FROM LAB BENCH TO INNOVATION:
Critical Challenges to Nascent Academic Entrepreneurs

Roman M. Lubynsky
Massachusetts Institute of Technology

Ewing Marion
KAUFFMAN
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Introduction

University research laboratories are important sources of the inventions and discoveries that become significant innovations with broad economic and societal impact. Invention alone is not innovation; innovation is the long, hard work of taking new technologies and bringing them to commercialization. There are many pathways for the dissemination of new knowledge that arises from basic research at universities, ranging from traditional methods such as publication and training students to licensing technology to established firms or new ventures.

One way to transform new knowledge into valuable innovations is for university researchers to undertake the creation of new firms based on their discoveries through academic entrepreneurship. The problem is that university scientists and inventors with a discovery made at a laboratory bench face challenges beyond those experienced by traditional high-technology venture founders: they must finish creating the technology before they can begin using it (Jensen and Thursby, 2001; Pisano, 2006). Academics typically start with inventions so immature that their commercial success cannot be predicted (Jensen and Thursby, 2001).

Academic entrepreneurship is an emerging and developing phenomenon, and there is a growing body of literature about new ventures based on university academic. However, limited research has been directed toward nascent academic entrepreneurs (NAEs) to understand the key challenges of bringing innovations to market. The majority of this work has focused on the institutional experience rather than the academic entrepreneurs and their individual experiences (Rothaermel et al., 2007). Within the broader fields of entrepreneurship and innovation, it has been argued that high-potential startups such as academic ventures should receive particular attention from scholars (Davidsson and Gordon, 2011). The following research addressed this gap.

Nascent academic entrepreneurship involves more than transforming an invention into a commercialized innovation. It is about the genesis of ideas and the emergence of opportunities, the birth of new organizations, their evolution into new companies, and the transformation of scientists into leaders. It also is about providing the foundation for future innovation by others. Though nascent academic entrepreneurship is increasing in frequency, it is not well understood. The dissertation examines this important topic.

Purpose of the Study

The purpose of this inductive multicase study was to examine and understand the process and key challenges faced by nascent academic entrepreneurs[2] (NAEs) at the Massachusetts Institute of Technology (MIT) in transforming an idea or invention to initial commercialization, beginning with the initial inception of the idea. To understand the problem, this study focused on the following research question: what are the critical challenges experienced by NAEs in their emergence process?

The Literature: Overview

Nascent academic entrepreneurship is a new area of study. The literature that informed this research appears in two broad fields of study: innovation and entrepreneurship. Within the innovation domain, the focus area was on university spin-offs within the context of entrepreneurial universities. Within entrepreneurship, the focus was on the relatively new area of nascent entrepreneurship. The dissertation research is positioned at the intersection of these fields, as depicted in the conceptual schema shown in figure 1.

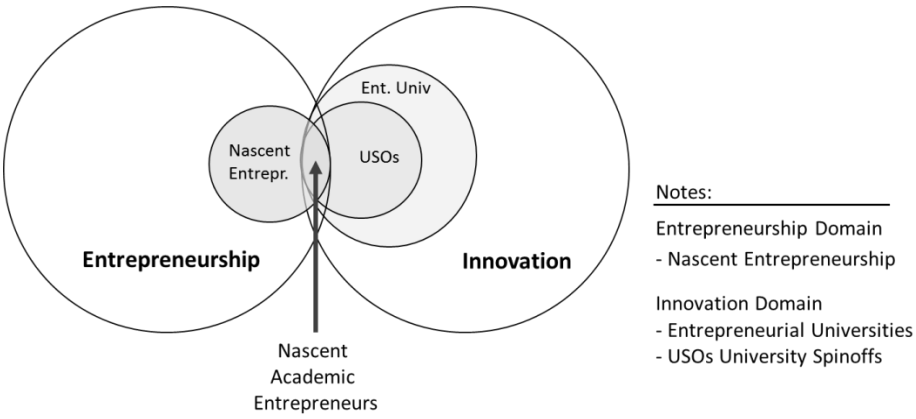

Figure 1. Topic positioning within literature.

