” format for such trainings, faculty members’ motivation for (or reasons against) participating in commercialization-related trainings, and the success of commercialization training programs. A particularly interesting opportunity for future research is the nature in which faculty members’ commercialization and entrepreneurial experiences influence the courses they teach and their mentoring of students (graduate and undergraduate).

6.4 Summary

In conclusion, I conducted a multiple case study of engineering faculty members’ experience with university commercialization at three land-grant universities. After completing both within- and cross-case analyses of the data, I developed an activity system model identifying the similarities among faculty experiences and highlighted a few key differences within the commercialization work system. Similarities reported by participants included the following

- participants were predominantly male, tenured, and had prior industry/commercialization experience;
- participants described being motivated primarily by the desire to have a societal impact beyond publications and presentations;
- funding, trainings, and formal commercialization tools such as university forms were the primary tools;
- participants identified commercialization community members both within and external to the university that were essential to the process;
- both formal and informal commercialization rules and attitudes influenced participants’ experiences, and included both support for and stigmas against commercialization;
- participants delineated clear roles, activities, and levels of responsibility they both would and would not take on;
- multiple outcomes resulted from commercialization efforts, including not only licenses and startups, but also publications, student job placement, and increases in knowledge; and
- participants experienced both strongly positive and strongly negative emotions and attitudes associated with their commercialization experiences.

Differences identified included the

- robustness of the commercialization ecosystem,
- ways in which the commercialization community was discussed,
- amount of negative emotions and attitudes expressed by faculty, and
- wide variety within the *Tools* element of the activity system.

My analyses also identified supports and challenges impacting participants' engagement with university commercialization. These supports and challenges were organized into four categories (Individual Attributes, Commercialization Resources, Formal and Informal Rules, and Time Commitment) comprised of specific supports and challenges. Individual attributes such as prior industry/commercialization experience, commercialization knowledge and expertise, and the ability to build relationships were identified as both supportive and challenging. Supportive and challenging commercialization resources included the technology transfer office, sources of commercialization funding, and commercialization-focused seminars and trainings, with access to knowledgeable colleagues being identified as a support only. Within the formal and informal rules category participants identified commercialization attitudes as both supportive and challenging, and identified rules and attitudes associated with intellectual property, developing company partnership, and promotion and tenure as being a challenge. Lastly, the time commitment necessary for commercial engagement was identified as challenging.

In addition to describing a faculty perspective of the commercialization work system and supports and challenges associated with university commercialization, I also offered 7 recommendations for entrepreneurial faculty and administrators who are looking to bolster their university's entrepreneurial ecosystem. I, then, connected this study's findings to the broader literature, which identified other major contributions including

- evidence that university commercialization is currently an activity for male, tenured faculty,
- evidence that partially aligns with, while also challenging, our current conception of faculty members' motivation for participation in university commercialization (desire to have an impact),
- an understanding of the various roles in university commercialization,
- insights into the intricacies between land-grant universities' mission and the university commercialization work system, and
- a unique methodology enabling data collection and analysis at both the individual and systems levels of a human activity.

These contributions enhance the field of engineering education because they support our understanding of an activity that is becoming more pervasive at universities throughout the world, especially technical universities known for science and engineering. Additionally, university commercialization activities often permeate the university at multiple levels including formal coursework, faculty members' research labs, and student organizations offering formal

and informal learning opportunities for students. Finally, this study also adds value to the higher education governance and policy literature by highlighting provisional supports and challenges associated with university commercialization that can be acted on or studied further. By better understanding faculty members' commercialization experiences, administrators and policymakers can have more-informed discussions and take the appropriate governance and policy actions to meet their local, national, and higher education-specific goals.

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Appendix A: Tenure and Promotion Language

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Supporting Information

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Table S1. Language used to incorporate entrepreneurial activities in tenure and promotion documents at universities

