ABSTRACT


Academic entrepreneurship and technology transfer continues to evolve through a developing interest in patent, license, and start-up creation. For emerging academic entrepreneurs, this has resulted in increased avenues for commercialization (Grimaldi, Kenney, Siegal, Wright, 2011). This study aims to analyze two of the most popular channels for market commercialization from academia: spin-offs and license agreements. NC State University New Venture data is used to assess prior output of license agreements and startups. In addition, a case study is conducted to discuss and evaluate the journey of an academic entrepreneurship venture based out of the NC State University Wilson College of Textiles.

Results of this study include a qualitative analysis of interviews from academic entrepreneurs, business mentors, and external companies involved with the university. These responses highlight the benefits and risks of university technology commercialization. Results discuss the large amount of time and effort required to pursue a venture as well as the benefits to academics, students, and the business community. The study concludes with recommendations and implications for future academic entrepreneurs. Accordingly, three major recommendations are made. These discuss the necessity of a value proposition package, an external business management team, and market research testing.
From Academic Research to Product Commercialization: Analyzing Academic Entrepreneurship in the Textile and Apparel Industry

by
Lilah A Halbkat

A thesis submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the degree of Master of Science

Textiles

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APPROVED BY:

Dr. Andre West
Committee Chair

Dr. Delisia Matthews

Dr. Emiel DenHartog
DEDICATION
To my grandparents, four bright lights in my life. Your pursuit of knowledge and education has been my ultimate inspiration.
BIOGRAPHY

Lilah Halbkat was born in 1996 in Tryon, North Carolina. She grew up surrounded by the beauty of the outdoors in the foothills of the Appalachian Mountains. Throughout her life, she grew a passion for sustaining and protecting the environment, which led her to support environmentally friendly textile and apparel efforts at the NC State University Wilson College of Textiles.

Lilah received her undergraduate degree from the Wilson College of Textiles in 2017 in three years of study. Throughout her experience as an undergraduate, she had the opportunity to lead the Greater Good Textile Group, organize three Business Sustainability Forums, study photography abroad in the Czech Republic, and intern at Low & Bonar, a company that produces nonwovens for green roof drainage applications.

She decided to continue her Master of Science in Textiles degree at the Wilson College of Textiles in 2017, diving into a mosquito resistant apparel project with a team of five distinguished professors at NC State University. During this experience, she helped to establish the startup company while simultaneously studying the methods in which to do so. Before graduating, she had the opportunity to intern at Newell Brands, in which she gained a passion for color, material, and finish design.

Lilah is excited to be a Masters graduate and enter the world of technical textiles where she aims to make an impact on sustainability, global health, and innovation.
ACKNOWLEDGMENTS

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I would also like to thank the Vector Textiles team who allowed me to grow my knowledge in the area of mosquito resistant textiles. I have grown exponentially with your belief in my abilities. Thank you, Dr. Charles Apperson, Dr. Marian McCord, and Dr. Mike Roe for teaching me about a subject that was foreign to me. You helped round out my education in a way I had never expected. Also, I would like to thank the Office of Technology Transfer at NC State for allowing many interviews, conversations, and questions throughout this process. Without this office and the growing interest in entrepreneurship at NC State, the motivation to pursue this thesis topic would not exist.

I want to extend a special thank you to my loving parents, who always believe in my abilities and push me to keep working towards my goals. Thank you to my brother Rob, who adds both drama and laughter to my life. A thank you and dedication to my grandparents who are constant supporters of my education. Last but not least, a thank you to my partner Hank Pelfrey who supports me in an infinite number of ways. I could not have done it without all of you!
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<tr>
<td>Startup</td>
<td>A recently created business that is still in the process of developing and refining its product or service offering (Spin-out, 2015).</td>
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<tr>
<td>Spinoff or Spin-out</td>
<td>A startup in which a minority shareholder is often an educational institution such as a university. Intellectual property and human capital move from an educational institution to a new company that is a separate trading entity (Spin-out, 2015).</td>
</tr>
<tr>
<td>OTT or OTCNV</td>
<td>Offices of Technology Commercialization and New Ventures, also known as Office of Technology Transfer (OTT), are semi university-independent organizations responsible for &quot;organizing inventions with the greatest potential for making a significant positive impact and choosing the best course of action to support their development&quot; (Gubitta, Tognozzo, Destro, 2015). Their primary function includes acting as intermediaries between researchers at academic institutions and the business sector, particularly aiding with license agreements and access to funding.</td>
</tr>
<tr>
<td>Technology transfer</td>
<td>The process of commercializing innovative technology from an academic research setting (OTT Statistics, 2018).</td>
</tr>
<tr>
<td>Academic entrepreneur</td>
<td>A university faculty, student, or staff member who aims to commercialize an innovation discovered or developed at a university setting (Hayter, 2015).</td>
</tr>
<tr>
<td>Disclosure</td>
<td>The release of information from academic researchers to their respective university. Disclosures include patents, inventions, spin-off companies, and license agreements (OTT Statistics, 2018).</td>
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 CHAPTER 1: INTRODUCTION

Overview of Academic Entrepreneurship

Academic Entrepreneurship, the “establishment and impact of spinoff companies founded by university faculty, students, or staff”, is fast becoming a principal instrument in early-stage technology design (Hayter, 2015). These innovations aim to solve a particular problem or fulfill a societal need, but on many occasions, fail to translate into pragmatic solutions that are fit for direct commercialization (Abbas, Trainor, Tutell, 2018). Innovation and entrepreneurship in the United States account for one-third to one-half of economic growth, making it imperative for academics to understand this commercialization process (Godfrey, Moore, 2017). With increased communication between the business and scientific communities, academics can now offer patentable solutions to everyday problems to the public. University leaders are acknowledging this opportunity by implementing technology transfer and communication strategy plans for academic employees and students (Gubitta, Tognozzo, Destro, 2015). These institutions frequently assist company spin-offs as well as facilitate university licensing agreements by leveraging the university’s reputation, regional economic development, and funding for faculty projects (Hayter, 2015).

The past thirty years have seen increasingly rapid advances in university-funded technology. Research universities such as the Massachusetts Institute of Technology (MIT) and Stanford University have a history of commercializing a large number of license and start-up ventures. The Bank Boston Economics Department calculated that start-up companies from MIT alone generate 232 billion dollars of sales every year to the US economy (O'Shea, Allen, Chevalier, Roche, 2005). An increasing number of universities are following in MIT's footsteps, boosting respective entrepreneurship programs. The NC State Technology Entrepreneurship and Commercialization (TEC) program has helped create over 350 new jobs in spin-off businesses and has contributed $1.2 billion in added income from spin-offs for the state of North Carolina since its creation in 1990 (Boocock, Frank, Warren, 2009). The university has received national recognition from the Association of University Technology Managers and is ranked #2 in number of license and options executed, #5 in number of invention disclosures, and #5 in number of spin-offs launched among universities without medical schools. In 2017 alone, NC State University secured $4.4 million in total licensing revenue (CEDNC, 2018).
The Wilson College of Textiles within NC State University has been heavily involved in the entrepreneurial success of the university over the past five years. From the years 2013 to 2017, the Wilson College of Textiles at NC State University has provided the third highest number of total disclosures (such as patents, inventions, spin-off companies, and license agreements). The College of Engineering and College of Agriculture are ranked first and second; these colleges employ over 7 times and 2 times the amount of faculty researchers respectively (See Figure 12) (OTT Statistics, 2018). The before mentioned disclosures include a broad range of ideas and products, but many specialize in highly technical medical devices such as mesh innovations in hernia repair (Deep Blue Medical, 2018, Products, 2018).

Issues surrounding academic technology transfer have received considerable attention as the field continues to evolve. However, there has been little quantitative analysis of the impact of academic entrepreneurship on involved community members and external company partners. In addition, few studies analyze the success of various paths of commercialization for academic entrepreneurs in the textile industry. This study addresses community impacts of entrepreneurship and analyzes two of the most popular channels for market commercialization, academic spin-offs and external license agreements, at NC State University.

Current Problems

Research has consistently shown that even with university support and influence from the Office of Technology Commercialization and New Ventures (OTCNV), bridging the gap between the scientific community and everyday consumers can prove to be no small feat. In some cases, projects fall victim to the ‘Valley of Death,’ a concept in which early-stage technology fails to make it to commercialization (Yu, 2016). See Figure 1 for a graphical depiction of the Valley of Death. The inability to bridge the gap between existing research resources and commercialization causes this phenomenon (Markham, Kingon, Lewis, Lii, 2002).
Research collected in a study of 57 academic entrepreneurs discusses the challenge of establishing a company as a part-time endeavor. It can be difficult for an academic individual to achieve ambidexterity when simultaneously engaging in entrepreneurial, research, and teaching activities (Erikson, Knockaert, Foo, 2015). Time restraints, as well as little support from peers and employers also contributed to this challenge. Many academic researchers have extensive experience in innovation and scientific discovery, but little experience in knowledge exploitation; the commercialization of academic discoveries (Siegal et al., 2007). Universities have shown an increased interest in recruiting business executives and entrepreneurs to help translate research into the commercial space (Mehta, 2004). Without an experienced entrepreneurial influence, many academics find that they are unable to complete the process of creating a spin-off company. Erikson found that more than half of the entrepreneur respondents decided to forgo technology commercialization and focus on translational research such as contractual technical consulting (Erikson et al., 2015).

According to Paul et al., (2015), university technology transfer methods that are currently available do not always result in success for academic entrepreneurs. For these technology transfer models to succeed, they must be feasible and easy to implement for those without a traditional business background (Siegal, Vieuogelers, Wright, 2007). Many academic entrepreneurs are looking for a conventional business model that is hypothesis-driven and formulaic. However, models like NC State University’s Technology Entrepreneurship and
Commercialization algorithm are based on trial and error decision making, and not on a one-size-fits-all commercialization technique (Bookock, 2009).

**Purpose of the Study**

This thesis will examine the trials of academic entrepreneurship as well as the two main methods of commercializing new and innovative technology from an academic research setting: spin-off development and license agreements. Data from the past five years from the NC State University OTT office was analyzed and discussed. In addition, a case study was constructed that analyzes the path to commercialization for an academic entrepreneurship venture created at NC State University.

The research objectives are as follows:

1. Investigate two current available avenues for technology commercialization from the academic sector: spin-offs and license agreements
2. Investigate community impact of academic entrepreneurship at NC State University
3. Discover the intricacies involved with academic entrepreneurship in the textile sector and the industry’s unique issues and success factors

**Primary Research Questions**

The following questions guided this research:

a. Are there difficulties regarding technology transfer for some academic entrepreneurs at NC State University?

b. How are spin-offs and license agreements useful in commercializing a highly technical textile product as measured by defined commercialization?

c. How is the surrounding community impacted by academic entrepreneurship ventures?
Academic Entrepreneurship

While corporations were once the main drivers for innovative research and development, they are now choosing a more private and internal approach. In 1980, roughly 17.7% of corporations published in scientific journals, compared to the 6.1% that published in 2007 (Marcolongo, 2017). Therefore, universities have become the primary source for exploratory research and innovative technology. While many academics have little to no experience navigating intellectual property laws, licensing agreements, and business finance, they continue to push their discoveries towards a more commercial market (Hayter, 2015). Research shows that factors like good management, financing, government support, and even various personal qualities are more critical to a successful venture than prior experience in business (Yusuf, 1995).

A considerable amount of literature has been published regarding academic entrepreneurship. The main focus of these publications include commercialization challenges academic entrepreneurs face as well as the strategies they use to combat these issues (Columbo, 2008). Qualitative research conducted by surveys, interviews and case studies is the most widely used methodology (Godfrey et al., 2017). Authors Siegal and Wright (2015), researched the shift of academic technology transfer from a focus on university growth to the growth of the economy and community. Phan (2016) places emphasis on trial and error methods for technology translation, and discusses how market development can make or break a startup or license venture. Marcolongo's (2017), book, Academic Entrepreneurship, guides a potential academic entrepreneur through the many steps to bringing innovative research to the marketplace.

Success and Motivation. Across all industries, having a passion and dedication for an idea is indicative of entrepreneurial success (Godfrey et al., 2017). Motivations for academic researchers to embark on an entrepreneurial journey are shown to be different from the motives for a typical entrepreneur. Motivations to create spin-off companies specifically include the opportunity to apply research knowledge to practical commercial applications, identify market opportunities, gain independence from the university setting, and gain the opportunity to participate in a riskier environment than what academia typically allows (Chiesa, Piccaluga, 2000).
In a study of technical academic entrepreneurs from MIT, the typical entrepreneur desired a high level of independence, a moderate desire for achievement, and a low need for university affiliation. The primary motivation for bringing their research to commercialization was the desire to see the technology in practice (O'Shea et al., 2005). Some academic entrepreneurs pursue ventures that offer little monetary gain potential but provide personal satisfaction. Instead, these entrepreneurs may have the desire to create a good for the benefit of society (Parker, 2006).

Researchers Siegal and Wright (2015), discuss traditional versus emerging perspectives of academic entrepreneurship in their book Academic Entrepreneurship: Time for a Rethink?. Instead of focusing on the generation of financial returns, academic entrepreneurship now focuses on providing social and economic benefits to the university and the surrounding ecosystem. While licensing, spin-offs, or patents were once the main focus, start-ups and job creation are a new emerging perspective on commercial success. The future employment of graduate students is now becoming a focus of academic entrepreneurship as well (Massa & Testa, 2008).

Many academics strive for careers in consultancy and make this the goal of spin-off companies and license agreements (Massa & Testa, 2008). Consultancy companies have low financial need and risk. Disincentives for entrepreneurship, as noted in an Italian study of 48 academic entrepreneurs, include losing the freedom and privileged status of working for a university as a professor or distinguished researcher (Chiesa & Piccaluga, 2000). Many academic entrepreneurs may not desire to leave a well-respected and tenured academic position (Fritsch et al., 2010).

The Path to Commercialization. There are many different paths used by academic entrepreneurs from the lab to the marketplace. Figure 2 shows an evolving path from academic discovery to commercialization. The innovative research starts with patent protection and publication and begins the perilous path through market testing, tech transfer, and a possible angel investor (Marcolongo, 2017). Studies describe three ways to innovate creatively: offer a new perspective of an existing design, explore the need for market alternatives, or start with consumer insights such as product likes and dislikes. In the textile and apparel industry, creativity is involved in each aspect of these entrepreneurial designs (Hodges & Link, 2018).
Figure 2. The path from academic discovery to commercialization (Marcolongo, 2017).

Despite academic efforts to simplify entrepreneurship paths, universities in the USA and elsewhere are developing new ways to improve and promote innovations. These include ‘entrepreneurial garages' which provide space, resources and mentoring to facilitate student and alumni spin-offs, in some cases integrated with undergraduate and graduate curriculums (College of Textiles, 2017). Universities have also begun supporting business plan competitions, and public/private "incubators" (Siegal et al., 2015).