The dissertation reviews the literature starting with an examination of innovation and technological change, establishing why they are important to society. This establishes the foundation for a definition of innovation for the purposes of this study, as well as its relationship to science and invention. Understanding the process elements and timelines of moving from scientific discoveries to their widespread application provides important overall context for the study, which leads to the topic of entrepreneurial

[2] In this study, a nascent academic entrepreneur (NAE) is defined as a researcher at a university (faculty, staff, or student) who has left the university, or intends to leave, to devote full-time attention to the development of a company based upon research that originated at the university in which he or she was significantly, if not principally, involved, and who has not yet achieved repeating real economic activity from the sale of products or services based on that idea.

universities and the connection of these institutions to innovation, including how their role has evolved, current directions, and the debates surrounding these issues. Examining changes in regional and national innovation systems establishes a foundation for discussing the impact on universities and academics resulting in the growth of technology transfer via the creation of spin-off ventures. Narrowing in further, the review includes the relatively recent but growing literature concerning these university spin-offs (USOs) to establish their increasing significance and why they are different from other entrepreneurial ventures.

Returning to the broad picture, this study also falls within the expansive area of entrepreneurship literature that has received scholarly attention from many disciplines. The focus of the review is on the dominant themes and debates most relevant to NAEs that emerge from the extant literature to provide a basis for focusing the research, including entrepreneurial opportunities, new organizations, and the individuals who create them. Within this area, the subtopic of nascent entrepreneurship in general is examined, particularly in relation to the dominant themes above and to establish that the study of emerging new ventures is not the same as existing young firms.

The product of these examinations within the two broad domains of innovation and entrepreneurship culminates, and is integrated, in the review of the limited emerging literature on NAEs that lies at the intersection of all the previous topic areas. This is the focus of the study and establishes the basis for the research question.

Research Approach

Methodology. This study explored the development process of NAEs following the genesis of an idea through initial commercialization. This is a new area with limited previous research activity. The study used a longitudinal, multicase empirical approach that focused on building theory that emerged from the data (Eisenhardt, 1989). The attributes of inductive inquiry elicit fresh understandings and it is well suited to entrepreneurship research and areas that have been little studied. A multiple-case design permitted a replication logic treating each case as an independent experiment (Yin, 1994). Data and theory were constantly compared and contrasted throughout the data collection and analysis process.

Research setting. This study examined scientists who are academic entrepreneurs at MIT, recognized as one of the world's leading educational institutions, consistently ranking at the top in many science and engineering disciplines (O'Shea et al., 2007). MIT also is recognized as an important driver of innovation by producing the academic research that underlies many important industrial innovations (Mansfield, 1995) and results in new firms and industries (National Research Council, 2012). MIT also has a long history as a leader in producing university spin-offs (Kordal et al., 2010; Shane, 2004).

The researcher has unique access to a novel population of academic entrepreneurs pursuing spin-offs—those enrolled in the MIT Venture Mentoring Service (VMS) program—that otherwise would not be visible or accessible. A number of delimitations further set the scope for this study. First, participants were limited to academic entrepreneurs engaged with VMS because (a) this provided access to a normally invisible sample and (b) robust archival data was known to be available. Second, case participants were scientists who met the definition of NAEs as defined by the study. Third, the invention or discovery serving as the basis for the entrepreneurial effort was significant and novel. Finally, case participants were limited to first-time NAEs.

At the time of conducting this study, the researcher had been employed for ten years at MIT as a VMS staff member. For this inquiry, the researcher brought practical experience and personal observation of many hundreds of prospective entrepreneurs as they navigated from idea toward operating a real firm, including many academic entrepreneurs. This experience gave the researcher distinct knowledge and understanding of the environment and context.

Research sample. The study investigated as cases ten NAEs in eight academic ventures. The unit of analysis was the individual NAE founder. These cases spanned the life cycle from idea to commercialization in a wide range of technologies and industries. The research included multiple data collection methods such as interviews, longitudinal contemporaneous observations, and extensive archival data. Multiple informants also were used in each case. The study comprised thirty-four interviews with twenty-two informants and a review of more than 3,400 archival documents. Following Eisenhardt (1989), cases were selected on the basis of theoretical sampling, which introduced a deductive element in that cases were chosen one at a time and analyzed.

Table 1 contains a summary of the NAEs and ventures, along with the status of the NAE at the time the venture idea was formed, the current or ending status of the venture, the number of staff employed, and a description of the outcome. The table includes the number of years spent in each phase the participant reached.