Institution	Date founded	Public/private	Tenure and promotion language
Auburn University	1856	Public	"Evaluation of Research...Other indicators of research productivity which can supplement one's record include external grants and the creation of intellectual property, copyrights, and patents" (1).
Carnegie Institute of Technology at Carnegie Mellon	1900	Private	"Research: Measures of excellence in this area include the quality, volume, and impact of publications, including papers, monographs, books and research reports; evaluation of research by others; patents; prizes and awards for research; solicited and invited lectures; the amount of financial support; and the contribution of the candidate's work towards the needs of society" (2).
Clemson University	1889	Public	"2.) Scholarship (refereed scholarly work is weighed much more heavily), as indicated by the following possible supporting evidence: 2.6.) Patents awarded" (3).
East Carolina University	1907	Public	"Research/Creative Activity:... Patents" (4).
Florida Atlantic University	1961	Public	"Evidence of achievement in the appropriate discipline(s)...where appropriate, patents and research grants" (5).
Florida Institute of Technology	1958	Private	"Research/Scholarly Activities:...List and describe briefly any disclosures of inventions or resulting patents" (6).
Florida International University	1965	Public	"Research/Scholarship/Creative Work: e. Patent Disclosures/Applications/Awards: Patent disclosures, applications, and provisional and final patent awards should be listed. If there are co-investigators on the disclosure, application or award, these should be indicated" (7).
Kent State University	1910	Public	"Evidence of the scholarship of discovery, integration, application and teaching, as well as university citizenship...In addition, candidates are expected to provide documented evidence which may include... evidence of outstanding achievement, such as awards, patents, and copyrights" (8).
Lehigh University	1865	Private	"Publications and Creative Activities: Creative Activities:... Original designs, plan, inventions, and patents" (9).
Lincoln University	1866	Public	"Scholarly Research/ Creative Activity and Professional Achievement:... Documentation of externally funded grants and inventions and patents..." (10).
New Jersey Institute of Technology	1885	Public	"A complete curriculum vitae documenting publications and patent applications since appointment or last promotion...Applications for, and granting of patents and copyrights are recognized as a measure of importance and/or peer evaluation of the work in the field" (11).
North Dakota State University	1890	Public	"[T]he development and public release of new products or varieties, research techniques, copyrights, and patents or other intellectual property..." (12).
Northeastern University	1854	Private	"...the receipt of patents represents professional recognition of research activities. In some fields technical, procedural, or practical innovations made clinically or professionally are evidence of productive scholarship" (13).
The Ohio State University	1870	Public	"2. List of creative works pertinent to the candidate's professional focus:... Inventions and patents, including disclosures, options, and commercial licenses" (14).
Oregon State University	1868	Public	"Authorship of a patent in the faculty member's field is considered as evidence of creative scholarship" (15).
The Pennsylvania State University	1855	Public	"Other evidence of research or creative accomplishments as appropriate (patents, new product development, new art forms, citation index analysis, etc.)" (16).
Purdue University (Consumer Sciences and Retailing)	1869	Public	"Benchmarking Excellence: ... Patents and license agreements resulting from research done while at Purdue" (17).
South Dakota State University	1881	Public	"Examples (non-exhaustive) of publications or activities of research, scholarship, and creative activity:...patents," (18).
Stevens Institute of Technology	1870	Private	"Scholarly activities:...patents" (19).

Table S1. Cont.

Institution	Date founded	Public/private	Tenure and promotion language
Texas A&M University	1876	Public	"Patents or commercialization of research, where applicable" (20)... Patents are listed under "Other Research, Scholarship, or Creativity Accomplishments," in the faculty summary table (21).
Texas Tech University	1923	Public	"Evidence of research and creative activity includes print or electronic publications, non-print presentations, funded grant applications and reports, patents and other intellectual property, curatorships, and artistic productions and performances. Textbooks and innovative instructional materials having significant value beyond this campus may be considered contributions to research and creative activity" (22).
The University of Alabama at Birmingham	1969	Public	"Although scholarly work takes many forms, including design, basic and applied research, and other creative activities, a faculty member's effectiveness can be demonstrated by such achievements as ... patents, and the like. The quality of the individual's scholarly approach, capacity for independent thought, originality, and products of scholarship must be addressed" (23).
University of Arkansas at Little Rock	1927	Public	"The Scholarship of Integration may result in a traditional academic product such as an article, book or presentation. It also may take the form of a product or patent. As in other areas, appropriate forms of external review must be used to determine the merit of such products" (24).
University of Arizona	1885	Public	"... promotion and tenure reviews, as detailed in the criteria of individual departments and colleges, will recognize original research contributions in peer-reviewed publications as well as integrative and applied forms of scholarship that involve cross-cutting collaborations with business and community partners, including translational research, commercialization activities, and patents" (25).
University of Colorado Denver	1912	Public	"Research and/or Other Scholarly Activities:... Patent or patent applications" (26).
University of Houston	1927	Public	"Generation of intellectual property: List any patents issued or pending including patent number, date of filing, and status (provisional, non-provisional, issued)" (27).
University of Illinois at Urbana-Champaign	1867	Public	"Publications and Creative Works:... H. Patents " (28).
University of Maryland System	1856	Public	"Original Designs, Plans, Inventions, Software and/or Patents" (29).
University of Michigan School of Music	1817	Public	"Full recognition, both in evaluating tenure and promotion cases, will be given for a broad range of entrepreneurial, outreach and creative activities in which faculty engage. These activities may enhance any of the criteria on which faculty are measured – teaching, research and service... Examples are ... • creating a start-up company that enhances the broader scholarly, public service, or health care missions of the University,... • creating new or enhanced practices, products or services, • working with the Office of Technology Transfer to patent or license an invention, • encouraging and instructing students in entrepreneurial and public service activities, • developing collaborative approaches to solving complex world problems" (30).
University of Minnesota	1851	Public	"[I]nclude significant publications and, as appropriate, the development and dissemination by other means of new knowledge, technology, or scientific procedures resulting in innovative products, practices, and ideas of significance and value to society" (31).
University of Nebraska at Omaha (Medical Center)	1869	Public	"Evidence of Scholarly Activity: ... A complete listing of patents, patents pending, and any licensed products are also required in this evaluation. ... Scholarly activity should be accepted in its broadest sense, and should not be viewed solely as basic or clinical research as acknowledged traditionally... recognize as scholarly activity the development of innovative teaching methods, the synthesis of new concepts based on data already published by the candidates or others, technology transfer successes, software design, website design, or other activities related to information sciences, etc." (32).
University of North Carolina – Greensboro	1891	Public	"Research and creative activities may include, but are not limited to, the following:... Developing innovative solutions that address social, economic, or environmental challenges (e.g., inventions, patents, products, services, clinical procedures and practices)... Granted patents, Patent applications, Disclosures of innovation, Entrepreneurship and related activities..." (33).