Current Issues. In Phan’s book, Academic Entrepreneurship (2016), the role of universities in economic and industrial development has been analyzed, as well as the problems with the translation phase of the technology transfer process. The translation period refers to the need to find different markets for various technologies, and commercialization strategies that appeal to the right target consumer. Phan and Boocock suggest that the translation phase explores several plans for commercialization through a non-avoidable trial-and-error period. In this perspective, a hypothesis-driven method is discouraged, as the learning process adds a greater angle to find the ideal market segment (Phan, 2016, & Bookcock, 2009).
Despite the possibility of economic gain for both the university and the local economy, there is a skeptical view that research and entrepreneurial activities compete for the researchers’ time (Buenstorf, 2009). This view suggests that a greater focus on inventing technology decreases the amount of research and publication output for the academic employee. Universities argue that inventions are products of research and are also suitable for publishing (Phan, 2016). In many life-sciences, "patent-paper pairs," or scientific papers based on patented product creation, are common and can be mutually beneficial for both the university and professor (Buenstorf, 2009).

**Office Technology Transfer (OTT) and University Facilitation**

The OTT, or the OTCNV at NC State University, is a semi-independent organization responsible for "organizing inventions with the greatest potential for making a significant positive impact and choosing the best course of action to support their development" (Gubitta et al., 2015). They work as intermediaries between researchers at academic institutions and the business sector, particularly aiding with license agreements and access to funding (Moutinho, Au-Yong-Oliviera, & Coelho et al., 2016). This funding can be sourced from venture capitalists as well as university commercialization funds when deemed appropriate by the TTO. The TTO is also seen as a credible party to signify possible market success for a discovered technology to those seeking to fund university spinoffs. With higher levels of academic technology transfer support, there is a higher proportion of industry-level funding (O'Shea et al., 2005).

The idea of technology transfer services arose in 1970 with the creation of the Association of University Technology Managers (AUTM). University-driven services like these create billions of dollars’ worth of benefits to the US economy. Between the year 1998 and 2005 academia transferred over 3,500 products to the marketplace (Marcolongo, 2017).
TTO offices also facilitate government interventions such as federal and state grants for startups and innovation. The Small Business Innovation Research (SBIR) program, has awarded 112,500 awards that total $26.9 billion on the federal level (Hayter, 2015). On a state level, the State of North Carolina can offer partial grants to SBIR awarded companies to further commercialize innovation. Additionally, academic entrepreneurs can utilize Manufacturing USA, which focuses on bringing industry and federal funding to facilitate the research and development of U.S. manufacturing capabilities (Godfrey et al., 2017).

The success of the NC State University entrepreneurship initiative can be in part explained by The Office of Technology Commercialization and New Ventures (OTCNV). The term "new ventures" indicates business endeavors during the first five years of the venture's establishment (Zhao & Brookshire, 2014). The office describes itself as “a protector of research discoveries and intellectual property, a creator of industry partnerships, and a promoter of spin-off acceleration.” By providing programs and services that market and license intellectual property, the office assists academic entrepreneurs in finding markets for their innovative technology. Programs and services offered by the OTT include the National Science Foundation Innovation Corps (NSF I-CORPS), Venture Mentoring Services, and university license/spin-off development as well as various grants and economic resources (OTT Statistics, 2018).

The National Science Foundation (NSF) was formed in the 1970s to fund and support research at universities, while also bringing together government, industry, and academia (NSF,
NSF I CORPS is a six-week program created in 2012 that encourages a final team decision on whether or not to pursue the commercialization of a technology (OTT Statistics, 2018). The program facilitates customer interviews and communication to determine the correct market for a product or innovation. It utilizes the Business Model Canvas (Figure 4), a strategic lean spin-off template used to develop business models, and helps entrepreneurs organize their efforts. The NSF I CORPS service helps to bridge the gap between innovative academic research and market commercialization through customer and market discovery (NSF, 2018).

![Business Model Canvas](image)

*Figure 4. Business Model canvas utilized by the NSF ICorps program (Strategyzer, 2018).*

The Council for Economic Development (CED) Venture Mentoring service based in Raleigh, NC is an additional source available to academic entrepreneurs through the OTT (OTT Statistics, 2018). This mentoring service, developed by MIT and licensed by the CED, pairs entrepreneurial companies with 3-4 mentors that work together to help make critical hires, find new customers, develop partners, seek licensing deals, and more. Having access to a team of experienced business professionals is valuable for NC State University academics as they negotiate license agreements and spin-off development (Making, 2018).

Researcher Boocock (2009), discusses the particularly booming entrepreneurship program supported by NC State University, which developed a revolutionary Technology
Entrepreneurship and Commercialization Algorithm in 1990 that continues to evolve today.

![The TEC Algorithm](image)

**Figure 5.** The TEC Algorithm (OTCNV, 2018).

The phases include:

- "Search and Ideation," in which researchers generate ideas for potential product applications. To maximize growth, researchers should create multiple applications for an innovation (Boocock et al., 2009). When researchers find numerous revolutionary applications for emerging technology, there are fallback target applications to consider if one fails. Also, there is more room for depth and expansion (Marcolongo, 2017).

- "Assessment and Analysis," in which commercial viability is related to many functional areas. This step eliminates any ideas with 'fatal flaws.' Fatal flaws include limited growth potential or the inability to protect intellectual property.

- "Commercialization Strategy" in which the proposed route to commercialization is chosen. An important note about this algorithm is that it does not offer a success/failure prediction, but it supports decision making with no exact science or mathematical precision. It is essential when using the algorithm to rethink ideas and change direction throughout the phases with each decision (Boocock et al., 2009).

When using the TEC algorithm, focusing on the development of a high growth potential technology that is neither too broad nor too narrowly focused is imperative for success. When using the algorithm, business to business manufacturing technology has shown more success than consumer goods. There is also a significant time commitment when using the entire TEC
Algorithm. The process can take around 200 hours for students and academic staff (OTCNV, 2018). There could also be a conflict of interest between the university and the academic researcher who is spending time educating him/herself on enterprise rather than teaching (Boocock et al., 2009).

Academic researchers at NC State University are required to complete Online Disclosures to the Office of Technology Commercialization and New Ventures (OTCNV) for Copyright, Invention, Plant, or Software innovations. This information is available to those belonging to the institution under the NC State University Research Administration Data & Reports, or RADAR system. RADAR is an online database that lists information on investigators, departments, colleges, project status (awarded or not), sponsor (direct or primary), subcontractor, activity type, and other parameters regarding various research-related projects. This information includes a listing of business collaborators, or sub-recipients, that researchers at the institution have previously worked with, along with Risk Level Assessments for each collaborator. These organizations span local and federal government, large nonprofits, foreign entities, institutions of higher education, for-profit small business, and large for-profit business. Here researchers can also monitor projects started, and awards received (Policies, 2018).

Notices of Intent (NOI) and Conflicts of Interest (COI) are also detailed in this system, to ensure proper guidelines for academic entrepreneurs. Faculty members and professional staff are required to submit an NOI when planning to engage in an external professional activity that involves payment. NOI and COI guidelines allow the university to monitor and protect itself and its employees. Among the situations considered unacceptable within the academic setting of NC State University are those that pertain to entrepreneurship. These include conducting external professional activities for pay that involve time commitments that interfere with university duties and responsibilities. Additionally, holding equity interest in a corporation in which the exclusive function is to accommodate a researcher's external consulting activities is also unacceptable. External support for university research that requires results to be confidential, unpublished, or delayed in publication is unpermitted (OTTNV, 2018).

University TTO's facilitate the building of network structures with private firms outside of academia that are critical resources for entrepreneurs. Four factors that can determine sustainable returns for academic entrepreneurs include the initial level of resources, capabilities, social capital and level of investor involvement in the venture, all of which allude to the
importance of social networking (Wright, 2004). Brian Eller at the OTCNV at NC State University stresses the importance of networking stating that “academic entrepreneurship is not a formulaic process, but one that is all based on personal connections, especially with venture capitalists and relevant industry connections.” He also states that many successful academic inventions come from business needs that have been expressed directly to academia by these personal connections, and academics use research to satisfy the existing need in the market (Eller, 2018).

Literature has also explored the success of Technology Transfer Offices themselves. The most effective TTOs network and create relationships with venture capitalists to understand their investment criteria. Networking ensures that new entrepreneurial ventures are taken seriously by those from which they can obtain funding (Gubitta et al., 2015). Arguments present that due to time restraints, the average university TTO office cannot give every academic entrepreneur the attention needed to create a spin-off or start-up venture (O'Shea et al., 2005). In addition to implementing and educating students and academics on ways to commercialize their technology, many TTO’s have traditionally acted as lead marketers for university IP, to both the community as well as significant corporations (Eller, 2018). The process can become overwhelming and expensive, especially as a university is continually developing technologies in various sectors. Large corporations tend to avoid licensing with universities and instead focus their energy on internal R&D efforts, which is a setback that TTO license officers must face (Marcolongo, 2017).

**Entrepreneurship in the Textile Industry**

While academic entrepreneurship has been studied extensively by researchers, there is a lack of research in the textile and apparel sector regarding new entrepreneurial ventures and the distinct issues these ventures face (Godfrey et al., 2017). However, according to the US Bureau of the Census, 59% of employees in the textile and apparel sector are employed by small-sized firms, and start-ups are common. Many entrepreneurial successes in this industry base success on unique design innovations, such as the innovative arch support technology that put athletic company New Balance in the commercial space (Hodges & Link, 2018).

In the early 1800’s, the textile and apparel industry helped to develop manufacturing facilities, mills, and entire towns built around the trade (Hodges & Link, 2018). Today, textile and apparel entrepreneurs face difficulties due to high market volatility and intense global
competition. Recently, global manufacturing shifts to lower cost areas has dramatically lowered product prices, ramping up competition between small and large firms (Plieth, Bullinger, Hansen 2012). In addition to these new competitive issues, the industry itself is already one of the most complex, involving skills and manufacturing techniques such as fiber and yarn creation, dyeing, and garment production (Gil-Pechuan et al., 2012).

Similarly to other industries, the government plays a role in motivation and success for textile and apparel entrepreneurship. For example, the Advanced Functional Fabrics of America (AFFOA) helps take fibers, yarns, and fabrics and integrate them into manufacturing networks and systems (AAFOA, 2018). Academic entrepreneurs that have discovered an innovative fiber or fabric could connect with AFFOA to leverage these efforts into mainstream applications. The State of North Carolina also provides matching funds for entrepreneurial startups through the One North Carolina Fund (OTT Statistics, 2018). In a publication by Blanton Godfrey (2017), extensive interviews were conducted mainly of entrepreneurs in the North Carolina textile industry. A few differences between starting a textile venture compared to others like medical equipment or software is the cost and regulatory environment. The textile industry requires a high amount of capital to enter even on a small scale, with costs reaching over a hundred thousand US dollars for one manufacturing machine. In contrast, apparel companies can have much lower start-up cost as existing global manufacturing resources are plenty (Hodges & Link, 2018).

Innovation and design processes are unique in the textile and apparel industry. Unlike many other consumer goods industries, textile innovations revolve around manufacturing processes and component innovations such as fibers, fabrics, and garment design (Plieth et al., 2012). Strategies such as branding, customization, and consumer insight are used to market these products, and in many cases, manufacturing transparency gives consumers insight into the intricacies involved in material development (Hodges& Link, 2018). Hodges states that there are six types of design innovations in the apparel industry: product-driven, process-driven, technology-driven, culture-driven, brand-driven, and consumer-driven (Hodges & Link 2018). Many academic entrepreneurs focus on technology, process, and product-driven innovations, while many startups and corporate R&D teams focus on culture, brand, and consumer-driven innovations.
Some of the struggles faced by these apparel entrepreneurs were directly related to the intricacies of the textile and apparel business. Detail-driven decision making in regards to investment in materials proved to be valuable as a single fabric decision could affect the durability, quality, and visual appeal of an entire line of products (Hodges & Watchravesringkan et al., 2015). The apparel market is hugely competitive in both global and local markets, especially in regards to pricing (Godfrey et al., 2017). Imported clothing from countries with lower labor wages and export tax rates profoundly affect pricing for local entrepreneurs who may have more substantial overheads and more personal funds involved in the company (Plieth et al., 2012). Instead of competing with price, many of these entrepreneurs focused on branding, niche markets, and a higher quality product. High customer service and customized products helped differentiate these small entrepreneurship ventures in the market (Hodges et al., 2015).

New ventures in China showcase the difficulty of entering the textile and apparel industry. In this country, approximately 80 percent of apparel new ventures fail within the first five years of establishment (Zhao & Brookshire, 2014). The skyrocketing number of Chinese apparel ventures due to increased global sourcing methods make success an anomaly (Phan, 2016). Zhao conducted in-depth interviews of sixteen top apparel companies in China to determine the secret to success for the companies that survived. Results showed that many of the most successful Chinese apparel ventures were merely the first to market. Companies reported that finding a niche market, maintaining a down-to-earth work ethic, finding a unique branding position and cultivating external relationships were critical factors for success. Also, having the ability to predict what would happen in the future of the apparel industry was essential for both trend forecasting and business development for the new venture (Zhao & Brookshire, 2014).

A study by Yu (1995) discussed entrepreneurship without the need for an innovative product. The study showed that 88 percent of Hong Kong apparel manufacturers focused on imitating similar clothing that had already appeared on the market, and only 8 percent attempted to make a unique product (Yu, 1995). This type of apparel entrepreneurship, no matter how prevalent or successful, would not be appropriate for academic entrepreneurs, adding another layer of difficulty to the creation of a new venture. Studies focusing on female entrepreneurs show similar factors for success. Currently, women-owned businesses make up about 30 percent of all small enterprises (Shane, Dolmans, Jankowski, et al., 2014). In Russia, South Africa, and
Thailand, essential factors of success for these female-run apparel ventures included positive word of mouth, social networks, passion, and flexibility (Hodges et al., 2015).

The textile and apparel industry is the second largest polluting industry in the world and is estimated to produce 10% of the world’s carbon emissions (Conca, 2015). Many entrepreneurs are using rising sustainability trends as a platform for textile venture success. As sustainable practices are growing in popularity in every industry, the textile and apparel industry has recently been the focus of many environmental efforts due to the significant effect these products have on the planet (Phan, 2016). Large corporations have been incrementally improving their environmental impact, and smaller entrepreneurial companies are beginning to form the core of their company on these sustainability efforts (Plieth et al., 2012). These companies aim to find a niche market that places value on their sustainable efforts and is willing to pay more for these products (Hodges & Link, 2018). However, not every market is willing to pay higher prices for sustainability, especially with the parallel rise in fast fashion and inexpensive clothing. In a case study of an entrepreneurial venture that produced sustainable clothing in Germany, it was found to be challenging to find local production facilities without searching globally, as well as competing in the price-sensitive industry (Plieth et al., 2012).