As this information is potentially sensitive, the names of the participants and their ventures have been given pseudonyms. Quotes from participants have been altered only where necessary to ensure that their identities remain anonymous or where they have requested that certain confidential details not be included.

Summary of Findings

There were six major findings from the study. The researcher aimed to capture a broad range of experiences along with the participants' perspectives to provide the reader with deep context for those experiences. The intent was to let the participants' voices speak for themselves. Illustrative quotations taken from the interview transcripts present the varied perspectives of the participants and convey a sense of the richness and complexity of these experiences. The following tables provide a summary of the key elements of the findings along with a sample of representative quotes.

Finding 1: Many NAEs are students when they start their venture activities.		
Elements	*Results*	*Comments*
Students are important pathways for USO formation	9 out of 10 NAEs were students at initiation of venture idea	In 7 out of 8 ventures, the technology resulted directly from students' research.
Representative quotes "I was interested in this topic because it had the potential to change the world for the better . . . I really threw myself entirely into this research. I mean, it did not escape me that I was at MIT in . . . arguably the best PhD program on the planet. This is not just a once in a lifetime experience, this is an experience that most people don't get even once in their lifetime." (Founder2, Beta Bio)		

Table 1. Summary of NAEs and ventures

						Years in phase				
NAE name	*Venture name*	*Industry / discipline*	*NAE*	*Current / Ending Status*	*Status / Outcome*	*Idea*	*RBSU**	*TBSU***	*Comm*	*Total*
Founder 1	**Gamma Materials**	Materials / materials	Student	Idea / early science	In progress / plan RBSU	**0.5**	**–**	**–**	**–**	**0.5**
Founder 2	**Beta Bio**	Biotech / biology	Student	RBSU early science	In progress / plan TBSU	**0.5**	**1**	**–**	**–**	**1.5**
Founder 3	**Kappa AI**	Software / AI	Student	RBSU / attempting TBSU	Failing	**4**	**6**	**–**	**–**	**10**
Founder 4	**Lambda Magnetics**	Magnetics / physics + materials	Faculty	RBSU / pre commercialization	Failed	**1**	**10**	**–**	**–**	**11**
Founder 5		Magnetics / physics + materials	Student							
Founder 6	**Epsilon Energy**	Energy / chemical engineering	Student	TBSU / pre commercialization	In progress / transitioning to TBSU	**1**	**8**	**1**	**–**	**10**
Founder 7	**Alpha Chips**	Computing / physics	Student	TBSU / pre commercialization	Intelligent outcome / acquisition	**2**	**7**	**1**	**–**	**10**
Founder 8	**Delta Pharma**	Pharma / chemical engineering	Student	TBSU / pre commercialization	Intelligent outcome / acquisition	**2**	**5**	**1**	**–**	**8**
Founder 9	**Zeta Web**	Software / signal analysis	Student	TBSU / post commercialization	In progress / growth	**1**	**3**	**2**	**2**	**8**
Founder 10		Software / NLP	Student							

* Research based startups
** Technology based startups

Finding 2: The first challenge that NAEs face is acting upon the idea of a venture and actually exploring it.		
Elements	*Results*	*Comments*
Research motivations for NAE	For 8 of 10 NAEs it was curiosity driven	Primary motivation was finding an interesting scientific idea with potential for contribution to scientific knowledge.
Recognizing potential impact and future applications	When research results appeared promising, began considering future applications	The dominant perception (8 out of 10 NAEs) was that somebody else would commercialize the technology.
Openness to entrepreneurship	Before initial venture idea, 9 of 10 NAEs expected careers as professors and researchers.	However, majority also were open to thoughts of entrepreneurship
Idea formation and initiating exploration	For 8 out of 10 NAEs, the idea formed as a result of thinking about future applications.	Dominant perception at time was they were not committed, just curious about one possible option.
	Turned to local entrepreneurial ecosystem for advice on how to explore the options.	Common steps taken to explore a) Spoke with peers seeking sources of advice. b) Enter business plan competition. c) Enroll in VMS.
Representative quotes "I felt it was interesting scientifically and it could be a real contribution. You know, initially it was just seemed like it could be a really valuable contribution and would be a neat thing to do." (Founder6, Epsilon Energy) "I imagined if we can figure this out, we will have nature papers and science papers and we'll be famous scientists and that would be great. I didn't know really anything about business or industry." (Founder2, Beta Bio) "You know this probably sounds silly now and I think at the time we were rather naïve about the whole thing, but when you're a student at MIT the coolest thing on campus is to start a company, right? We were talking about the business plan competition . . . and so we were trying to think of things that we might be able to do and this was the one idea that I had that I thought could be valuable." (Founder6, Epsilon Energy)		