Table S1. Cont.

Institution	Date founded	Public/private	Tenure and promotion language
University of Saskatchewan	1907	Public	"Evaluation of research, scholarly and/or artistic work for tenure and promotion at all ranks will address the quality and significance of the work. Evidence will include the peer-reviewed publications and presentations referenced above, but may also include other works (e.g., artistic works, performances, research related patents, copyrighted software and audio-visual materials)" (34).
University of Southern California	1880	Private	"While patents cannot replace peer-reviewed publications in a candidate's dossier, they are a sign of impact and productivity and will be considered accordingly" (35).
University of South Florida	1956	Public	"Other Creative Activities... Patents and Licensing... Other unique or entrepreneurial activities of significance" (36).
University of Wisconsin Madison	1848	Public	"[E]vidence of research performance and of a candidate's standing in a discipline includes... (9)patents or evidence of intellectual property. The case must be made as to the quality and level of contribution of the candidate's present work" (37).
Utah State University	1888	Public	"Research or creative endeavors encompass a wide variety of scholarly activities that lead to the advancement of knowledge and/or to original contributions in the arts and humanities. Documentation supporting such activities must include peer recognition of their value and may include, but is not restricted to:... intellectual contributions represented by patents, inventions and other intellectual property" (38).
Virginia Polytechnic Institute and State University (Virginia Tech)	1872	Public	"Economic contributions and entrepreneurship: 1. Start-up businesses (including competitive grants and contracts such as SBIR awards and other notable business achievements), 2. Commercialization of discoveries, 3. Other... Intellectual properties: 1. Software, 2. Patents, 3. Disclosures (pre-patent)" (39).
Washington University at St. Louis (Sam Fox School of Design & Visual Arts)	1853	Private	"Other kinds of recognition for research may include patents, production or product development contracts, and demonstration of influence through citations, papers, awards, graduate student support, and the ability of the research to attract further funding" (40).

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Appendix B: Faculty Recruitment Email

Subject: Faculty Experiences with Technology Transfer and Commercialization - Your participation is requested!

Dear [Land Grant] Engineering Faculty,

I am writing to invite you to participate in a study exploring the technology transfer and commercialization (university commercialization) experiences of engineering faculty members. university commercialization activities include evaluating market potential, licensing, and/or developing spinoff companies. The goal of this study is to better understand the university commercialization experiences of engineering faculty members in order to help universities support faculty who wish to engage in university commercialization. I'm seeking participation from any faculty member who has university commercialization experience regardless of whether you consider your experience(s) successful or not.

Your engagement involves participating in an interview as well as sharing any documents you believe would help me understand your experience(s). Our session will take place at a time and location that is convenient for you and, if necessary, can be completed virtually or by phone. I anticipate that each interview will last approximately 60 minutes. All sessions will be audio-recorded and transcribed for analysis.

If you are interested in participating in this study, please click the link to go to a survey where I request some basic demographic information (i.e., your name, contact information, types of university commercialization experiences, etc.). I will then contact you with further information and to schedule our session.