Textile and apparel innovations are complex and offer a wide range of opportunities for academic entrepreneurs. Academic researchers are innovating fiber makeup, color chemistry, and fabric manufacture technology and processes. Academics, as well as corporate research and development teams, innovate finish and laminate applications to create water, stain, or insect repellent textiles (Godfrey et al., 2017). It is more costly to create these kinds of innovations without a university grade research space. For this reason, academic researchers in this field may have a lower barrier of entry as they have access to chemical knowledge, industrial manufacturing equipment and researchers with in-depth industry knowledge (Hodges & Link, 2018).

**University Licensing**

While every university has a different policy regarding ownership of inventions, most universities have the right to own any discovery created using university facilities, equipment or funds (Guippa, 2015). Traditionally, the goal of academic entrepreneurs was to license their innovative technology to a large public company. About 80% of license agreements from universities go to existing companies rather than start-ups (Marcolongo, 2017). However,
universities have become more interested in "risky" options such as forming spin-off companies or licensing to a small private firm. This shift may be a result of an increasing number of companies hosting an internal R&D team (Columbo, 2008). Many times, a large corporation avoids licensing from a university because the innovation is too "early stage." Often the technology needs further proof of concept, development or scale-up feasibility (Moutinho et al., 2014). For this reason, smaller companies and spin-off companies may be a more natural way of market entry. However, these options do not always result in a successful commercialization venture for academic entrepreneurs (Powers & McDougall, 2005).

A direct license from the university to the corporation is the most straightforward way to commercialize technology as there is little university conflict, personal risk, or finance needed (Marcolongo, 2017). The license agreements allow the company the rights to use the invention, and the company pays the university royalties and patent expenses occurred. The university researchers then receive a percentage of these royalties once received by the university (Gubitta et al., 2015). However, there are risks involved with this as well, including the risk that the corporation may never use the technology in a commercial application resulting in no royalty after initial licensing fee.

Deciding whether or not to license a product or create a spin-off can be a difficult decision for many academic entrepreneurs. If the innovation is an improvement to a product that already exists, the university can form a license agreement with a company that is already participating in that business. The existing company may also want to advance a product or block competitors from advancement (Marcolongo, 2017). The identifying potential for licenses and commercialization depends on the human capital that the academic entrepreneur brings to the table. A researcher can possess in-depth knowledge about the technology that is intrinsically valuable to the university and the purchasing company (Buenstorf, 2009). For this reason, academic entrepreneurs can also benefit from payment for consulting or continued research support in the form of grants (Grimaldi et al., 2011).

When inventions are patentable and seen as having high commercial potential, academic entrepreneurs and university attorneys can develop patent applications (Gubitta et al., 2015). Researchers and the TTO office work together to decide if licensing or the creation of a spin-off is the most enticing offer for the innovation (Buenstorf, 2009). Licensing is a solution for academic entrepreneurs in 90% of cases. However, if there is an opportunity to develop a range
of different products for different markets from the technology, a spinoff is usually chosen as it has the potential to sustain a new company (Gubitta et al., 2015).

**Academic Start-ups and Spin-offs**

The creation of an academic spinoff refers to when the licensee, the academic researcher, founds a new company with the goal of market commercialization of a product or service (Gubitta et al., 2015). The federal and state government focuses its policy on spinoff companies rather than licensing with the goal of economic development and job creation (Shane et al., 2014). There are ways that TTOs determine whether or not researchers should develop an academic spin-off in place of the more popular direct license approach. Degroof and Roberts' "comprehensive support and selectivity" academic spin-off policy is taken by many universities, including the entrepreneurship powerhouse the University of Michigan. This approach includes the following: an opportunity search that stimulates disclosures, strong intellectual property rights protection, financial support networks and partners, discussion about financial partners and their role in the project as it moves forward, and market research and product development mainly with outside consultants (Gubitta et al., 2015).

There are various kinds of academic startups or spin-offs that can be created by an academic entrepreneur. These include university startups, where the faculty identifies a discovery and aims to bring it to commercialization by starting a new company. Another is similar to a consultancy, where an external entrepreneur seeks help from a university when developing a company in the form of research or prototyping. The third is when a university works with an existing firm to create a joint venture spin-off company (Wright, 2004). A spin-off is determined by whether the new firm has received a formal transfer of intellectual property that it is exploiting commercially (Colombo & Piva, 2008).

Researcher Colombo (2008) states that if academic entrepreneurs can team up with individuals with that have work experience in the relevant industry, whether technically, commercially, or socially, their startups are more likely to be successful. In many cases, success for an entrepreneurship venture relies on the availability of resources such as labs, financial institutions, and authorities proved critical to business development and networking (Chiesa & Piccaluga, 2000). In the case of many new ventures, inventors embody technological knowledge and act as human capital, making the economic value uncertain. For this reason, it can be difficult to license the technology or act as consultants. As many universities see generating spin-
offs as an alternative way to generate profits, many academic entrepreneurs are encouraged to create spin-offs as an alternative to licensing (Moutinho et al., 2016).

Because university spin-offs often initiate from discovery and not necessarily from a clearly defined product and market need, university start-ups can take a great deal of additional R&D before they can become a viable business according to Lubynsky (2013). Further development can be a frustration to the academic inventor who has worked, perhaps many years already on initial inventions, only to hear repeatedly that the technology is "early stage" by investors and the broader business community (Moutinho et al., 2016). Some academic inventions, due in part to being created from a research-centered setting, are not immediately marketable and may require innovative effort to become commercial products (Buenstorf, 2009). In this case, academic entrepreneurs can develop a spin-off company in which the company licenses the technology from the university, and then applies for seed funding (Spin-Out, 2015). The funding and exposure potentially received from this venture can be used to mitigate risk for a corporation buy out, and give greater proof of concept for both the researcher and a potential buyer. Some faculty chooses to abstain all negotiations entirely, and others decide to become CEO of their spin-off.

Another way to secure funding and proof-of-concept for a spin-off is to develop a crowdfunding campaign. Major crowdfunding platforms Indiegogo and Kickstarter started in 2009 and 2010 respectively and are estimated to be at a $90 billion investment by 2020 (Bennett & Al, 2015). These sites allow the public to contribute funds to the product or research organization. These "backers" or "donors" receive giveaways or products in return. The spin-off venture can also receive feedback in this way after contributors have received a product or technology (Godfrey & Moore, 2017). While the benefits can be great, there are risks such as lack of intellectual property protection, or the project not meeting its financial goals, which occurs in about 50% of crowdfunding campaigns (Bennett et al., 2015).

**Startups vs. License Agreements**

Why are some university inventions commercialized by using a spinoff company and some are licensed to the private sector? It is important to note that the significant financial returns generated by university commercialization efforts are from equity holdings in spinoff companies (Shane et al., 2014). Research has been conducted to determine what factors impact the decision to pursue a spinoff vs. a private license agreement.
Decisions made by the Office of Technology Transfer officials are not always formulaic due to the uncertain commercial potential of early-stage technology (Eller, 2018). In most cases, the possible market applications and target markets have not been entirely explored by the time of evaluation. However, when an OTT is deciding whether or not a product will be licensed to an established business or a spinoff company, the decision is not always discretionary (Boocock et al., 2018). For example, Owen-Smith and Powell have researched selection criteria used to choose between research opportunities. This criterion considers the nature of the technology, potential exploited market, university policies, and the attributes of the inventor wishing to commercialize. Innovations deemed more critical, generic, disruptive to the market, early stage development, and strong patent protection are most likely to be chosen to become a spinoff (Shane et al., 2014).

The university evaluating the invention also affects spinoff odds (Boocock et al., 2018). If a university offers a smaller amount of share royalty income to researchers, it is more likely to develop spin-off companies, as are those more willing to make equity investments in these companies that are backed by faculty and students (Shane et al., 2014). Some universities make it easier for faculty members to create spinoffs by allowing the use of university facilities throughout the development of the company and offering leave of absence policies for academic entrepreneurs (NCSU Policies, 2018). Universities that have higher research funding, research quality, prestige, and entrepreneurship education programs also are more likely to support and produce spinoffs (Shane et al., 2014).

Research conducted on a German public research organization has found that academic entrepreneurship may interfere with research output and performance. Researchers who licensed their inventions to private sector firms produced a higher number of publications and citations than those who created spinoffs. Academic entrepreneurs that decided to move forward with a spinoff and were strongly tied to the public sector experienced long-run declines in research output and decreased numbers of citations (Buenstorf, 2009). Even so, universities continue to support and encourage academic entrepreneurship and the creation of academic spin-off companies. Universities globally are looking to improve their strategies for entrepreneurship and their methods for determining commercial success from early-stage research (O'Shea et al., 2005).
Research shows that the demographics and background of the entrepreneur plays a significant role in whether or not a spinoff is chosen versus a private sector license agreement (Hodges et al., 2015). TTO decisions are made with uncertainty and therefore use of the representativeness heuristic, "a tendency to make choices from the similarity between a particular case and the typical example," which is in this case is the "typical" entrepreneur (Shane et al., 2014). Gender, industry experience level, and perceived difficulty to work with can affect the odds that the TTO recommends the project for a university venture capital fund. Those perceived as challenging to work with and those with no industry experience were the most likely to be dissuaded from pursuing a spinoff company (Shane et al., 2014). Overall, it is a difficult decision to choose between a license agreement and a spinoff, and there are many factors to consider when making this decision as an academic researcher (Boocock et al., 2009).
CHAPTER 3: METHODOLOGY

Primary Research Questions
The following questions guided this research:

a. Are there difficulties regarding technology transfer for some academic entrepreneurs at NC State University?

b. How are spin-offs and license agreements useful in commercializing a highly technical textile product as measured by defined commercialization?

c. How is the surrounding community impacted by academic entrepreneurship ventures?

Background to Methodology

There is a large amount of prior research regarding this topic due to the high rate of failure for academic entrepreneurship ventures (Marcolongo, 2017). Past research stresses the importance of understanding both economic and technical nuances rather than applying theory to the methodology. This is because entrepreneurial ventures are difficult to predict, and entrepreneurship ventures are volatile (Phan, 2016). Taking this into consideration, a Participatory Action Approach was utilized in order to have a deeper understanding of the technical nuances affecting a specific textile venture, and a specific theory was not devised or followed. Because of the different institutional and cultural constraints faced by each unique entrepreneurial venture, this study focuses on one institution, NC State University, and one unique entrepreneurial venture in the textile industry, Vector Textiles, Inc.

OTT Data Collection

The Office of Technology Transfer Data from NC State is used to assess the prior output of license agreements and startups from the university from the past four years, 2013-2017. This analysis attempts to give an overview of previous academic entrepreneurship ventures from each college at NC State University, mainly focusing on output from the Wilson College of Textiles. The researcher has collected and analyzed data from public records from the NC State OTT Key Performance Indicators Dashboard. It is essential to keep in mind that this does not include a random sample of startups, but those that are chosen to move through the Technology Transfer Office assessment.

Case Study Data Collection

This exploratory study was conducted to analyze the business development of an NC State academic entrepreneurial venture in the textile realm. A qualitative research design was
employed which included in-depth primary data collection and twelve interviews with academic entrepreneurs, local entrepreneurship mentors, and potential business partners involved with the firm. These three categories of respondents were chosen to give a broader understanding of the community impact of academic entrepreneurship ventures.

Upon Institutional Review Board approval from the university, recruitment for the study was conducted through individualized emails to contacts involved with university technology transfer. Table 1 includes information about each participant, including occupation, years in business, and business type. Reference labels that coordinate with each respondent were used to protect the anonymity of the participants. Interviews lasted between 15 and 30 min and were audio-recorded with the participants’ consent. The following statements and questions, among others discussed in Appendix C, were asked during the interviews to gain a broader understanding of the role academic entrepreneurship has in the university and surrounding community: (a) What is your experience and perception of academic entrepreneurship? (b) Is there a difference between typical entrepreneurship and academic entrepreneurship? (c) In your experience are there any risks involved in conducting business with academic faculty members? (d) Is there anything that surprised you or exceeded your expectations when working with academic entrepreneurship ventures?
Table 1. Occupation, years in business, and business type of the participants.

<table>
<thead>
<tr>
<th>Name</th>
<th>Years in Business</th>
<th>Occupation</th>
<th>Business Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respondent 1</td>
<td>40</td>
<td>Business Mentor</td>
<td>Venture Mentoring Service</td>
</tr>
<tr>
<td>Respondent 2</td>
<td>30</td>
<td>CEO</td>
<td>Garment Company</td>
</tr>
<tr>
<td>Respondent 3</td>
<td>10</td>
<td>CEO</td>
<td>Garment Company</td>
</tr>
<tr>
<td>Respondent 4</td>
<td>30</td>
<td>Academic Entrepreneur</td>
<td>Public University</td>
</tr>
<tr>
<td>Respondent 5</td>
<td>30</td>
<td>Business Mentor</td>
<td>Venture Mentoring Service</td>
</tr>
<tr>
<td>Respondent 6</td>
<td>3</td>
<td>Licensing Analyst</td>
<td>Technology Transfer Office</td>
</tr>
<tr>
<td>Respondent 7</td>
<td>5</td>
<td>Business Lead</td>
<td>Academic Spinoff</td>
</tr>
<tr>
<td>Respondent 8</td>
<td>5</td>
<td>Business Mentor</td>
<td>Technology Transfer Office</td>
</tr>
<tr>
<td>Respondent 9</td>
<td>10</td>
<td>Business Mentor</td>
<td>Technology Transfer Office</td>
</tr>
<tr>
<td>Respondent 10</td>
<td>30</td>
<td>Academic Entrepreneur</td>
<td>Public University</td>
</tr>
<tr>
<td>Respondent 11</td>
<td>30</td>
<td>Academic Entrepreneur</td>
<td>Public University</td>
</tr>
<tr>
<td>Respondent 12</td>
<td>30</td>
<td>Academic Entrepreneur</td>
<td>Public University</td>
</tr>
</tbody>
</table>

Upon completion of the data collection, all interviews were transcribed verbatim and analyzed through an iterative process of analysis (Spiggle 1994). Interview responses were first assessed and compared by the researcher for commonalities and differences expressed by the participants. This was done by having the researcher find patterns in the data that expressed common meanings and common issues that emerged. Lastly, the categories were compared and contrasted and developed into themes used to structure the interpretation of the data (Spiggle 1994).

The researcher also gathered in-depth primary data by taking an active role in providing research expertise during the process of taking the innovative fabric to market. Phan states that there needs to be an "improving-by-doing" dynamic, with much trial and error to bring an
innovative product to market (2016). This trial and error process helps academic entrepreneurs avoid and recover from pitfalls involved in bringing innovative technology to market. For this reason, Participatory Action Research was implemented into this study as the commercialization process requires quick responsiveness to change.