Finding 3: One challenge is making the decision to launch a venture and an entrepreneurial commitment to it.		
Elements	*Results*	*Comments*
Pressure testing the idea	Using entrepreneurial ecosystem, especially business plan competitions, was critical for 8 out of 10 NAEs.	Gained knowledge, understanding and evidence to pressure test their ideas and the marketplace. Confirmed belief that their technology is important with potential for impact. But initial business plan was not viable—did not fit real world or technology maturity.
Best way for the technology to advance	All student NAEs realized that their technology was too embryonic for either the marketplace or licensing to others.	Primary motivation was technological gain, not economic. All concluded that best chance for their technology to advance was to form their own startup to finish the research or it would never be used. Their perception was that it was their responsibility or mission.
Forcing the decision	Most kept options open as long as possible until graduation before committing to launch.	Understood that someone needed to be the driving entrepreneur to lead the startup. Four of the students had top-tier academic job offers they turned down.
Representative quote "Part of it was that I was married to this thing for I guess four years at the time that I formed the basis of the technology, and then another year after that of PhD and trying to get off the ground. And I really felt that this technology had a great chance of success but I didn't think that there was anyone else out there that could foster that. And I felt that if the things that I just said were true and that there was no way to license and there was no way to really continue in academia, then I felt—and that I wanted it to succeed—I sort of felt I was the leader of this venture by default in that if I didn't do anything it would just sit there… I don't think that anyone understood it intimately enough to take the reins and try to de-risk it the way that I could. So for me it wasn't for any other reason than to give it a shot at success and I knew that there was a huge need for it." (Founder8, Delta Pharma)		

Finding 4: Ventures based on university research still on a lab bench start off in a science phase (RBSU) to continue the research, and this phase can last a long time.		
Elements	*Results*	*Comments*
Start as RBSU due to embryonic nature of technology	All participants realized much more development needed to reach commercialization.	All noted the first phase was to do more research to understand the science.
Moving from academic to commercial research	All encountered differences in how academic versus real-world research is done.	Examples: academic research designed to demonstrate for publication; organization is different; leadership to make a team versus independent research.
Takes many resources	All found they required more people and funding to achieve the critical mass needed to progress.	In research phase, most grew to between 12 and 40 people (mostly PhDs and researchers, few business people). Collectively, all NAEs raised over $70M for research phase.
Still a science project	Participants frequently encountered new science questions and fundamental flaws as they progressed.	Moving from lab bench proof of principle to large scale real-world applications needed for commercialization.
RBSU phase takes a long time	NAEs spent the most time in this phase, requiring up to 10 years.	This was far longer than originally anticipated for any of the NAEs.
Representative quotes "And we were working on the technology but it was very slow going. You know, we were trying a lot of different things, very few of them worked or showed any kind of progress and so . . . I don't want to say we were naïve about it, but I would say that the literature on this subject was very misleading in that they had demonstrated protein splices in all of these model systems, and those model systems were really designed specifically to demonstrate protein splicing. So that was a big challenge for us." (Founder6, Epsilon Energy) "The biggest problem was that I didn't realize that time matters and speed matters. And the [grant] money I collected was designed for very low speed." (Founder3, Kappa AI) "I thought that a startup would probably be the necessary vehicle because just looking at the resources I figured it was going to need a 10 to 20 person team for like 3 to 5 years to make it real." (Founder7, Alpha Chips) "And then we realized that there was a fundamental flaw in one of the components of the system and that we could only really have known when we went to large animal studies." (Founder8, Delta Pharma)		