[Insert link here]

Thank you in advance for your willingness to participate.

Sincerely,

Cory Hixson

Doctoral Student

Engineering Education

Virginia Tech

hixson@vt.edu

Additional Contact Information: If you have any questions or concerns about this study or if any problems arise, you may also contact me at (240) 244-9766. If you have any questions or concerns about your rights as a research participant, please contact the Virginia Tech's institutional review board at irb@vt.edu.

Appendix C: Faculty Screening Survey

First Name: [text]

Last Name: [text]

Sex: (*Male/Female/Prefer not to respond*)

University commercialization activities include evaluating market potential, licensing, and/or developing spinoff companies. Common phrases used to describe these knowledge translation activities are “technology transfer” and “technology commercialization.”

Have you ever participated in any of these activities?: (*Yes/No*)

What activities have you participated in as a faculty member? [Choose all that apply] (*Licensing, Spinoff/Startup Development, Evaluating the market potential of research, Other: _____*)

Please list the academic institution(s) where you have participated in university commercialization as a faculty member.

Please list the academic context(s) in which you have participated in university commercialization at [institution] (e.g., engineering, veterinary medicine, general medicine, agriculture, other). If interdisciplinary, feel free to combine contexts.

Academic Rank while participated in university commercialization?: [Check all](*Full Professor, Associate Professor, Assistant Professor, Instructor/Lecturer, Adjunct Professor, Department or Section Head*)

Are you willing to participate in a ~60-minute interview about your university commercialization experiences? (*Yes/No*)

If yes, please provide an email address where you can be reached: [text]

Appendix D: Admin/TTO Recruitment Email

Subject: Faculty Experiences with Technology Transfer and Commercialization - Your participation is requested!

Dear [Land Grant Admin or TTO Employee],

I am writing to invite you to participate in a study exploring the technology transfer and commercialization (university commercialization) experiences of engineering faculty members. university commercialization activities include evaluating market potential, licensing, and/or developing spinoff companies. The goal of this study is to better understand the university commercialization experiences of engineering faculty members in order to help universities support faculty who wish to engage in university commercialization. As [an Engineering Administrator or a TTO Employee] your participation in my study provides important contextual and systematic data that I need to accurately understand faculty members' experiences.

Your engagement involves participating in an interview to help me understand university commercialization activities at your institution. Our session will take place at a time and location that is convenient for you and, if necessary, can be completed virtually or by phone. I anticipate that each interview will last approximately 60 minutes. All sessions will be audio-recorded and transcribed for analysis.

If you are interested in participating in this study, please send me a brief email at the address below. I will then contact you with further information and to schedule our session.

Thank you in advance for your willingness to participate.