This form of research requires intention or planning to precede action, followed by a critique and review afterward. Researcher Bennett (2004) argues that academics can carry their own biases and beliefs into the research more readily by using PAR. In this scenario, bias and beliefs, while backed with market research, can be seen as beneficial and necessary for guiding and making decisions for the study. The author of this study spent two years with the team as a graduate research assistant working close to the five academic entrepreneurs. The advantages of this particular type of research include flexibility and deliberate and continued reflection, and it takes into account that each route to commercialization is unique. Consequently, there is a large number of internal documents and personal experience utilized in the data collection of this case study.

Defining Commercial Success

It is essential to consider the definition of commercialization, as well as the definition of success, for these entrepreneurs as well as the university they represent. While the definition of both of these terms is highly subjective, the following gives insight as to what these terms mean in the context of this study.

Success for Academic Entrepreneurs. Academic entrepreneur respondents in prior studies have defined success as receiving enough funding to support translational research, such as SBIR grants, enhancing teaching and publication quality, supporting postdoc researchers and other employees, and bettering the world with technology diffusion. Others have more traditional versions of commercial success such as product development goals or financial gain (Hayter, 2015). Some academics are more likely to participate in entrepreneurship if they worked in institutions that offered technology transfer services, or if respected members of their academic community were also participating in academic transfer, which may signify a desire for peer recognition (Marcolongo, 2017). Also, the ability to fund graduate and post-doc students had a significant impact on these entrepreneurial projects.

Table 2 shows the motivations behind the foundation of academic spinoffs from a study of 22 academic spinoff companies. These motivations suggest that commercial success for many
academic entrepreneurs focuses on determining a market opportunity or finding a practical application for research and entering a higher risk and less bureaucratic atmosphere (Chiesa & Piccaluga, 2000).

Table 2. Motivations behind the foundation of spin-off company (Chiesa & Piccaluga, 2000).

<table>
<thead>
<tr>
<th>Motivations</th>
<th>Number of Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification of market opportunities</td>
<td>6</td>
</tr>
<tr>
<td>Need to bring projects to completion</td>
<td>2</td>
</tr>
<tr>
<td>Need to apply knowledge to practical applications</td>
<td>5</td>
</tr>
<tr>
<td>Monetary reasons</td>
<td>2</td>
</tr>
<tr>
<td>Need to exploit the experience</td>
<td>3</td>
</tr>
<tr>
<td>Aversion to bureaucracy and low risk orientation of the research environment</td>
<td>6</td>
</tr>
<tr>
<td>Personal success</td>
<td>4</td>
</tr>
<tr>
<td>Need to be more independent</td>
<td>5</td>
</tr>
<tr>
<td>Other factors</td>
<td>5</td>
</tr>
<tr>
<td>N. of companies</td>
<td>22</td>
</tr>
</tbody>
</table>

While success regarding license agreements with the private sector focuses on financial gains for both the university and the inventors, success with startup or spinoff ventures can be much more subjective. Shane researched three routes for spin-off development for academic entrepreneurship success. These include obtaining external funding, undergoing an initial public offering (IPO), and mortality (Shane & Stuart, 2002).

**Success for TTO and University.** The NC State University Technology Transfer Office defines success as making money through license agreements, whereas the office receives a percentage of returns to support future entrepreneurial ventures. Traditionally, revenue for the office was considered a success, but more recent success can also be defined by increased economic engagement and the creation of jobs, specifically through startups and spin-offs (Parker, 2018). In this specific case, the goals of the NC State TTO and the Vector Textiles entrepreneurs are similar: obtaining external funding. However, the TTO is much more focused on job creation and community involvement than the entrepreneurs. This could be a reoccurring issue if TTO’s and academic entrepreneurs do not have similar goals for the venture.

**Research Design**

The data for this case study of Vector Textiles was collected through direct observation in the form of participatory research, documentation such as meeting agendas, progress reports, and media articles, and interviews of those involved with the business development of the firm.
These individuals include venture mentors and potential business partners. Through this process, the study aimed to identify the reasons behind success and failure for each attempted business development avenue. Success is determined using the top motivations and identifiers of success expressed by the five academic entrepreneurs leading the project. The table and figure below shows the motivations and success identifiers. The top success characteristics according to the academic entrepreneurs at Vector Textiles include financial gain, and publicly offering a product. Others include gaining funding for translational research and supporting postdoc researchers and employees.

Table 3. Motivation factors for academic entrepreneurs at Vector Textiles.

<table>
<thead>
<tr>
<th>Critical Motivation Factors</th>
<th>Overall Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apply Knowledge to Practical Applications</td>
<td>8.2</td>
</tr>
<tr>
<td>Make a Difference in the World</td>
<td>7.8</td>
</tr>
<tr>
<td>Bring Projects to Completion</td>
<td>6.2</td>
</tr>
<tr>
<td>Gain Research Funding</td>
<td>6</td>
</tr>
<tr>
<td>Identify Market Opportunities</td>
<td>4.8</td>
</tr>
<tr>
<td>Personal Success</td>
<td>3.8</td>
</tr>
<tr>
<td>Need to be More Independent</td>
<td>3.4</td>
</tr>
<tr>
<td>Monetary Reasons</td>
<td>3.2</td>
</tr>
<tr>
<td>Aversion to Low-Risk Academic</td>
<td>1.6</td>
</tr>
<tr>
<td>Environment</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6. Motivations of Academic Entrepreneur Comparison.
Compared to the motivation data by Chiesa & Piccaluga (2000), the Vector Textiles team had different motivations for academic entrepreneurship. While the groups both shared a desire to identify market opportunities, the Vector Textiles team were not as motivated by a low risk academic environment, or the need for independence as the group described in Figure 6. The groups placed similar importance on personal success and the importance of market opportunity identification. The Vector Textiles team listed “making a difference in the world” as an extremely high motivational factor, which was not mentioned in the Chiesa study. This could be due to the humanitarian nature of the entrepreneurial project, or the way the options were presented by the researcher in the separate studies. In addition, while the Vector Textiles team did not see financial gain as a main motivating factor, they did see this as a determinate of venture success.

Based on this response as well as the success determinates created by Shane (2002), overall success for the venture will be determined as follows: obtaining external funding or profit and undergoing an initial public offering. Failure will be considered lack of mortality (inability for the venture to financially survive in the market), or failure on the part of the academic entrepreneurs to exert effort to develop a new venture (Shane & Stuart 2002).
CHAPTER 4: RESULTS AND FINDINGS

NC State University Academic Entrepreneurship Data

Data on disclosures, patents, agreements, licensing revenue, and startup companies formed at NC State University from the years 2013-2017 has been analyzed and extrapolated. Data from these years was chosen due to its public availability on the OTCNV website. This segment aims to examine academic entrepreneurship at NC State University further as well as individually at the Wilson College of Textiles. Any patterns or trends found will be examined and discussed.

Academic entrepreneurship initiatives at NC State are becoming increasingly successful, and the Association of University Technology Managers ranked the university second in licenses and options executed, and fifth in the number of invention disclosures and number of startups launched. The university currently has over eight hundred operating commercialization agreements, 135 launched startups, and 1,010 US patents issued. The NC State OTCNV has also seen almost 600 products go to market, and has helped facilitate over 3500 jobs in North Carolina. In 2018, the office generated $5.3 million in revenue in project royalties (OTCNV, 2018).

**Patent Information.**

![NC State Disclosure to Patent trend](image)

*Figure 7. NC State University disclosure and patent information 2013-2017.*
Figure 8. NC State University WCOT disclosure and patent information.

License Agreements.

Figure 9. NC State University number of commercial license agreements 2013-2017.
Figure 10. NC State Wilson College of Textiles commercial license agreement 2013-2017.

Figure 11. NC State University WCOT agreements compared to total university.
Figure 12. NC State University number of miscellaneous agreements (CDA, MTA) from 2013-2017.

Figure 13. NC State University WCOT miscellaneous agreement data 2013-2017.
Figure 14. NC State University and Wilson College of Textiles Total Licensing Revenue 2013-2017.

Figure 15. Wilson College of Textiles Licensing Revenue from 2013-2017.
New Venture Data.

*Figure 16. NC State University and Wilson College of Textiles new ventures 2013-2017.*

*Table 4. Wilson College of Textiles New Ventures and Operation Information.*

<table>
<thead>
<tr>
<th>Name</th>
<th>Year Established</th>
<th>Market Offering</th>
<th>Academic Entrepreneur Run</th>
<th>Currently Operating</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA Laboratories, Inc.</td>
<td>2015</td>
<td>Specialty Pharmaceuticals</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Precision Diagnostics</td>
<td>2015</td>
<td>Diagnostic Testing</td>
<td>Partial</td>
<td>Yes</td>
</tr>
<tr>
<td>Textilescents Inc.</td>
<td>2015</td>
<td>Essential Oil infused textiles</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Thermo-Flex Technologies Inc.</td>
<td>2015</td>
<td>Thermoelectric Textile that harness wasted heat to generate electricity,</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Deep Blue Medical Advances, Inc.</td>
<td>2017</td>
<td>Medical products: Hernia Mesh</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Karamedica, Inc.</td>
<td>2017</td>
<td>Biopolymer-based products</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Disclosures and Patents. Academic researchers at NC State University are required to complete Online Disclosures to the Office of Technology Commercialization and New Ventures (OTCNV) for Copyright, Invention, Plant, or Software innovations. Many of these innovations go on to be patented in the United States or abroad. Figure 7 compares the number of NC State University disclosures by academic researchers with the number of patents filed and the number of patents issued. Over the past five years, the number of disclosures for NC State University range from 242 disclosures in 2013 and has increased to 275 disclosures in 2017. The number of patents filed has steadily increased as well from 182 patents in 2013 to 250 patents filed in 2017 (OTCNV, 2018). The number of patents issued is considerably lower than the number of patents filed. This can be attributed to the length of time it takes to receive a patent after filing (Parker, 2018). It can take an average of 12-32 months to receive acceptance for a filed patent from the United States Patent and Trademark Office (USPTO), and up to an average of 34 months to receive a patent for an engineering application (UPCouncil, 2018). Despite the number of disclosures and patents filed growing over the last five years, the number of US patents issued has stayed roughly the same, and the number of foreign patents issued has decreased. This decrease could be due to difficulties obtaining a foreign patent in the current economic climate, or the time needed for the patent office to issue a patent to the innovator.

The Wilson College of Textiles has made up 12.5% of total university disclosures and was third only to the much larger College of Engineering and College of Agriculture and Life Sciences. See Figure 17 below for a size comparison.
The Wilson College of Textiles disclosure to patent data shown in Figure 8 shows the overall upward trend in the number of disclosures by academic researchers to the NC State University OTT office. In 2013, the office received 25 disclosures, and this has increased to 37 disclosures in 2017 (OTCNV, 2018). This increase has had a seemingly little impact on the number of patents issued for the college, as it can take a lengthy period to issue and file a patent.

**License Agreements.** Commercial license agreements are indicative of technology transfer into the commercial space. In this case, a commercial agreement is any agreement involving monetary value such as license and option agreements. Six categories can be used to group these commercial agreements: software, plant, patent license, option, copyright, and tangible research material. The most common agreement used for a commercial license from NC State University is an option agreement (OTT Statistics, 2018). Option agreements can be either exclusive or non-exclusive and allow the licensee the right to evaluate NC State University intellectual property for a short period before executing a full license agreement (Parker, 2018). An exclusive option agreement would allow only the licensee to evaluate the IP, while a non-exclusive option agreement would allow multiple external parties to evaluate the IP (Parker, 2018).

Figure 9 and Figure 10 show the number of commercial license agreements between NC State University and the NC State University Wilson College of Textiles and a commercial entity. NC State University license numbers have been gradually increasing from 117 license agreements in 2013 to 176 agreements in 2017 (OTCNV, 2018). The majority of these
commercial agreements are Option agreements, due to external companies wishing to evaluate the IP before purchasing a patent license. These Patent Licenses make up the second highest percentage of agreements. Plant licenses from the highly regarded NC State University College of Agriculture and Life Sciences make up the third largest percentage.

Figure 10 shows that the Wilson College of Textiles commercial agreements have also been increasing from 16 agreements in 2013 to 27 in 2017. The vast majority of these agreements are Option agreements, with some Patent License agreements and a small percentage of software agreements. These copyright agreements often derive from the textile management and business development portion of the COT, whereas software derives mainly from the textile technology sector. Figure 11 shows the percentage of COT agreements that make up the total commercial agreements executed by the entire university.

Figure 12 and Figure 13 show the number of miscellaneous agreements conducted by NC State University. These agreements include confidential disclosure agreements (CDAs), material transfer agreements (MTAs), and plant trial agreements. Total university numbers of miscellaneous agreements have stayed roughly the same over the past five years, with the slight majority of the agreements being CDA’s. The Wilson College of Textiles miscellaneous agreement numbers has decreased from 97 to 65 with a vast majority being CDA agreements. This decrease could be due to a large number of confidential research agreements conducted with COT the US military forces and large corporations.

While monitoring the numbers of commercial and miscellaneous agreements are good indicators for tracking academic entrepreneurship involvement, tracking licensing revenue is the most crucial measure for Offices of Technology Transfer success as well as the university research as a whole. As shown in Figure 14, NC State University licensing revenue peaked in 2015 with $7.5 million. It had since decreased to a yearly revenue of $4.48 million in 2017. The data shows that The College of Engineering has reduced its licensing revenue from roughly $700 thousand/year in 2015 to $350 thousand in 2017. The College of Education has also steadily decreased licensing revenue from a high of $750 thousand in 2013 to $205 in 2017 (OTT Statistics, 2018). These changes could be brought about by failed or expired licensing partnerships.

Figure 15 shows the percentage of licensing revenue the Wilson College of Textiles has brought to NC State University over the 2013-2017 period. The college has earned 34% of the
total university licensing revenue. As one of the smallest colleges at NC State University, this indicates excellent academic entrepreneurship initiative and connection with the commercial industry. Figure 15 shows that COT licensing revenue has more than tripled from $100 thousand in 2013 to over $350 thousand in 2017. The growth of industry partnerships within the College as well as the resurgence of the local textile industry in the United States could be affecting this increase in revenue (College of Textiles, 2017).

**NC State University Startup Ventures.** Academic entrepreneurs from NC State University have created over 100 startups from the university, including widely successful companies such as SAS Institute, CREE, and Tethis (OTCNV, 2018). SAS Institute, a producer of analytics, software, and business solutions, was created in 1976 by NC State University professors Jim Goodnight and Jim Barr, NC State University employee Jane Helwig, and graduate student John Sall. The academic entrepreneurs chose to leave NC State University and incorporate SAS Institute as a private company. The academic spinoff now holds over 14 thousand employees, customers in over 146 countries, and a 2017 revenue of $3.24 billion. Jim Goodnight currently still holds the position of CEO, and John Sall is currently the Executive Vice President of the company. Jim Goodnight attributes the company's early entrepreneurship success partly to receiving funding from government and academic sources rather than from venture capital. According to Goodnight, this route results in less pressure to please investors or incur significant employee layoffs as business cycles develop (High, 2004).