Finding 5: To achieve commercialization, the venture must transition from the research phase into the form of a typical technology-based startup (TBSU).		
Elements	*Results*	*Comments*
Moving from the RBSU to TBSU phase	The NAEs in 6 ventures had reached a point where they had, or tried to, transition from research to building a product or service to commercialize. The NAEs in 4 ventures were successful in this transition. Three NAEs (in 2 ventures) were not successful.	The 4 ventures that did transition experienced changes in several key aspects: a) Views of entrepreneurial opportunities. b) Configuration of the organization and its resources. c) The role and perspectives of the NAE founders. The NAEs for the 2 that failed related very different experiences for the same aspects.
Views of opportunities	<u>Successful:</u> In RBSU, focused on technology target, not customers. Engaged with customers to keep confirming the technology requirements. To transition to TBSU, identified new entrepreneurial opportunities, as if launching new tech venture. <u>Unsuccessful:</u> In RBSU, did not begin with clearly identified technology target derived from viable business opportunities. Little to keep pace with market or identify business opportunities.	 Used initial viable future opportunities from exploration phase to form technological view of required target. Provided performance and other factors required to marketability envelope. Some similarity to initial, but redefined and adapted from deeper understanding and in response to other technological and market changes. Weak exploration phase for both ventures, limited identification of viable markets and no technological target defined. No actions to seriously pursue a product. Became stuck in RBSU. NAEs came to view getting more research grants as the opportunity.
Organizational configuration and resources	<u>Successful:</u> To transition, two key areas saw change: composition of team and funding sources. Both needed active advanced planning and effort. <u>Unsuccessful:</u> No change in these two areas.	 NAEs acted to change team from just researchers to a customer-facing and selling organization with mix of staff. Funding changed from grants and friendly angels to professional institutional investors. Team did not change. No success in changing from grants to equity investors. Little planning or effort.
Role and perspectives of the NAE founders	<u>Successful:</u> Based on planned outcomes, made decision about remaining CEO or finding industry professional. <u>Unsuccessful:</u> NAEs remained as CEO.	 NAEs planning to reach commercialization and then grow did recruit experienced CEO. NAEs expecting to be acquired before product released remained as CEO. Founder3 did recruit a CEO very late, but when virtually out of financial resources.

Finding 6: NAEs may face a number of potentially serious conflicts.		
Elements	*Results*	*Comments*
Conflicts with faculty	NAEs of 3 ventures had serious conflicts arise with their faculty advisors.	Clear policies exist concerning conflicts of interest that prohibit faculty and the students they supervise from being involved in a business together.
	Founder8, while a student, was negotiating equity split of venture with advisor.	NAE described "haggling over equity" with the same person who would decide if he got his PhD. Worked out without becoming major issue.
	Founder2, as student, had major intellectual property and relationship issues with advisor.	NAE reached point where advisor could not talk to him anymore and he could not get a license to the technology of which he was principal inventor.
	Founder1, currently a student, has an advisor involved in the venture idea.	NAE and advisor have good relationship, but as NAE intends to launch before graduating, he will take leave from PhD program.
	The other 7 NAEs graduated before forming a company.	Did not have conflicts with faculty over venture or technology, received necessary licensing.
Representative quotes "He believed I was trying to deceive him, or somehow rob him of his rightful share of equity, by being reluctant to discuss equity while I was his student." (Founder2, Beta Bio) "I would love to stay and get my PhD. . . But there are just so many things that wouldn't work out . . . I need to take a leave . . . I'm not going to finish this last year, I don't think." (Founder1, Gamma Materials)		
Elements	*Results*	*Comments*
Conflicts arising from business plan competitions (BPC).	NAEs of 3 ventures had conflicts develop with team members from the competition.	There are many BPCs in the area and nationally these NAEs may enter. They are increasingly popular.
	Founder8 was sued by an MBA student from another university who was on his BPC. team.	One MBA student sued him, days before he even graduated. Almost took company down before it even started. Years later, court threw it out.
	Founder6 had some potentially significant issues with MBA students on BPC team.	Threats were made by MBA students. NAE was able to resolve relatively satisfactorily.
	Founder1's BPC team was fellow researchers, had problems when deciding to launch.	Made equity split at start of BPC, however not everyone planned to actually join venture. Fixing it created significant stress and difficulties.
Representative quotes "I've heard a lot of stories and ours wasn't really all that bad . . . But I've heard of some total horror stories from competition." (Founder6, Epsilon Energy) "They tell you to make a founder's agreement in the competition. We learned it's not a good idea. . . . You know nothing at that point and . . . all that does is set expectations that should've never been set. We're fixing it, but . . . no matter what, we're going to end up destroying friendships and relationships." (Founder1, Gamma Materials)		