Sincerely,

Cory Hixson

Doctoral Student

Engineering Education

Virginia Tech

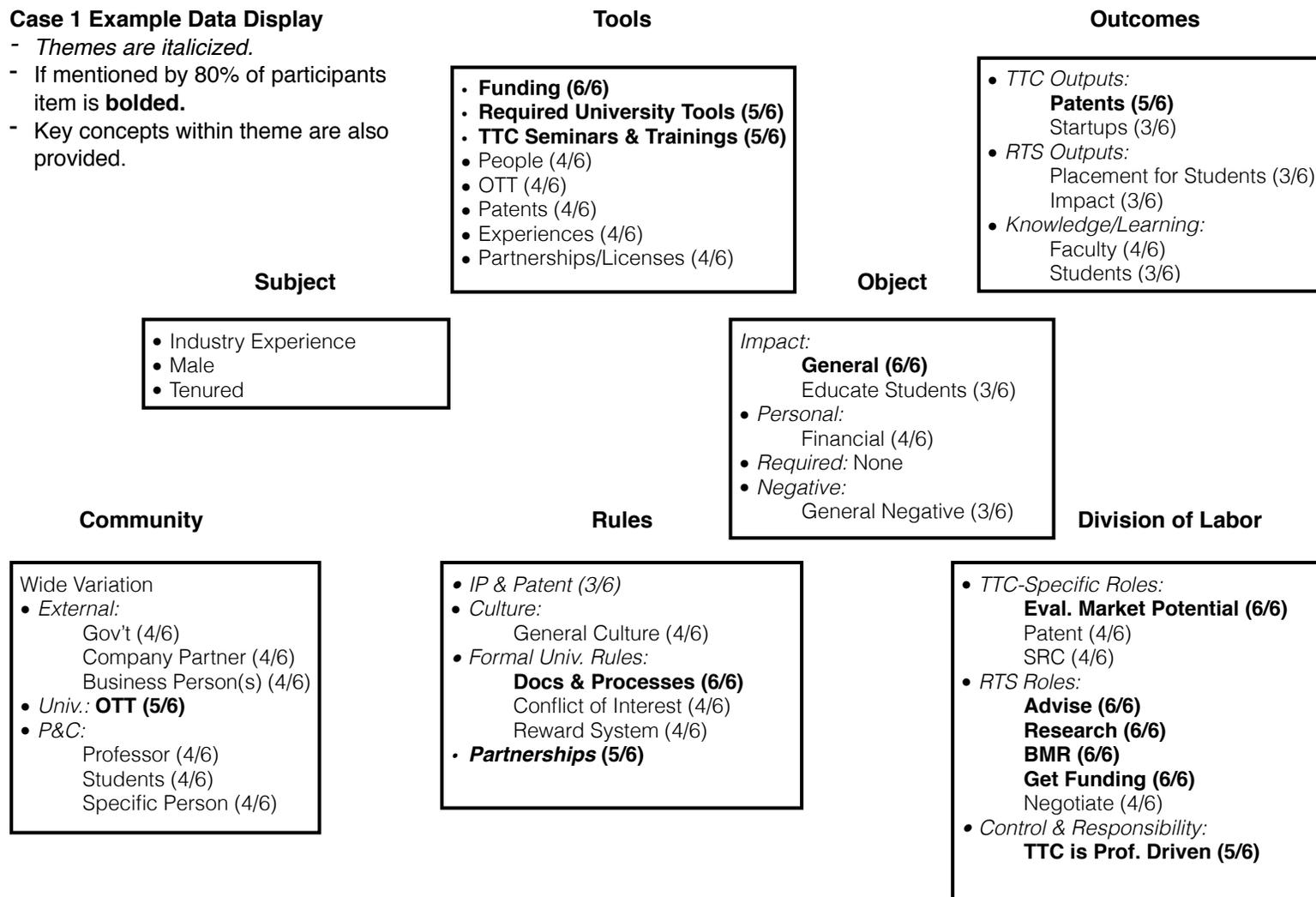
hixson@vt.edu

Additional Contact Information: If you have any questions or concerns about this study or if any problems arise, you may also contact me at (240) 244-9766. If you have any questions or concerns about your rights as a research participant, please contact the Virginia Tech's institutional review board at irb@vt.edu.

Appendix E: Example Data Display

Case 1 Example Data Display

- *Themes are italicized.*
- If mentioned by 80% of participants item is **bolded**.
- Key concepts within theme are also provided.



Appendix F: Codebook

Engineering Faculty Commercialization – Full Codebook

Subject/Person: The subject of an activity system is the individual or group whose viewpoint is adopted.				
	<u>Code</u>	<u>Subcode</u>	<u>Description</u>	
Codes & Subcodes	Commercialization Experience		Captures any prior commercialization experience (does not have to be as a faculty member)	
	Inventor		Captures if and what participants have invented (does not have to be as a faculty member)	
	Industry Experience		Identifies prior industry experience	
	Goals		Captures participants discussion of their goals as a faculty member	
	Title(s)		Captures participants formal titles both inside and outside the university	
Division of Labor: The division of labour involves the division of tasks and roles among members of the community and the divisions of power and status.				
	<u>Code</u>	<u>Subcode</u>	<u>Description</u>	
Codes & Subcodes	Starting-Running a Company		Descriptions of startup experience	
	Disclosing Intellectual Property		Descriptions of disclosure experience	
	Prosecuting Patent		Descriptions of patenting experience	
	Evaluating Market Potential	Find company-market research		Actively helps find partner companies and/or market the research outside of the university
		Evaluate commercializability		Any activity that can help one determine if the discovery is commercializable.
		Develop argument-communicate value		Determining and communicating why anyone should care about your discovery.
		Business model development		The process of developing a model that conveys the best approach for commercialization.
	Advising		Adviser to Faculty, OTT, OSP, licensee (or potential licensee), and students	
	Negotiating		Captures involvement in the negotiation process	
	Researching		identifies any mention of conducting research	
	Building-Mediating Relationships		Captures approaches and experiences faced with respect to relationships between faculty, licensees, funders, potential partners, students, OTT,	
	Securing Funding		Identifies approaches used to fund research, commercialization, students, etc.	
	General Marketing		Captures marketing oneself and one's work (e.g. at conferences)	
	Managing Money		Identifies handling money and budgeting	
	Completing paperwork		Captures any mention of completing paperwork	
	Some commercialization activities faculty don't want to do		Reasons why faculty prefer to not do commercialization	
Roles change over time		Ways in which faculty members' roles change throughout their career		
Students		Use if student was given responsibility for activities		
Faculty (Professor Driven)		Use if faculty member was given responsibility for activities		