The startup Cree, Inc. was created in 1987 by a group of NC State University engineering students. The students created innovative LED lighting technologies, semiconductors, and wireless communications that currently leads the clean energy revolution (OTCNV, 2011). The company has over 5,000 employees worldwide, and a yearly reported revenue of $1.49 billion in 2018. John Palmour, Co-founder and Chief Technology Officer of Cree, Inc. was able to fund and expand his company through family and friend fundraising as well as federal contracting from the US Military, which helped provide business and capital to grow before reaching the residential product market (Stan, 2013, UNC Kenan, 2014). He stated that the biggest challenges facing technology transfer today are increasing global competition, and finding individuals who focus on both STEM subjects and business aspects such as entrepreneurs (UNC Kenan, 2014).

In the years 2013-2017, NC State University registered new ventures have increased in number from 8 in 2015 to 15 in 2017, as shown in Figure 17. The prevalence of these academic
spinoffs and startups are much lower than that of license agreements due to a large amount of
time, funding, and support necessary to start one. Academic entrepreneurs created four Wilson
College of Textiles new ventures in 2015, and three new ventures in 2017. Information regarding
these ventures is available in Table 4. This table gives an overview of the year established,
market offering, whether or not an academic entrepreneur runs the company, and whether or not
the company is currently operational. All of these recently developed companies are currently
operational except for one. This company is also the only company that is still entirely run by
academics.

The majority of these startups hired an experienced CEO or other business professionals
to run the daily operations of the firm and push the innovative product towards a commercial
market. In the companies that are labeled "partially" academic run, the company continuously
involves the inventors and academic researchers as a large part of the business leadership.
Almost all of the companies have placed the academic researchers on the advisory board to
ensure the IP and innovative involvement is not lost in translation to the commercial space.

**Case Study of Vector Textiles**

**Introduction**

An academic entrepreneurship concept venture, Vector Textiles LLC., was chosen for an
in-depth case study. The creators of this concept company are five academic entrepreneurs
employed at various colleges at NC State University. Dr. Marian McCord of the NC State
College of Natural Resources specializes in textiles that prevent or treat disease or improve
human health and well-being. Dr. Charles Apperson and Dr. Michael Roe of the College of
Agriculture and Life Science work as experienced insect toxicology and vector biology experts
and provide insect testing knowledge and facilities. Dr. Emiel DenHartog of the Wilson College
of Textiles specializes in biomedical physics and ensures comfort, quality, and protection for
textile products. Dr. Andre West of the Wilson College of Textiles acts as the product
development manager with experience in manufacturing garments and embarking on
entrepreneurial ventures. The entrepreneurs have discovered an innovative fabric that blocks the
proboscis of a mosquito from biting. The team currently owns the rights to use this fabric for
various forms of mosquito protection. The concept company acquired these rights by working
with an international fabric supplier in Europe and obtaining a usage patent in the United States.
Vector Textiles is currently run entirely by the academic entrepreneurs with the help of research assistants, postdoctoral students, and volunteer consultants. The group of academic entrepreneurs considers success financial gain and the public offering of an apparel product as shown in Figure 6. The group has received a large grant for ongoing research and commercialization of their products from NC State University. The concept company aims to produce apparel products for outdoor insect protection and is open to both license agreements and the creation of a startup venture.

**Case Information**

This case covers a two year period in which the academic entrepreneurs aim to commercialize the fabric innovation. The study begins with the hire of the fifth team member, Dr. Andre West, an academic entrepreneur and faculty member with solid business experience who aims to push the project to the marketplace. This beginning point was chosen because the technology transfer process began at this point. The study ends after two years after many foreseeable transfer methods were attempted. The case study aims to discover whether license agreements succeeded when the NC State OTT was facilitating the process. The case study also studies how the TTO had an essential impact on target market identification and customer development. Review the section regarding Research Design in Chapter 2 for a further description of the case study methodology.

This case study analyzes the current process for academic entrepreneurship translation, taking note of the pitfalls and successes after each commercialization attempt. Before this research was conducted, competing explanations for the outcome were kept in mind. These competing explanations included: the success or failure was due to the entrepreneurs individually rather than a generalizable translation process issue, the innovative technology merely is not desired in the current market, and that the observation is a result of chance only.

**Funding.** A grant from the U.S. Army funded the research for the innovation. The purpose of the research was to protect military personnel from vector-borne illnesses such as malaria, dengue fever, yellow fever, and the Zika Virus. The goal was to create a mosquito-resistant product that was safe, cool, comfortable, fashionable, and appropriate for the military market. The U.S. Army had a specific need for mosquito resistant garments at this time in 2015, due to the recent growth in vector-borne illnesses. With this grant funding, the academic team
was able to research and test various textile materials to find the most effective mosquito resistant fabric.

The beginnings of Vector Textiles was not unlike many other academic entrepreneurship ventures. In the textile and apparel industry, there is a long history of innovation and development stemming from military needs. As shown from the development of khakis, trench coats, and bell bottoms, once a product has been used for specific military applications it can be used for various other applications for the general population (Reed, 1998). External research-based companies such as Dupont have worked with the U.S. military for over 200 years. Fabric innovations created include the addition of Nomex for fire resistant garments for flight and explosion protection (Dupont, 2018). The increasingly popular embedded sensor technology used in apparel was an innovation created for the military by the Georgia Institute of Technology and has widely expanded to other technical fields. In 2015, the U.S. Army started developing a $50 million research center at MIT to create the newest generation of uniforms, and researchers from Harvard have been awarded a contract to create pants that mimic leg muscles and tendons for joint support (Scataglini et al., 2015).

Samdra Erin (2015) from the U.S. International Trade Administration states that the U.S. Federal Government “wants to be a smart customer of commercial technology.” The Natick Soldier Research, Development, and Engineering Center (NSRDEC) listed textile and apparel needs such as ergonomics, chemical resistance, insect repellent, and fiber reinforced textiles as high demand for the U.S. military. One of the top high demand materials listed was tropical vector protection to protect soldiers from vector-borne illness. The military was considering thick spacer fabric, nonwoven fabric, and fabrics with a densely woven pore size much like the Vector Textiles products (Landgraf, 2015).

The combination of an experienced cross-functional team, substantial military funding, and the use of a sophisticated university research facility led to a proposed solution. The creation was a textile product that mechanically blocked the proboscis of a mosquito, without the use of harmful chemicals and insecticides. The team realized that this product had many other potential uses and embarked on the journey to explore commercialization options.

**License Opportunity through TTO.** After necessary disclosure information was released to NC State, the team began to speak with the TTO to consider license agreements and further funding. With the use of industry connections, the skillful connections TTO contacted a
small company, Company 1, with the possibility of a license agreement. Company 1 was a private company located in Midwest City, Oklahoma with less than ten employees. The company desired the Vector Textiles product to use as hunting and fishing protection worn under the clothing. The team created a memorandum of understanding (MOU). An MOU is an agreement between parties that are simpler and more flexible than official contracts. This creates guidelines and expectations as they work together towards a common goal (Chandler, 2011). Funding was exchanged to create prototypes and continually test them in the NC State University entomology lab.

![Image of lab testing of mosquito resistant apparel prototypes](image)

*Figure 18. Lab testing of mosquito resistant apparel prototypes.*

Various construction techniques were used such as sonic welding, padding, and knit layering to create garments that would offer the most significant amount of protection to the wearer. Various volunteers wore the garments into cages of mosquitoes, bite and landing counts were observed as shown in Figure 18. From this process, it was decided using two layers of the final selected fabric provided the most significant amount of protection in areas of stretch such as knees and elbows.
International R&D alliances can be beneficial in production and globalization of technology. In this case study, the researchers created an agreement with a manufacturing facility in Italy as the technology needed was challenging to find domestically. This manufacturing facility was used to produce garments for Company 1 as detailed in the confidential MOU agreement. The agreement also detailed that a percentage of sales for the final product would be allocated to the NC State TTO as well as the Vector Textiles team.

Company 1 currently offers the product in the form of socks, leggings, shirts, gloves, and hoods to be worn under other clothing. The product is sold online at several large online retail stores such as Amazon.com and Walmart.com. The product can be found in brick-and-mortar retailers across the United States and Canada such as Sportsman’s Warehouse, Bass Pro Shops, Runnings, and in other local sporting goods stores.

**Spinoff Development.** As the TTO did not have any other potential license partners at this time, the Vector Textiles team decided to pursue a concept spin-off venture. At this point, the team decided on a name for the concept company, Vector Textiles Inc., and became involved in commercial product development. Student researchers assisted in market and prototype research for the textile application.

The TTO Digital Content and Creations team worked with the group to create a logo for the concept firm, using the team’s original logo ideas. Figure 19 shows the development of the concept logo throughout the design process. The initial logo was a graphic symbolizing vectors and vector protection. The reinvented logo was an iteration of a mosquito that incorporated the stripes seen on a military uniform sleeve. The development options created by the TTO Digital Content and Creations team along with the academic researchers was a university color appropriate option that indicated vector protection using a black “antenna” and red “wings.”
A concept website was created using the color scheme of the new logo. The website advertised the new venture as a research and development consulting firm.

_Services_

Offering research, testing, and consulting centered around insect bite protection.

**Areas of Practice**

**Branded Fabrics**
Vector Textiles can take your manufactured fabric and certify it as insect bite-resistant. Vector Textiles has access to highly technical entomology laboratories as well as textile comfort specialists who will be there for you at every step of the fabric development and branding process.

**Consulting**
If you already have a fabric that you think is insect bite-resistant, or would like to improve your existing textile product to become insect bite-resistant, Vector Textiles can provide professional consulting services to make sure your product hits the mark.

**Product Certification**
Vector Textiles provides bite resistance certification for existing products on the market. Either arrange product testing in our facilities or simply get a basic hang tag for your product that certifies it is insect bite resistant.

**Product R&D**
If you would like a product made for a specific application, Vector Textiles can work with your company to make a product from our line of mosquito bite resistant fabrics.

*Figure 20.* A snippet of the Vector Textiles website that explains company service offerings.

**Commercial Product Development.** While Company 1 was venturing into the hunting and fishing market, the researchers again researched additional markets in which this product could protect people and animals. In 2016 and 2017, the Zika Virus was plaguing tropical
countries as well as emerging in parts of the United States. There were 1700 reported cases of the Zika Virus by pregnant women in the United States at this time. As the virus is transmitted by the bite of the Aedes Aegypti mosquito, the Vector Textiles team decided to use their technology to protect women who were in danger of contracting this vector-borne illness. Vector Textiles was given the opportunity to publish this idea in the May 2017 edition of Textile World Magazine, in which the project was featured on the cover as shown in Figure 21.

![Image](image.png)

**Figure 21.** The May 2017 Textile World magazine cover featuring Vector Textile's venture.

**Chancellors Innovation Fund.** In order to obtain further funding and resources for maternity product commercialization, the team applied for and received the 2017 Chancellors Innovation Fund, a prestigious monetary award given to researchers to support short-term commercially focused projects. The award was created in 2010 and has since launched 22 academic entrepreneur startups and awarded 2.9 million dollars for researchers to support their academic entrepreneurship ventures (CIF, 2018). The proposed use of the funds was to research and develop a garment prototype that could protect pregnant women against the Zika virus, which causes irreversible damage to the fetal brain. This product theoretically would appeal to pregnant women as it required no undesirable chemical repellents or synthetic insecticide. The Vector Textiles product would be used to develop a comfortable, cool, and fashionable line of maternity wear for women at risk for contracting the Zika virus (Fandel, 2017). Vector Textiles
aimed to research a maternity garment that could be distributed directly to consumers, rather than initiating an external license agreement with an existing company.

**Maternity Development.** With funding procured from the Chancellors Innovation Fund, the team was able to design and create prototypes of maternity garments and test them for mosquito bite resistance. The team created a concept logo design as well as a name for the product: Pro-Tex Maternity.

![Pro-Tex Maternity logo](image)

*Figure 22. Logo for Pro-Tex Maternity line.*

As Vector Textiles conceptually planned to enter the maternity market through online sales, it was essential to start with a highly visible online presence in order to gain traction. A volunteer model was contacted to take photos wearing the garments for the brand. These photos were used throughout the concept development of digital media outlets. Social media platforms Instagram, Twitter, and Facebook, were used to spread the word about the upcoming project. While these currently remain inactive, they remain ready to launch when the product is ready to enter the market.
Figure 23. Examples of photos used on social media platforms.

**Indiegogo for Maternity Wear.** As online crowdfunding sites like Indiegogo and Kickstarter continued to be a significant source of initial startup funding and press (estimated to be at a $90 billion investment by 2020 (Bennett & Al 2015), the Vector Textiles team created a concept Indiegogo campaign to launch the maternity clothing. The campaign included an informative video of the product and how it protected the wearer against mosquitoes. It also included in-depth information regarding the garments that were available for purchase. The Indiegogo campaign offered a platform for consumers to donate project funding in return for a maternity garment. The garments available for selection included two maternity tops and two maternity bottoms.

The campaign remained inactive until approval from all Vector Textiles team members. It had a proposed campaign running time of 48 days, and a goal of $20,000 in funding. However, the team decided not to run the campaign as there were legal concerns regarding the use of the word "Zika Virus." The legal team, as well as the Vector Textiles team, was concerned for the safety of pregnant mothers. The garments had been up to 98% mosquito bite resistant in lab testing, but this did not guarantee protection from the Zika Virus and other mosquito-borne illnesses for the wearer. Because of these legal concerns, the campaign was put on hold and was
not released. The team took this time to conduct further market research and investigate other uses for the mosquito bite-resistant fabric.

I-CORPS. The National Science Foundation (NSF) Innovation Corps (I-CORPS) is a program developed to bridge the gap between innovative academic research and market commercialization through customer and market discovery. It was built in 2011 to assist university scientists and researchers with product commercialization specifically. Vector Textiles enrolled in the I-Corps short course at the NC State site. This program lasted a duration of six-weeks to research and better understand the possible target customer for the mosquito resistant fabric. Throughout the six-weeks, the Vector Textiles team created a concept business model canvas and interviewed 25 pregnant and recently pregnant women. The Business Model Canvas is a strategic lean spin-off template used to help entrepreneurs organize their business goals. The goal of the I-Corps process was to complete the Customer, Value Proposition, Distribution Channel, and Customer Relationship segments of the canvas. The initial customer segments tested included pregnant women, expectant fathers, and women who attract mosquitoes who are not pregnant. The proposed channels included online Indiegogo sales and donations to maternity clinics in areas profoundly affected by the Zika Virus.