Conclusions

Academic ventures are different. A major finding of this research is that, in contrast to regular high-technology startups that take existing technologies and combine them in novel ways to create new products, ventures based on discoveries originating from a lab bench must first demonstrate that the technology development is complete prior to its marketability. A conclusion drawn was that academic ventures launch as RBSUs with the mission of maturing an embryonic technology before reaching the same point as a regular TBSU. The RBSU phase is distinct, has unique challenges, and differs from the startup process typical high-technology ventures follow. The findings also indicated that academic ventures spend years in this research mode, more time than any other phase. A further and related conclusion is that the challenges NAEs face can be exacerbated if nascent academic ventures are treated as though they are typical high-technology startups. For example, the local entrepreneurial ecosystem may include mechanisms such as business plan competitions and a variety of other support programs for new ventures. However, the unique needs of an NAE in the idea exploration or RBSU phase may require a very different set of advice or actions than a typical new technology startup, and the support programs may not be geared to identify and differentiate between the types of startups. This can lead to incorrect or potentially even damaging assistance as the NAEs attempt to navigate these offerings to obtain the information and learning they need to make good and appropriate decisions concerning their venture.

Perceptions of opportunities. A second key finding of the study was that the decision to launch an academic venture as an RBSU was driven principally by the perception of technological gain, which can be described as the belief that there is real potential for a significant innovation. Nascent academic entrepreneurs believe that the only effective path to advance their embryonic technology to maturity is to form their own startup and direct further development themselves. A conclusion drawn was that exploiting technological opportunities, not entrepreneurial opportunities, is what initially motivates NAEs to create academic ventures. This drive to take early promising results on a lab bench and continue to build a useful technology to the point at which it can be applied practically is one of the distinct characteristics of the RBSU phase. A related conclusion is that identifying a clear and viable entrepreneurial opportunity is necessary to successfully transition to the TBSU phase and to commercialize the technology—posing another key challenge, as NAEs must undergo a shift in their perspectives as the technology develops. A further conclusion is that invention and development of new technologies creates a range of entirely new future entrepreneurial opportunities, many of which may not be clearly visible. The challenge for NAEs is to identify those opportunities their venture can successfully exploit in the near term and learn how best to enable themselves and other entrepreneurs to discover and pursue other opportunities in the future.

Process experienced by NAEs. The findings also indicated that by viewing the venture development process from a technological perspective, NAEs proceed through several distinct phases from idea genesis to reaching the marketplace. Starting from academic

research, NAEs first go through the idea exploration phase, then the RBSU and TBSU phases, before achieving commercialization. Each of these is different in terms of objectives, views of opportunities, structure, resources needed, funding sources, and the role of the NAE. A conclusion drawn is that at each phase the nascent academic venture is different in configuration and focus, and successfully transitioning from one to the next produces significant challenges in recognizing the changes needed at each time and executing them. A further conclusion is that the transition from RBSU to TBSU is the most critical and challenging. The findings also indicated that NAEs who fail to identify a clear entrepreneurial opportunity and do not act to reconfigure the nascent venture may find themselves stuck in the RBSU phase—not a permanently sustainable state—in which they exhaust their available financial resources and are forced to terminate the venture.

Students as NAEs. A significant finding of this research was that the majority of NAEs in this study were students at the time they formed the initial idea and began exploring the possibility of a venture based on their research activities. A conclusion drawn was that students as academic entrepreneurs are an important pathway for transferring technologies from universities to the marketplace. The findings also indicated that the exploration phase is critically important in supplanting NAEs' prior plans for academic or research careers in several ways: (1) by giving them confidence in their abilities as entrepreneurs and business leaders; (2) by providing them with sufficient evidence that their technology could be the basis of a viable business in the future; (3) by helping them gain an understanding of the full requirements, capabilities, and maturity level needed by their technology to address those opportunities; and (4) by enabling them to assess the current state of their technology relative to the requirements. That assessment generally leads to the realization that the technology is embryonic and unlikely to be licensed effectively by anyone else. A conclusion drawn from these findings was that the path from lab bench to launching an academic venture may be more serendipitous than deliberate. This part of their journey is, especially, a process of discovery. A further conclusion is that business plan competitions are extremely important in providing a mechanism and structure for this discovery, though perhaps not entirely in the ways expected. Competitions tend to promote an image that the ventures are ready to go as operating businesses and judge the entrants based on their compelling market story and whether they are attractive to venture investors. An additional conclusion was that as academic and research career options become increasingly limited, greater numbers of students likely will be exploring and potentially launching academic ventures as NAEs.