	University (includes TTO)		Use if university entity (other than students and faculty) was given responsibility for activities
Rules: Rules are explicit and implicit norms that regulate actions and interactions within the system (Engeström, 1999; Kuutti, 1996).			
	<u>Code</u>	<u>Subcode</u>	<u>Description</u>
Codes & Subcodes	Supported by Unit Leaders		Attitudes supporting commercialization activity
	TTO - controls everything		The belief/attitude that the TTO controls the commercialization process
	Not a "required" academic activity		The belief/attitude that the faculty do not "have" to engage in the commercialization process
	General Attitudes		Catch all for other attitudes described by participants
	Partnerships		The rules /attitudes associated with a formal relationships with an external client
	IP & Patenting		The rules/attitudes associated with university intellectual property and patenting
	Overhead		The rules/attitudes associated with handling university overhead
	Formal documents/processes		Descriptions of formal documents and processes associated with commercialization
	Conflict of Interest (commitment?)		Rules/attitudes regarding conflict of interest/commitment associated with commercialization
	Must spin out of the Unit		The belief that all commercialization must be developed into a university startup
Community: Community refers to the participants of an activity system, who share the same object/motive.			
	<u>Code</u>	<u>Subcode</u>	<u>Description</u>
Codes & Subcodes	I-Corps		A code was made for each possible community member; therefore the codes to the left represent all members of the commercialization community identified by participants.
	alumni		
	competitors		
	connectors		
	consultants		
	customers		
	licensees		
	incubator		
	startup		
	family		
	private foundation		
	investors		
	funding agency		
	company partner		
	government officials		
	practitioners		
	market		
	government agency		
	business person people		
	manufacturers		
college			

department		
Campus Eship Center		
business school		
provost		
OVPR		
TTO		
Spark		
OSP		
university		
university leadership		
industry relations		
specific people		
Students		
another professor		
department head		
partners		
post doc		
study reviewers		
scientists		
mentor		

Object/Motive: Object "refers to the 'raw material' or 'problem space' at which the activity is directed and which is molded or transformed into outcomes with the help of physical and symbolic, external and internal tools" (Engeström, 1999, p. 67). It precedes and motivates activity.

	<u>Code</u>	<u>Subcode</u>	<u>Description</u>
Codes & Subcodes	educate students		Commercialization serves as a tool to educate students.
	startup company		Faculty want to start a company
	market gap		Commercialize because it will address a gap in the market
	IP development		Commercialize because that is the only way the intellectual property can advance
	solve a problem		Commercialize because it will solve a real-world problem
	exploring potential		Commercialize because they seek to determine if something valuable is there
	general impact		A desire to have an impact with university activity
	advance the field		A desire to advance the field through commercialization (as opposed to publications)
	tenure		Commercialize because I can count the outputs toward P&T
	learning		Commercialize because I want to learn something new
	think differently		Commercialize because its what I'm wired to do
	interesting		Expressions of interest/curiosity driving one to commercialize
	family		Commercialize because I come from a family who are entrepreneurs
	ambitious		Commercialize because its I don't settle for the status quo of faculty work
	financial		Commercialize because I want to make some money
resume builder		Commercialize because it will add to my overall credentials	

	fun		Expressions of enjoyment driving one to commercialize
	disclose before publishing		Disclosing because one wants to publish, not because they seek to commercialize
	responsibility - service mission		commercialization is part of being an academic (responsibility)
	negative reasons	Protection	The desire to protect oneself from the university
		Fear university	Commercializing because one is afraid of what the university will do if they don't
	student Initiated		Students desire to commercialize or learn about commercialization,
	approached by company		Companies learn about a faculty members' research and seek out the faculty member

Tools: Tools mediate the object of activity. They can be external, material (e.g., a textbook, a computer) or internal, symbolic (e.g., language). Tools take part in the transformation of the object into an outcome, which can be desired or unexpected. They can enable or constrain activity.

	Code	Subcode	Description	
Codes & Subcodes	Funding Tools		A code/subcode was made for each possible type of tool; therefore to the left you see all of the types of tools identified by participants.	
	Seminars_Trainings			
	Required University Tools			
	People			
	TTO			
	Patents			
	Publicity Mechanisms	Meetings		
		Academic Papers & Presentations		
	Findings/Research Artifacts			
	Partnerships/Licenses			
	Software			
	Mentoring			
Competitions				

Outcomes: Outcomes are the realized outputs, tangible or intangible, that result from participating in human activity systems.