Value Propositions
- I need to protect myself and my unborn baby
- I need to protect the mother of my child and
- I need to enjoy being outside without worrying

Customer Relationships
- Get: Social Media Advertsments,
- Keep: updating and adding to our product
- Grow: Word of mouth, expanding products to

Customer Segments
- Pregnant Women
- Expectant Fathers
- Women who attract mosquitoes

Channels
- Online Indiegogo Sales
- Donations on Indiegogo then to clinics where
- In person maternity clinics

Figure 24. Business Model Canvas Development.
Throughout the interview process, the team collected information regarding the women’s awareness of the Zika Virus, preferred mosquito resistance methods, and preferred maternity clothing. The full interview questions are included in Appendix A. There were three initial hypotheses when starting the I-Corps program:

Hypothesis #1: Women in the US see Zika Virus as a threat
Hypothesis #2: Women are willing to spend high prices on protective clothing for their baby
Hypothesis #3: Women wear maternity clothing for any occasion

This hypothesis drastically changed after the completion of the 25 interviews. The respondents from the U.S. regions did not seem concerned about the Zika Virus, and many thought that the virus no longer existed, or had heard the word of a possible vaccine. The Vector Textiles team also found that the women were not specifically concerned about mosquitoes unless they were performing a specific outdoor activity. The cost was also a significant factor in maternity clothing, as the women viewed maternity clothing as a solution to a very temporary problem. They did not seem willing to pay high prices for maternity clothing as it was not comfortable or flattering to wear after pregnancy.

This experience thoroughly changed the course of the concept company, as the Vector Textiles team realized maternity might not be a lucrative or relevant market for the innovative fabric. The team began to look past maternity to other markets.

**Procuring a CEO.** One of the goals for the Chancellor Innovation Fund was to help procure a CEO for the concept company that could lead the business operations of the firm, as the Vector Textiles founders wished to focus on their academic careers and further research. The team presented the idea of mosquito resistant maternity wear to the Executives in Residence (XIR) board, a service by the TTO that provides access to entrepreneurial leaders and mentors in the Raleigh, NC area. The presentation included information about the proposed company, as well as prototypes of the maternity garments.

From this experience, the team gained access to a network of contacts that could assist in launching their startup concept company by providing guidance and input regarding untapped opportunities. One of the most valuable takeaways from this experience was that many consumers could benefit from this technology and that the maternity market was small in comparison to another potential market. An experienced entrepreneurship mentor noted that the
team would gain a greater market share if the product instead catered towards sports and outdoor wear.

**Sports and Outdoors Wear.** The team began to conduct extensive market research to determine the best market for the mosquito resistant fabric. The team found that the women’s activewear market was much larger than the maternity market and was growing exponentially. The market for sports and fitness clothing is projected to reach $231.7 billion by 2024 and is driven by a growing interest in a healthy lifestyle. The recent athleisure trend also contributes to this growth, mainly regarding yoga pants and leggings worn as everyday apparel (Statista, 2018). Outdoor recreation activities are among the most popular overall demographics, and participation is projected to rise to 25.9% of the population by the year 2023 (Statista, 2018).

The team inferred by the growing number of companies providing repellent and insecticide-treated clothing that many consumers desire this kind of protective apparel when traveling and spending time outdoors. These companies include retailers such as ExOfficio, Elimitick, Insect Shield, Craghoppers, Bass Pro Shops, L.L. Bean, Columbia, and R.E.I. The team desired to create insect protective clothing for those who participate in outdoor trail running, hiking, yoga, and cycling. They began trend forecasting various activewear styles and designs for women. The next steps included developing prototypes and deciding on the best route to commercialization for this product.

Funding remained in the Chancellors Innovation Fund, and the team used this to help create a concept branding presence for the sportswear line, as well as prototypes of the garments. The line was named “Superfine Apparel” based on the idea of an extremely fine knit.

![Superfine Apparel](image-url)

*Figure 25. Logo for Superfine Apparel sportswear brand.*
The first round of garments was created with brightly colored accents to mimic the colors found in many insect species. Colors like bright yellow, orange, and red were used in piping and hood details for the women’s garments.

*Figure 26. Inspiration and initial designs for Superfine Apparel sportswear.*

These garments were showcased on concept social media outlets Facebook, Instagram, and Twitter using student models. These social media pages along with a website were used to create a digital presence for the line, again setting the scene to sell merchandise using online platforms.

*Figure 27. Facebook sample page for Superfine Apparel sportswear brand.*

**Exposure: Smithsonian and Magic.** To gain much-needed exposure for the project, especially with the sudden product change, the team accepted an invitation to exhibit the technology at the ACC Smithsonian Creativity and Innovation Festival in October of 2017. The festival was held at the National Museum of American History in Washington D.C. by Virginia
Tech and the Smithsonian Institution. The festival encouraged the public to visit the museum over a three day period in which over 200 university projects are exploring science, engineering, art, and design were displayed. The Vector Textiles team displayed the garments by wearing shirts made of the mosquito resistant material and showing the Superfine Apparel clothing on mannequins.

Through this experience, the team collected valuable feedback from over 300 visitors to the display. The takeaway from this feedback was that the team needed a minimum viable product (MVP) that was simple and universally appealing. As the primary purpose of the clothing was to showcase the protective qualities, the design needed to be simple in order to protect those who may not be attracted to brighter colors. The team recreated the designs using pure black and white pieces for both men and women. They provided options for both running and yoga wear that were simple and more practical than the colorful insect-inspired garments.

Figure 28. Re-evaluated designs to provide a minimum viable product to future customers.

The team was given the opportunity through NC State Wilson College of Textiles to showcase their project at the Las Vegas apparel tradeshow MAGIC. This show was held in February 2018 over four days. The team had the chance to display in the Sourcing segment of MAGIC, focusing on making connections with textile and apparel companies that would potentially be interested in partnering with Vector Textiles. The team collected many industry contacts and passed out over 150 brochures about the technology.
Figure 29. Brochures and business cards distributed to industry contacts at MAGIC.

**Indiegogo 2.** The team wanted to leverage the exposure created by the ACC Smithsonian Festival as well as the MAGIC trade show by creating a second concept Indiegogo campaign in February of 2017, directly following the MAGIC trade show. The release included an informational video, in-depth description of the technology and application, and twelve “perks” that backers could receive when contributing to the campaign. These perks included the eight individual tops and bottoms shown in Figure 28, as well as four package options providing each full outfit. The prices ranged from $40-60 per garment. The goal of the campaign was to raise $25,000 and release a small run of the garments for testing and research purposes. Having the opportunity to analyze the reviews of the products as well as the location of the buyers would be extremely helpful to the team when developing and producing mosquito resistant garments.

As the funding source for the project at this time was for research purposes, the team decided to move on and pursue licensing efforts with existing companies while using the concept of brand materials created as leverage. The team found that was becoming difficult to find both sufficient funding and time to create a startup venture.
**Independent Licensing Efforts.** At this point, the Vector Textiles team was looking for license agreements with existing companies to either partner with the team or purchase the technology. The license agreement with Company 1 was performing well in the hunting and fishing department and could be found at Bass Pro Shops, Amazon.com, as well as smaller outdoor retail shops across the country. The team had reached out to many sports apparel companies and had been in contact with a few major players such as P.V.H., Adidas, Carhartt, as well as garment manufacturers and military supply personnel. As a result, a military and service protection garment company, Company 2 had expressed interest in a partnership with Vector Textiles, as well as a garment manufacturer, Company 3, skilled in creating military apparel. As the Vector Textiles team consisted of academic faculty and students, the members did not have the time or funding to pursue these agreements without further guidance and business input. For this reason, the team created a partnership with CED Venture Mentors set up through the NC State OTT.

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**Figure 30.** Timeline of startup attempts for Vector Textiles.
CED Venture Mentoring. MIT developed the CED Venture Mentoring service (CED VMS) in 1984, and it now spans across the United States, offering over 80 active mentors for entrepreneurial startups. These startups are matched with 3-4 CED VMS mentors who have extensive business and entrepreneurship experience to help with customer outreach, licensing partnerships, pricing models, grant procurement, and more (Accelerate, 2018).

The Vector Textiles Team was matched with four mentors in the Raleigh-Durham area who were well versed in academic entrepreneurship and technology commercialization. The team had a few goals when entering the mentoring process that they hoped the group could help them solve. The first goal was to decide what kind of concept company the team wanted to develop. At this point the VT team could continue to pursue startup ventures, could license the technology to an existing company, or could develop the company into a consulting firm. The second goal was to procure a CEO or business manager to run the concept company as the founders did not have the time or business interest to do so. The third goal was to artfully navigate safe and profitable license agreements with the two interested parties, Company 2 and Company 3.

The team met with the group of CED Venture Mentors every three to four weeks to discuss progress and goals throughout all 2017-Summer 2018. Through this process, the mentors helped Vector Textiles establish a business framework that focused around consulting. The developed framework is shown in Figure 31. With this concept, Vector Textiles would refrain from producing its startup venture and would instead service existing fabric and garment manufacturers and apparel/military corporations. The Vector Textiles team would act as experts in the mosquito resistant clothing field and would test existing apparel and fabrics for bite resistance. NC State would theoretically receive a percentage of sales from fabrics branded “Vec-Tex Bite Resistant.” Also, if a garment manufacturer wanted an exclusive product made, the team would receive either a portion of the sales of the finished product or would charge for the testing and consulting fees if the company did not want to affiliate the Vector Textiles brand.
After the framework for the company structure was created, the team worked with the CED Venture Mentors to evaluate the need for an external CEO and business manager. The team decided that there was a need for a project member who could devote a majority of their time to the development of the concept company in its formative months. It had proved difficult to find someone who shared the same vision for the concept company as the rest of the team and had the necessary connections and expertise in the textile and apparel industry.

With the help of CED-Venture Mentors, the team interviewed and hired a local entrepreneur S. to help part-time with negotiations and business development. The first tasks given to S. were to finalize negotiations with interested companies Company 2 and Company 3. At this point, the protective garment manufacturer Company 2 had sent a letter of intent to

**Figure 31. Business Framework for Vector Textiles developed with CED Venture Mentors.**
license the bite-resistant fabric from Vector Textiles, and the fabric manufacturer Company 3 had shown interest in a fabric manufacturing and auditing relationship.

**Updates and Conclusions.** After several months of negotiations with the two companies, the group was unable to establish a license agreement. The potential reasoning behind this is later discussed in the Results and Discussion portion of the study. The business lead S. pursued various other license agreements in the months following. These efforts focused on large apparel companies in the outdoor recreation field. S. found it challenging to connect with these large companies as part of a small startup. S. reported that the next step for the corporation would be to hire a full-time business manager to raise funding and utilize existing connections within the textile industry. Currently, the team has created no further license agreements or spinoff efforts.

**Case Study Interviews**

**Vector Textiles Discussion**

Several respondents had worked with the Vector Textiles venture directly and had opinions and insight related to this specific venture. These opinions will be discussed in this section. Most of the respondents reported high enthusiasm and technical expertise of the team. Respondent 1 and Respondent 5, entrepreneurship mentors, shared similar positive sentiments about the group.

*Respondent 1:* I was pleasantly surprised with the energy and enthusiasm from the vector textiles team.

*Respondent 5:* If I were to score them against other academic companies that I worked with, I would say that they were an A or an A-. They listened and did their homework and did a good job on their homework.

Respondent 3, CEO of a garment company, responded similarly.

*Respondent 3:* I was surprised by their knowledge and their expertise. And their willingness to work with us, with us understanding their side of it. It has been an excellent relationship so far.

While all respondents reacted positively, Respondent 2, CEO of a garment manufacturing company, and Respondent 10, an academic entrepreneur, disclosed some problems regarding the team’s management style.
Respondent 2: This is a very large group with many different individuals, and it was very difficult to work in that environment.

Respondent 10: Trying to manage the different styles among the co-founders has been challenging but realizing that everybody brings different strengths you learn how to maximize the contribution and the value of each of those individuals.

Several respondents mentioned the need for a CEO for the venture as it progresses further. Respondent 7, a business lead for an academic entrepreneurship company, stressed the importance of this. Respondents 5 and 1, entrepreneurship mentors, and respondent 10, an academic entrepreneur, agreed with this sentiment.

Respondent 7: They are really smart people. Through this process, I believe in this technology, but I think they need a CEO.

Respondent 5: I would have loved it if they were able to get some more money to hire someone to work full time. If they had more money where they could have hired a full-time sales/business development person I think they would be further along right now.

Respondent 10: It disappointed me that the team didn’t use equity to attract a really good CEO. I feel like they need to go down that road.

Respondent 1: I know that nobody really wants to or is in a position to take a leadership role and be more assertive on that, but I think a leader would be beneficial for Vector Textiles to get where everyone wanted to go.

Despite any setbacks, several respondents noted the high value of the technology presented and the desire to see the team continue to pursue the venture. Respondent 4, an academic entrepreneur, and Respondent 2, CEO of a garment manufacturing company, had a positive outlook on the result.

Respondent 4: I think the team put something out there that is totally original that is solving a lot of problems. I can live comfortably saying that we did this as a group and that to me is enough.

Respondent 2: It is so attractive that there is a mechanical way of preventing insects from biting without the need for chemicals.
The researcher identified three main themes from the discussions regarding academic entrepreneurship: (1) *Entrepreneurship as a Valuable Necessity*, (2) *Finding Direction for a Venture*, and (3) *The Multitude of Risks*. Each theme gives a different perspective regarding the progressive stages of an academic entrepreneurship venture. The *Entrepreneurship as a Valuable Necessity* theme discusses how academic entrepreneurship is an integral piece of university success. The *Finding Direction for a Venture* theme explores the process of making initial decisions surrounding the venture in order to advance. The *Multitude of Risks* theme discusses the surrounding risks and highly debated concerns of academic entrepreneurship as a whole. The results will conclude with information specific to the Vector Textiles venture.

**Entrepreneurship as a Valuable Necessity**

Qualitative analysis of the data revealed that the participants, whether the respondent was an academic entrepreneur, a business mentor, or a company owner, viewed academic entrepreneurship as an integral part of an academic’s job description. For example, many university faculty members operate consulting businesses on the side, which requires an entrepreneurial mind and business acumen. Respondents viewed problem solving as an inherent trait in academics, which is a critical factor in successful entrepreneurship. Multiple respondents viewed academic entrepreneurship as an essential part of teaching at the university level. In addition, using academic entrepreneurship ventures as an experimental learning tool for undergraduate and graduate students was viewed as necessary for future community entrepreneurship growth. Respondent 9, an employee of the TTO at NC State views learning as an impactful result of academic entrepreneurship:

*Respondent 9: We do not just study entrepreneurship as an academic course, it is an actual living and breathing entity at NC State. There are many ways for people to engage and come out with real-life skills that they can use whether they want to create a startup or be part of a larger organization.*

The act of research is a job requirement for most academic faculty, and respondents viewed the academics as having a level of education that is critical to advance technology and humanity. For example, academic faculty member Respondent 10 strongly felt that entrepreneurship was inherently present in their job description:
**Respondent 10:** I think that faculty is very entrepreneurial by nature. A lot of what we do is having ideas and then going and seeking funding for those ideas, so I think in that way faculty are incredibly entrepreneurial.