NAEs experience conflicts. The findings indicated two particular areas where potentially serious conflicts can arise early in the academic venture emergence process. The first was unique to student NAEs and academic ventures, and related to students' conflicts with their faculty advisors. Although institutional policies may prohibit faculty from entering into business relationships with current students, it sometimes happens. A conclusion drawn was that students who form companies and launch ventures before graduation expose themselves to the potential for a serious conflict. Different personal

goals as well as mismatched expectations about roles and ownership interests can lead to particularly difficult situations.

The second area of potential conflict involved team members from business plan competitions, and a conclusion drawn was that NAEs may enter and leave a competition with very different expectations for the path to be taken than their other team members. Although this variance could happen to any team entering the competition, NAEs may be more likely to run into issues because typical technology-based ventures may be able to actually move directly to a typical startup (TBSU), while academic ventures likely will find themselves first spending years to finish creating the science before they can begin using it. A further conclusion was that these differences in expectation are heightened when business school students are part of the team because their goals are more likely to include starting a TBSU right away.

Both of the previous conflict areas led to two additional conclusions. The first conclusion was that there is some dissonance in the messages communicated to NAEs and other stakeholders that increases the possibility of serious conflicts arising from mismatched expectations. For example, students clearly are key targets as participants in business plan competitions. However, some competitions' rules either directly state or imply that a company must exist to receive a prize. Another influence is the message that entrepreneurship is heavily encouraged as an option for students, but some faculty members may not be fully aware of all the policies that may affect students seeking to start new ventures. Second, a growing "hype cycle" promoting entrepreneurship that reaches students leads to the further conclusion that these conflicts are likely to increase in frequency absent some solutions.

Reconceptualization of the Academic Venture Emergence Process

The study supported a reconceptualization of the academic venture emergence process. The results of this study reveal that almost all of the participants followed a technology maturity development process rather than one based on business development of entrepreneurial opportunities, in contrast to prior literature. This technological perspective provides a simpler and cleaner explanation of the process followed by NAEs.

The process begins with the researcher conducting academic research that yields a potentially significant discovery. Next, the idea of a potential venture is explored to develop evidence of possible future opportunities and their technology requirements. Then an academic venture is launched to finish creating technology as an RBSU. When the technology is ready, the venture transitions into a TBSU to exploit a specific initial commercialization opportunity. The possible outcomes include commercialization, licensing, acquisition, intelligent exits, and forced terminations. Other than commercialization, any of the other outcomes are possible at any phase.

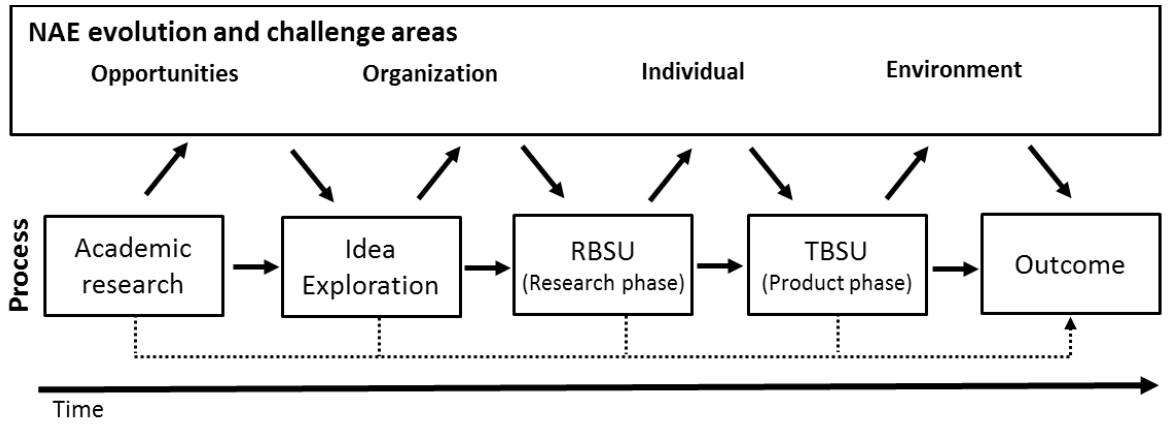

Figure 2. Academic venture emergence process framework.