	Code	Subcode	Description
Codes & Subcodes	university equity		A code/subcode was made for each outcome type identified by participants.
	reputation for the university		
	definitions of success_failure		
	economic development		
	revenue		
	product		
	patents		
	startup		
	licenses		
	publicity		
	awards		
	addition to P&T materials		

	partnerships		
	impact		
	publications	academic papers	
		dissertations	
	R&D		
	placement for students		
	funding		
	Learning	student learning	
faculty learning			
others learning			

Affect: Affect is participants' expression of emotion or the acknowledgement that commercialization engagement had an effect on the faculty member's mental or emotional state.

	<u>Code</u>	<u>Subcode</u>	<u>Description</u>
Codes & Subcodes	Negative Affect	Unsure	expressing uncertainty about participating in commercial activity and its acceptance
		Dissapointed	expressing disappointment about the commercialization process
		Overwhelmed	expressing a feeling of being overwhelmed about the commercialization process
		Sad/disheartening	expressing a feeling of being sad/disheartened about the commercialization process
		Angry	expressing a feeling of being angry during the commercialization process
		Frustrated	expressing a feeling of being frustrated during the commercialization process
		Stigmatized	expressing a feeling of being stigmatized during the commercialization process
		Astonished	expressing a feeling of being shocked (in a bad way) during the commercialization process
		Passionate	expressing a feeling of being passionate about a negative occurrence during the commercialization process
	Positive Affect	Trust	expressing a feeling of trust, particularly with other members of the community
		Happy	expressing a feeling of happiness about the university commercialization process
		Fun	expressing that university commercialization is fun/enjoyable
		Appreciative	expressing a sense of appreciation for university commercialization
		Interesting	expressing that university commercialization is interesting
		Exciting	expressing that university commercialization is exciting
	Satisfying	feeling satisfied about participating in commercial activity	
	Passionate	feeling passionate about a positive occurrence during the commercialization process	

Supports: Supports include anything that help a faculty member engage or succeed in commercialization activity.

	<u>Code</u>	<u>Subcode</u>	<u>Description</u>
Codes & Subcodes	tenure		Supports codes identify interview segments that discussed a topic (captured via the code) as supporting their ability to engage in university commercialization. For example, the code "tenure" captures each instance where a participant discussed the tenure system and having tenure as a support for the commercialization engagement. Another example, "money" was used to identify instances in which participants described money as

			supportive to their commercialization experience. This coding scheme was consistent for all codes identified in the Supports category.
	advice		
	advocates		
	collaborations		
	communication		
	culture		
	ecosystem		
	entrepreneurship centers & incubators		
	experience		
	flexibility		
	knowledgeable colleagues		
	learning		
	money		
	other		
	TTO		
	patents		
	a strong motive		
	publicity		
	published resources		
	R&D		
	relationships		
	reputation in field_marketing		
	specific people		
	synergy in activities		
	training		
	value in FAR		

Challenges: Barriers include anything that impedes a faculty members' engagement or success regarding commercialization activity.

	<u>Code</u>	<u>Subcode</u>	<u>Description</u>
Codes & Subcodes	big time commitment		<p>Challenges codes identify interview segments that discussed a topic (captured via the code) as challenging their ability to engage in university commercialization. For example, the code “big time commitment” captures each instance where a participant discussed the large time commitment and how it challenged their ability to engage in university commercialization. Another example, “lack of understanding” was used to identify instances in which participants described a lack of commercialization knowledge as detrimental to their commercialization experience. This coding scheme was consistent for all codes identified in the Challenges category.</p>
	relationships		
	company partner issues		
	culture		
	Expectations		
	Finding company partners		
	Formal Rules		

	job faculty don't want to do		
	lack of resources		
	lack of understanding		
	other		
	TTO		
	Person		
	P&T		
	Intersection of commercialization and scholarly roles		
Other: Use to gather insights that did not have a straightforward fit into another category			
	<u>Code</u>	<u>Subcode</u>	<u>Description</u>
Codes & Subcodes	Terms for successful entrepreneurial faculty		The language used to identify/describe successful entrepreneurial faculty (e.g., superstar, superhuman)
	General Suggestions		General suggestions about the commercialization process
	Impact of university location		Descriptions regarding how the university's location impacts a faculty members ability to do commercialization
	Advice to other faculty		General suggestions about the commercialization process targeted to other faculty
	Impact on faculty career		Descriptions regarding how commercialization has impacted the other parts of a faculty members' career