The university setting was viewed by respondents as a research and development platform. Respondents from outside academia viewed this as extremely valuable, as many companies do not have in-house labs and testing facilities. University research is seen to be on the cutting edge of innovation, and a joint venture-ship can allow a company to diversify. Respondent 9, an academic entrepreneur at NC State strongly believes in these innovative partnerships.

**Respondent 9:** When a company invests a small amount of their time and money into a university they create a bigger portfolio of areas that they can support that they could not if it was all in house. It is really a good feeling when they are supporting their local or international educational institution.

The value of participating in an academic entrepreneurial experience was an undisputedly positive learning experience. Respondents that were academic entrepreneurs themselves viewed it as a chance to learn how to manage a business and move from failure. While many respondents mentioned that starting a venture was an enormous undertaking, all respondents mentioned that engaging in entrepreneurship was an exciting and enjoyable experience. Respondent 2, CEO of a garment manufacturing company, stated having a positive experience collaborating with several academic ventures.

**Respondent 2:** It has been very successful...I would advise academics to take a look at what they do from an entrepreneurial perspective constantly, not just when they develop something that is ready to be licensed.

Respondents reported a need for their work to have an impact as the primary motivation for academic entrepreneurship and viewed academic entrepreneurship as an alternative platform compared to publishing scholarly work. Entrepreneurship mentors reported these positive motivations as a high indicator of future success. For example, Respondent 6, an entrepreneurial venture mentor states:

**Respondent 6:** There are the academic entrepreneurs that don’t want to be involved with the commercialization side, which is fine. However, there are also ones that say ‘Okay, I actually want to change the world and do something’ and those are the ones that get a lot out of the experience.
Finding Direction

The process of initiating an academic entrepreneurship venture was described as daunting and overwhelming by several respondents. However, many discussions arose regarding the assistance that university and community mentorships provide to make this process more enjoyable. NC State University Office of Technology Transfer offers a cradle-to-grave effort to assist academic entrepreneurs. Several mentors mentioned conducting IP agreements, networking, marketing, customer discovery, discovering scaling partners, and acquiring funding sources as main ways these services can help. Among the many ways these mentors assist academic entrepreneurs, Respondent 6, academic mentor through the TTO, thinks that managing expectations is one of the most difficult.

Respondent 6: It is such a different world than academia, licensing and doing a startup. They have so much to learn and a lot to figure out. To be able to put their work into context and bring them to reality is something that takes a lot of skill.

Several respondents mentioned that every TTO office is different, and a good or bad TTO office could make or break an academic entrepreneurship venture. The respondents discussed that a positive TTO has enough staffing, high technological expertise, and a large amount of flexibility for the researchers as they grow their business. A contrary TTO office was described as being rigid and narrow, difficult to work with, slow, and expensive. Respondent 7, business developer for an academic entrepreneurship firm at NC State, reported being disappointed by the process.

Respondent 7: I think the ICORP program was really awesome for startups, but I think it is a really narrow view for starting a venture. I think that the TTO has a long way to go. I think there are a lot of holes in the knowledge of how to start up a company from a university.

Respondent 2, CEO of a garment company, also expressed their opinion on the process.

Respondent 2: I think they should play a bigger role and be the mouthpiece in their business case for the academics. Show me the entire spectrum of what you have to offer, what it costs, what the market size is, and how you expect me to deal with you. This saves a lot of time upfront and enables the academics to catalyze their ideas into a format.
Several respondents reported the importance of networking as a crucial factor for success. Mentorships and TTO offices frequently connect academic entrepreneurs with local venture capitalists and mentorships. Respondent 8, business mentor through the TTO, discussed the importance of networking and delegating some business responsibilities to others outside the organization.

*Respondent 8:* We like to think that if you help put infrastructure around companies and technical founders and help them plug into their entrepreneurial ecosystem...these companies are more successful.

The term “clarity” arose multiple times in the data, referencing the clarification that mentors and TTO offices can bring to a beginning academic entrepreneurship venture. Active alumni networks and investor networks can help a venture decide what type of venture an academic wants to pursue with technology, whether it be a spinoff, a license agreement, a consultancy, or one of the many variations of these. Respondent 6, a venture mentor in the Raleigh Durham area, explains in detail how vital this clarity can be.

*Respondent 6:* We need to think about where this invention fits into the chain or the market. You are going to have IP you can use at some point in the chain, but where does that go? You have a chance to think about it like you have never thought of it before, which is really unique.

Several other respondents echoed this sentiment, stating the importance of finding a market gap for a product or service from academia. Respondent 7, business lead for an academic startup, reported that technology coming from a university setting could be challenging to adapt to the market.

*Respondent 7:* Technology coming out of a university usually stems from research, whereas technology that stems from an external startup is coming from where there is a gap in the market. Which is why maybe technology coming out from industry is more organic, per se.

Respondents also discussed the differences between licensing and the creation of a university spin-off or startup. Several respondents discussed how different kinds of research impacts this decision. For example, Respondent 9, an employee of the university TTO states that in many cases it can depend on how developed an innovation is before entering the market.
Respondent 9: *In many cases, incubation of an idea has to take place at a startup level before a larger company would be interested in licensing. It just depends on how developed the technology and the colleagues are, and how clearly and articulately the value proposition is.*

Respondent 8, fellow university TTO employee seemed to agree.

*Respondent 8: I think there are certain types of technologies and products that won't see the light of day if they do not go through a startup. So I think that some of these technologies just need a full-time committed team that can start a company and diligently push towards the goal.*

Several respondents mentioned the ability to let go of control as relevant to the decision of spinoff creation. In comparison to a license agreement, respondents mentioned that a startup might allow academics to have a more considerable continued involvement in the venture, and potentially a higher value proposition if the venture is a success. Where a license agreement may result in a commission or royalty fee paid to the academic, a spin-off could result in a much higher financial interest. However, respondents viewed spin-offs as requiring a much larger time commitment and upscaling of employees that several academics viewed as overwhelming.

*Respondent 5: If a company looks at all the skills they need and how this translates in terms of hiring people, they usually go with what in their gut is easiest. A lot of people think that a license agreement is easiest, but it might not be as profitable.*

**Multitude of Risks**

The respondents agreed that there is a multitude of risks for both academic entrepreneurs and companies licensing with entrepreneurs. This category covers the perceived risks for those involved with academic entrepreneurs, and opinions on how to mitigate these risks.

**Early Stage Technology.** Several respondents viewed the concept of early-stage technology to be an issue for commercializing a technological innovation. Respondent 11, an academic entrepreneur, and Respondent 6, an entrepreneurship mentor believe that many innovations that academics aspire to commercialize are not fully developed.

*Respondent 11: Most of the things that a professor wants to take forward are not fully developed, and a lot of investors want to be a lot closer to the end point before...*
starting to work with a university. Basically all of the risk is still there, and investors want to be down to the last 20%.

Respondent 6: Especially in the pharmaceutical space, it’s hard to find an established company that is going to want to buy a very early stage technology. It is too risky. A startup is a good way to get an early stage technology to get a larger company to even consider it.

**Procuring Funding.** Another potential risk is lack of funding. Academic entrepreneurs require venture capital and grant funding to continue research and development, which is not always the case with traditional entrepreneurship ventures. Most respondents, including academic entrepreneur Respondent 4 and entrepreneurship mentor Respondent 5 viewed this as an increased risk.

*Respondent 4: Academic entrepreneurship sometimes comes from the funding source whatever that may be. Sometimes you wonder who owns the idea, is it the funder or is it the academics that did the work.*

*Respondent 5: I’ve seen plenty of startups fail that have good people and good ideas, but they just can’t get the money.*

Respondent 2, CEO of a garment manufacturing company, believes that this may be mitigated by more business acumen.

*Respondent 2: I think that knowing how a business is run, how licensing works, and knowing how patents and royalties work can help to procure funding.*

**Time Constraints.** Knowing the intricacies of business was discussed as a challenge for many academics as most lifetime academics have had less work experience outside of campus. Also, time restraints were brought up by almost every respondent in the study. Respondent 9, TTO employee, agrees that having many obligations can be a huge setback for a growing venture.

*Respondent 9: They have teaching obligations and research in other areas, and they might not be aligned in terms of timelines and exact objectives. This could be a challenge for a company dealing with faculty if they aren’t accustomed to it. Trying to understand how to speak the same language and understand what timelines need to be mutual is important.*

Respondent 4 and Respondent 11, academic entrepreneurs, seem to agree with this statement.
Respondent 4: I think the biggest problem with academic entrepreneurs is time...and dedication to something that is pretty much a full-time occupation. Time split is detrimental to the entrepreneurship project, and the way entrepreneurship should be done.

Respondent 11: As an entrepreneur, you are 100% busy with being an entrepreneur, as an academic you are 100% busy with being an entrepreneur and 100% busy with being an academic. Figuring the right balance is difficult.

There were a few possible solutions discussed as part of the time commitment issue. The first was the assistance of graduate students. Many respondents brought up both concerns and praise regarding graduate students as a part of an academic entrepreneurship venture. Several respondents viewed graduate students as a considerable asset to the venture team, regarding them as a potential solution to time restraints faced by full-time faculty members. Respondent 5, business mentor, and Respondent 2, CEO of a garment manufacturing company, seem to agree.

Respondent 5: Graduate students, when properly funded, can be essential to an academic entrepreneurship venture.

Respondent 2: Why will the company have to hire someone from outside when there are assets within the school that can help them get to where they need to go? If the university has a business school, how can we enable their business school to be synergistic and cross-functional with academic entrepreneurship projects?

Respondent 12, an academic entrepreneur, viewed things differently. They discussed the potential risks of having graduate students on board.

Respondent 12: We have to pay them as employees, not grad students. They have restrictions on what they can do as far as the business. As a grad student you want to publish, as a company, you don’t want to publish. A patent takes a few years to complete, and at what point are you allowed to talk about it?

Another potential solution to time constraints could be hiring a CEO or business team to run the venture. The majority of respondents viewed hiring a CEO or business lead as a very positive decision. Respondent 12, an academic entrepreneur, and Respondent 5, an entrepreneurship mentor view this as a necessity.

Respondent 12: At a certain stage you...need to leave the university and become a full-time employer. You better hire someone to do the accounting, the business, the
marketing stuff…at some point you have to freeze the R&D idea and say how are we going to make this and how are we going to sell?

Respondent 5: I have seen many say ‘I don’t need sales people, I don’t need marketing people, and I am going to build this beautiful thing, and everyone is going to buy it.’ It is so naïve. That is the saddest thing about being a volunteer when I see people failing the way I’ve seen other people failing.

Respondent 4, also an academic entrepreneur agrees that there needs to be a certain point in which the researcher moves on with the venture.

Respondent 4: Licensing allows for an academic’s idea to get to a certain point and then move into the area of industry where people can then take it from there…There needs to be a letting go or an agreement that we are going to take it to a certain level and then we are going to sell it.

A conflicting opinion from Respondent 11 brought up issues with procuring an outside management team with little involvement from the academic creators of the innovation.

Respondent 11: If you want to be successful you basically have to take a leave of absence from being a professor. Even though you can hire management, they don’t necessarily have the same visions of the company. Without knowing the technology, they can struggle if it is something truly new.

Many respondents saw the lack of outside leadership to be a risk to companies looking to license with the new venture. Without full-time leadership of the firm, respondents believed that there was a time-commitment risk to partners of the venture. Respondent 1, an entrepreneurship mentor, believes this is imperative for conducting business.

Respondent 1: One of the key differences with general entrepreneurship and academic entrepreneurship is that outside ventures usually have someone who is already interested in leading the organization...I think identifying that person to lead the organization is key and in non-academic entrepreneurship startups, you already have that established.

Respondent 8, also an entrepreneurship mentor, sees the ownership of the company to be a key concern when licensing or procuring funding.

Respondent 8: I would be quite concerned…I would say it would be risky for investment opportunities anyway, to see a capitalization table that was primarily
made up founders who are working for a university or some other entity beyond the organization of the company itself.

Administrative Issues. Respondents reported administrative issues when conducting academic entrepreneurship for both outside companies and faculty members. Respondent 1, entrepreneurship mentor, discussed the aspect of speed as the main setback.

Respondent 1: I think there are generally more administrative requirements when working with a university versus without a university. When working with a non-university deal, there can be more flexibility and speed. However, it doesn’t have the benefits of working with a university can have.

Respondent 6, a TTO employee, also speaks to these issues.

Respondent 6: It goes a different pace from industry, and there is a lot in which legally our hands are tied. There are legally certain things we cannot agree to, and certain things that are very immovable and we cannot negotiate on.

A related issue discussed by several respondents was a conflict of interest. Respondent 11, an academic entrepreneur was affected by this during business dealings but describes how the TTO was able to help him avoid this while achieving his goals.

Respondent 11: I have to keep an arm’s length for all these negotiations because there is a very serious conflict of interest. This way I could let someone negotiate what was best for the company instead of me trying to negotiate what is best for the company, the university, the State, and myself.

The respondents had mixed responses to the process of licensing from the university. Several respondents stated the ease in which they were able to conduct business within the university setting. Respondent 11, an academic entrepreneur, Respondent 10, academic entrepreneur, and Respondent 3, CEO of a garment company, found these proceedings to be a positive experience.

Respondent 11: I found the licensing relatively straightforward. It was just a case of the person who put up the most money. My partner had worked with the university before, and he understood that the university needs royalties for what he’s getting. Respondent 10: I think the risks are relatively low because the security of the university as a partner. We need to understand that we represent the university and its university intellectual property. It really is a powerful asset in my opinion.
Respondent 3: I thought it was a safe partnership. After working with the university team, I felt very comfortable, so I didn’t have any reservations about a partnership.

Respondent 2, CEO of a garment manufacturing company, felt differently than the other respondents. They felt that conducting business with the university was very difficult.

Respondent 2: It’s very difficult to license something from a university because all of the processes they have to go through. I think it’s bureaucratic...For a company to engage with academia, it takes time and a lot of money in travel. It is sometimes difficult to assess what it is that academia really has.
CHAPTER 5: SUMMARY, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

Summary of Purpose of Objectives

The purpose of this research is to explore the trials of academic entrepreneurship as well as the two main methods of commercializing new and innovative technology from an academic research setting: spin-off development and license agreements.

The research objectives are as follows:

1. Investigate two current available avenues for technology commercialization from the academic sector: spin-offs and license agreements
2. Investigate community impact of academic entrepreneurship at NC State University
3. Discover the intricacies involved with academic entrepreneurship in the textile sector and the industry’s unique issues and success factors

Primary Research Questions

The following questions guided this research:

a. Are there difficulties regarding technology transfer for some academic entrepreneurs at NC State University?
b. How are spin-offs and license agreements useful in commercializing a highly technical textile product as measured by defined commercialization?
c. How is the surrounding community impacted by academic entrepreneurship ventures?

Overview of Methodology

The Office of Technology Transfer Data from NC State was used to assess the prior output of license agreements and startups from the university from the past four years, 2013-2017. This analysis attempts to give an overview of previous academic entrepreneurship ventures from each college at NC State University, mainly focusing on output from the Wilson College of Textiles. In addition, an exploratory case study was conducted to analyze the business development of an NC State academic entrepreneurial venture in the textile realm. A qualitative research design was employed which included in-depth primary data collection and twelve semi-structured interviewed with academic entrepreneurs, local entrepreneurship mentors, and potential business partners involved with the firm.

The researcher also gathered in-depth primary data by taking an active role in providing research expertise and facilitating the process of taking the innovative fabric to market (Lofman,
et al., 2004). Participatory Action Research was implemented into this study as the commercialization process requires quick responsiveness to change.

**Defining Commercial Success**

It is essential to consider the definition of commercialization, as well as the definition of success, for these entrepreneurs as well as the university they represent. While the definition of both of these terms is highly subjective, the following gives insight as to what these terms mean in the context of this study. The NC State University Technology Transfer Office defines success as financial gain through license agreements, whereas the office receives a percentage of returns to support future entrepreneurial ventures. More recently, success can be defined by increased economic engagement and the creation of jobs, specifically through startups and spin-offs (Parker, 2018).

Through this process, the study aims to identify the reasons behind success and failure for each attempted business development avenue. Success is determined using the top motivations and identifiers of success expressed by the five academic entrepreneurs leading the project discussed in Table 2. Overall success for the venture will be determined as follows: obtaining external funding or profit and undergoing an initial public offering. Failure will be considered lack of mortality, or failure on the part of the academic entrepreneurs to exert effort to develop a new venture (Shane & Stuart, 2002).

**Conclusions**

Academic researchers at NC State University mainly participate in commercial entrepreneurship, precisely at the Wilson College of Textiles. The university currently has over eight hundred operating commercialization agreements, 135 launched startups, and 1,010 US patents issued (OTCNV, 2018). The Wilson College of Textiles has played a significant role in this university success, making up 12.5% of total university disclosures and earning 34% of the total university licensing revenue. As one of the smallest colleges at NC State University, this shows excellent academic entrepreneurship initiative and connection with the commercial industry.

The data from the NC State University OTT gives insight into the current landscape for academic entrepreneurs, especially for those looking to be involved in commercial license agreements or new ventures. From analyzing the startup data from the past five years, it is interesting to see the recurring patterns in leadership. Analysis of the eight textile based new
ventures detailed in Table 4 shows that all of the surviving new ventures are at least partially led by those outside of academia. Within the companies discussed, academic inventors currently hold a variety of roles. Positions include serving as consultants, providing research support, making up the advisory board, or participating directly in the business operations of the company. According to case study interview data, inventors should add at least one team member with managerial and entrepreneurial experience.

A vast majority of academic spin-offs created from the Wilson College of Textiles have appointed CEO's or business leaders that have extensive experience in entrepreneurship. Having an experienced leader allows the academic entrepreneur to focus on research, innovation, teaching, and academic publishing. In two of the most successful spin-off ventures from NC State University, SAS Institute and Cree Inc., the researchers left their roles in academia to focus their efforts on the new venture. Maintaining a passion for the project and early funding to move the venture forward is necessary for a successful spinoff or startup venture.

**Case Study Conclusions**

The case study of Vector Textiles illuminates both the benefits and risks involved with academic entrepreneurship at NC State University. It provides insight regarding the experience from three different perspectives: entrepreneurship mentors, academics, and external companies. This broad perspective regarding academic entrepreneurship is not currently found in other literature. The findings from the case study interview data suggest that academic entrepreneurship is fully integrated in the university culture, and can be extremely beneficial to the academic, the university, and the local entrepreneurship ecosystem. Analysis of the Vector Textiles Case Study shed light on the difficulties and risks faced by these entrepreneurs when bringing a technology to the commercial space. Despite the difficulties regarding time constraints, administrative issues, and the hiring of management professionals, Vector Textiles can be considered a partial success by the original parameters set by the team members. The following table highlights this discussion.
Table 5. Evaluation of Vector Textiles, Inc. business performance.

<table>
<thead>
<tr>
<th>Commercial Attempt</th>
<th>TTO Success Parameters</th>
<th>Entrepreneur Success Parameters</th>
<th>Failure Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Financial Gain for University</td>
<td>External Economic Engagement</td>
<td>Job Creation</td>
</tr>
<tr>
<td>License with Company 1</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Maternity Spinoff</td>
<td>✕</td>
<td>✕</td>
<td>✗</td>
</tr>
<tr>
<td>Sportswea r Spinoff</td>
<td>✕</td>
<td>✕</td>
<td>✗</td>
</tr>
<tr>
<td>License with Company 2</td>
<td>✕</td>
<td>✕</td>
<td>✗</td>
</tr>
<tr>
<td>License with Company 3</td>
<td>✕</td>
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</table>

The license agreement with Company 1 was initiated by the NC State University TTO. This can be considered the most successful commercialization attempt for the venture. Vector Textiles procured financial gain for the university through licensing royalties. They were able to economically engage with the external company and its workers to create jobs and offer the product publicly. However, the following attempts were not as successful. While these attempts created jobs for graduate students and a part-time business coordinator, they did not create an initial public offering or profit for the entrepreneurs or the university. Throughout all of the commercialization attempts, the company maintained its mortality and the team did not fail to exert effort.

The benefits of cultivating a license agreement with an external company are shown throughout the study, highlighted by the initial success of Vector Textiles when licensing with Company 1. The benefits are also continually discussed in the qualitative analysis of the case study interviews. Academic entrepreneurship is seen as a teaching aid and experimental learning
tool for students, as well as a way to boost community entrepreneurship efforts. Companies see these ventures as a valuable research and development platform and a way to diversify their knowledge and product line. These ventures can be a valuable learning experience for academic entrepreneurs, as well as a way to bring their problem solving skills to the commercial space. The data from the NC State OTT shows the monetary value of these efforts from the result of patents, licensing royalties, and spinoffs.

The process of commercializing technology can be difficult, but are made easier through assistance from the TTO and local business mentoring efforts. The TTO was a continual source of assistance for Vector Textiles, providing logo and website design, licensing assistance, legal guidance, and network growth. Programs like I-Corps, Executives in Residence, and CED-VMS can make this process easier by assisting ventures with marketing, customer discovery, and funding acquisition. The Vector Textiles venture utilized many of these programs and gained clarity regarding the way they wished to position their product in the market.

The study illuminated the many risks academics and external companies can face when participating in academic entrepreneurship. The main issues that plagued the Vector Textiles team included time restraints, administrative issues, early stage developments, and the hiring of management professionals. As the venture was entirely run by full-time University faculty, the team did not have time to focus on the operations of the firm. University faculty have teaching obligations, research in many areas, and full-time occupations, which may lead to a misalignment in objectives and timelines. There are also more administrative requirements such as legal and funding source restrictions, which affected Vector Textiles when releasing both of the attempted crowdfunding campaigns. The inability of the Vector Textiles team to hire a CEO seemed to be an issue, as mentioned in case study interviews. A full-time business manager would have alleviated time restrictive issues and allowed the researchers to focus on R&D efforts. With further R&D and product development efforts, the venture could potentially have had a later stage product, which could alleviate risk for licensing partners.

Implications for Academic Entrepreneurs

When developing an academic entrepreneurship venture, there are many variables. By analyzing the data from this study, recommendations have been developed below for ventures stemming from the NC State University Wilson College of Textiles. In case study interviews, several respondents stated that academics should continuously think about what they do from an
entrepreneurial perspective. This allows the faculty member numerous possibilities to pursue an entrepreneurship venture during their academic career. When deciding whether or not to commercialize a technology, researchers should evaluate the stage of the technology to ensure it is not “early stage”. An early stage product can deter possible venture capitalists, TTO professionals, and license partners due to an increased risk factor and significant time commitment. One way to do this is to clarify the potential product offering. Decide where the product or service will fit in the commercialization chain in order to properly articulate the value proposition. Business mentors and professionals at the TTO can assist when evaluating this.

Once the potential product offering is clarified, consumer interviews, focus groups, and market tests should be conducted. Prototypes should be created and tested by potential consumers. This will help the academic develop a value proposition package. This includes a full description of the product, an evaluation of the target market and consumer, and all related costs associated with the product. In this stage, undergraduate and graduate students can be a valuable resource for assisting with market testing and prototype creation.

The TTO can be used as a resource to begin product commercialization. These professionals can evaluate the product and help decide whether to pursue a spinoff venture or license agreement. A license agreement allows the researcher to develop a product to a certain point in which the licensee is given the task of commercialization. This requires less time and commitment for the academic entrepreneur, but also requires the ability to release control of the innovation. The creation of a spinoff venture has the potential for a much higher level of involvement in the venture. In most cases, it is imperative for the academic to assess the time required to run and grow a profitable business venture. Academics may choose to hire a management team to complete the business operations of the firm, such as accounting, business development, and marketing. However, the academic could choose to take a leave of absence from the university in order to pursue the spinoff.

In conclusion, academic entrepreneurship continues to make an impact on technology innovation in the commercial space. While many ventures continue to fail to translate to pragmatic commercial solutions, these recommendations can assist academic entrepreneurs when mitigating fundamental mistakes in the technology transfer process. This study highlights the large amount of time and effort required to pursue an academic entrepreneurship venture, but also highlights the benefits to academics, students, and the business community. There is now
more assistance than ever for academic entrepreneurs in the form of TTO’s, business mentors, venture capitalists, and government funding. While there continue to be many variables involved with beginning any venture, this study sheds light on a few fundamental mistakes that can be mitigated by proper planning and assistance.

**Limitations and Recommendations for Future Research**

This study serves as a broad overview of academic entrepreneurship at NC State University. It examines an overview of the NC State University TTO data as it relates to academic entrepreneurship success. This study could be easily repeated using other entrepreneurial universities. There are many other interesting research topics that could stem from this data, including a comparison between NC State University academic entrepreneurship and other university TTOs. A study comparing the operations of multiple TTOs at several universities could give greater insight as to programs and efforts that are most effective in assisting academic entrepreneurs.

A limitation of this study is that the researcher only analyzed a single case study in the Wilson College of Textiles at NC State University. An exciting future research topic could compare the differences and similarities of multiple case studies, particularly ventures in very different product arenas. For example, commercializing an innovation in the medical industry may be a hugely different process than the textile industry.
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Appendix A: I-Corps Questions for Pro-Tex Maternity Customer Development

1. Have you been pregnant, or currently pregnant, or planning to be pregnant?

2. What are/ were your top three safety concerns regarding your pregnancy?

3. What have you done to relieve these concerns? Have you come across any obstacles?

4. If you could wave a magic wand and remove one of these concerns, what would it be and why?

5. Have you bought any maternity clothing? If you have or plan to, what was or will be your criteria?

6. At what point did you (or do you currently) feel comfortable wearing maternity clothing and why?

7. Do you think the selection of maternity wear available to you is lacking in any way?

8. In what environment/during what activities would you wear your maternity clothing?

9. Do you currently use any protection against mosquitoes? If so, what do you use?

10. What have you heard of the Zika virus?

11. Would you continue to use your current method while you are pregnant? If no, what would make you change this current method?

12. If there was a line of maternity wear that protected you from mosquito bites, what would you be willing to pay for a top and/or legging? How many pieces would you buy
Appendix B: Institutional Review Board- Informed Participant Consent Form

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Title of Study: Interviews Regarding Academic Entrepreneurship (IRB # 15415)
Principal Investigator: Lilah Halbkat
Faculty Sponsor (if applicable): Dr. Andre West

What are some general things you should know about research studies?
You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of this research study is to gain a better understanding of academic entrepreneurship and how it interacts with the commercial market space.

You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those who participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above or the NC State IRB office as noted below.

What is the purpose of this study?
The purpose of the study is to gain a better understanding of academic entrepreneurship and how it interacts with the commercial market space.

Am I eligible to be a participant in this study?
In order to be a participant in this study you have been involved with academic entrepreneurship either as an entrepreneur yourself, or have communicated with an academic entrepreneurship team. An academic entrepreneur is someone wishing to transfer university research to a commercial product.

What will happen if you take part in the study?
If you agree to participate in this study, you will be asked to answer interview questions regarding your experience. Quotes from your answer might be included in a master’s thesis conducted by the principal investigator.
Risks and Benefits
There are minimal risks associated with participation in this research. There are no direct benefits to your participation in the research. The indirect benefits include contributing to the research of transferring innovations from a university setting to a public space.

Confidentiality
The information in the study records will be kept confidential to the full extent allowed by law. No reference will be made in oral or written reports which could link you to the study.

Compensation
You will not receive anything for participating.

What if you are a NCSU employee?
Participation in this study is not a requirement of your employment at NCSU, and your participation or lack thereof, will not affect your job.

What if you have questions about this study?
If you have questions at any time about the study itself or the procedures implemented in this study, you may contact the researcher, Lilah Halbkat, 1204 Duplin Rd. Raleigh, NC 27607, lahhalbka@ncsu.edu, (828) 817-9828.

What if you have questions about your rights as a research participant?
If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the NC State IRB Office via email at irb-director@ncsu.edu or via phone at 1.919.515.4514. You can also find out more information about research, why you would or would not want to be in research, questions to ask as a research participant, and more information about your rights by going to this website: http://go.ncsu.edu/research-participant

Consent To Participate
“I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled.”

Click Yes to Consent: Yes ☐ No ☐
Appendix C: Qualitative Interview Questions Discussed in Case Study

1. Can you tell me a little bit about what you do?
2. Have you worked with academic entrepreneurship ventures before?
3. How valuable did these partnerships end up being?
4. What is your experience and perception of academic entrepreneurship?
5. Is there a difference between typical entrepreneurship and academic entrepreneurship?
6. In your experience are there any risks that you encountered when working with academic faculty? *Mentors: For example when helping universities license to outside companies?
7. What are your perceived benefits with licensing with a university?
8. What is your opinion on choosing to license vs. creating a startup from academia?
9. When you started working with Vector Textiles, what problem were you trying to solve?
10. Based on that problem what solutions did you consider?
11. Is there anything that surprised you or exceeded your expectations while working with Vector Textiles?
12. Is there anything that disappointed you?
13. What have you learned from working with us or other academic entrepreneurship ventures?