Appendix G: Cross-case Similarities with Descriptions

Code Category & Themes		Descriptions of Codes and Themes (Descriptions with a * are quoted directly from Murphy & Rodriguez-Manzanares, 2008 p. 443)
Division of Labor		<i>*Division of Labor</i> involves the division of tasks and roles among members of the community and the divisions of power and status.
Themes	Commercialization-Specific Activities	<i>Commercialization-Specific Roles</i> describes how faculty members discuss their commercialization-specific roles such as starting companies, disclosing IP, patenting, and evaluating market potential.
	Traditional Activities	<i>Traditional Faculty Roles</i> captures the connection between commercialization and traditional research, teaching and service roles.
	Responsibility	<i>Responsibility</i> identifies beliefs about responsibility to participate in commercialization and who is in control during these activities.
Rules		<i>*Rules</i> are explicit and implicit norms that regulate actions and interactions within the system (Engeström, 1999; Kuutti, 1996)
Themes	Attitudes	<i>Attitudes</i> describes participants' beliefs regarding the general culture and support for commercialization at the university.
	Formal Rules	<i>Formal Rules</i> identifies formal university rules such as invention disclosures, IP ownership, paperwork, etc.
	Promotion & Tenure	<i>Promotion & Tenure</i> captures participants' beliefs about how the attitudes and rules surrounding the promotion and tenure system impacts faculty university commercialization activity.
Tools		<i>*Tools</i> mediate the object of activity. They can be external, material (e.g., a textbook, a computer) or internal, symbolic (e.g., language). Tools take part in the transformation of the object into an outcome, which can be desired or unexpected. They can enable or constrain activity.
Themes	Funding	<i>Funding</i> identifies mechanisms (i.e., grant programs) that provide funding for faculty members to explore and accomplish commercialization.
	Seminars & Trainings	<i>Seminars & Trainings</i> are events that teach faculty members commercialization concepts and skills associated with commercialization activities.
	Required University Tools	<i>Required University Tools</i> are tools such as disclosure forms, policy documents, and handbooks that mediate commercialization activity.
Object		<i>*Object</i> "refers to the 'raw material' or 'problem space' at which the activity is directed and which is molded or transformed into outcomes with the help of physical and symbolic, external and internal tools" (Engeström, 1999, p. 67). It precedes and motivates activity.
Theme	Desire to Have an Impact	<i>Desire to Have an Impact</i> captures faculty members' motivation to do commercialization because it offers an opportunity to make an impact in the world.

Code Category & Themes		Descriptions of Codes and Themes (Descriptions with a * are quoted directly from Murphy & Rodriguez-Manzanares, 2008)
Community		*Community refers to the participants of an activity system, who share the same object.
Themes	External Actors/Entities	<i>External Actors/Entities</i> are individuals and entities external to the university who are relevant to faculty members' commercialization activity.
	University Actors/Entities	<i>University Actors/Entities</i> are individuals and entities within the university who are relevant to faculty members' commercialization activity.
	Peers & Colleagues	<i>Peers & Colleagues</i> are individuals who are closely connected to the faculty member and relevant to their commercialization activity.
Subject		*The <i>Subject</i> of an activity system is the individual or group whose viewpoint is adopted.
Themes	Has Industry Experience	The theme <i>Has Industry Experience</i> captures the consistent nature in which participant reported the influence of their prior industry experience.
	Is Tenured	<i>Is Tenured</i> captures both the fact that the majority of participants interviewed were tenured as well as their recommendation that commercialization activity should be avoided for pre-tenure faculty.
	Is Male	<i>Is Male</i> captures the fact that both the majority of participants interviewed and potential participant pool were male.
Outcomes		<i>Outcomes</i> are the realized products of participating in commercialization activity.
Themes	Commercial Outputs	<i>Commercial Outputs</i> are outcomes that would be considered "typical" to commercialization activity (e.g., patents & startups).
	Scholarly Outputs	<i>Scholarly Outputs</i> are outcomes of commercialization activity that are more in line with the traditional faculty work of research, teaching, and service.
	Learning	<i>Learning</i> captures participants' discussions regarding the ways commercialization activity has helped them develop new knowledge.
Affect		<i>Affect</i> describes the the expression of emotion or the acknowledgement that commercialization engagement had an effect on the faculty member's mental or emotional state.
Themes	Positive Affect	<i>Positive Affect</i> identifies emotions and mental states indicating positive motives or evaluations of the university commercialization system (e.g., positive feelings toward university commercialization, interest in commercialization, or lack of discomfort or stress).
	Negative Affect	<i>Negative Affect</i> identifies feelings and emotions associated with commercialization participation that result in a negative evaluation of the activity (causes discomfort or stress).