Table 2. Academic venture and NAE characteristics at each phase

	Phases			
Characteristics	Academic research	Idea exploration	RBSU	TBSU
Technology maturity	Create knowledge	Too embryonic for use or licensing	Finish creating the technology	Begin using the technology
Entrepreneurial opportunities	Scientific discoveries create possibility of future opportunities	Evidence for belief some opportunities are possible and valuable	Monitor for changes in possible opportunities	Identify a specific initial commercialization opportunity
Technological opportunities	Discover, publish, patent	Understand technology requirements to satisfy entrepreneurial opportunity	Continue research to satisfy requirements of entrepreneurial opportunity	Adapt and embody technology in initial commercialization opportunity
Organization	Academic lab	Ad hoc/ temporary project	R&D lab	Product company
People	Academics	Part-time, ad hoc/ ecosystem	Mostly scientists and researchers	Mix of researchers and business / customer-facing people
Funding	Sponsored research	Personal, friends and family	Grants, investment from nonstrangers	Investment from strangers
NAE role	Researcher	Researcher and project leader	R&D Leader	Decide on role, business or technical leader

Extending the framework with more detail, Table 2 provides a description of the characteristics of the academic venture and the NAE at each phase until reaching an outcome. This table may be helpful in two ways for academic entrepreneurs and those advising them. First, it provides assistance in performing an assessment to identify the current phase of the NAE and his or her venture. Second, it helps identify the key concerns they should focus on within each phase and provides a view of the changes necessary to prepare to transition to the next phase.

Limitations of the Study. Some caution is offered as this study was subject to a number of limitations, some of which are common to qualitative research in general and others of which are a result of the study design. These include: (a) the study is based on a small sample that was purposefully chosen; (b) qualitative studies are subject to researcher bias; (c) the findings may not be generalizable to repeat or frequent academic entrepreneurs; and (d) the findings may not be generalizable to other settings beyond MIT. Consideration was given to methods of identifying these limitations and minimizing their impact. These are discussed in the dissertation. It should also be noted that the study is strengthened by utilizing multiple sources of data; in particular, the use of deep archival data that includes contemporaneously recorded observations of the NAEs over the lifetime of their ventures.

Implications for Management Theory

The results of this study add to management knowledge in several areas within the broader streams of literature in the fields of innovation and entrepreneurship. In particular, this study of NAEs is positioned at the intersection of USOs and nascent entrepreneurship, adding to the literature in both. This study also adds to the literature concerning entrepreneurial opportunities within entrepreneurship and to the stream covering entrepreneurial universities.

This research found that NAEs launch in a specific and distinct organizational phase unique to academic ventures called the RBSU, which is focused on continuing the research needed to develop the technology to the point where it can be used in products. At that point, the academic venture must transition to the TBSU phase which is the place where typical high-technology startups launch. Prior studies of the emergence process of USOs do not differentiate between these two phases and present a single stage which is driven by developing previously identified business opportunities. For example, Vohora, Wright, and Lockett (2004) term it the “re-orientation phase.” Others call it “stage three” (Ndonzuau et al., 2002), “post-startup” (Rasmussen, 2011), or simply “startup” (Clarysse and Moray, 2004). While these studies recognize that academic ventures experience additional research and development, the research largely is treated as an appendage, with the focus placed on entrepreneurial opportunities. This study adds to the literature on university spinoffs and academic entrepreneurship by contributing a reconceptualized process model for NAEs, as well as propositions that the nature, purpose, and challenges of emerging academic ventures are different at each phase. By framing the phases by the maturity level of the

technology instead of by business opportunities, the new model reflects a simpler process with fewer stages and eliminates many of the iterations across stages found in the previous studies.

The study also adds new knowledge about the duration of the emergence process phases, including that the RBSU phase is the longest. The NAEs in this study spent an average of over nine years from initial exploration of the venture idea to reaching an outcome. Of that time, more than 68 percent was spent in the RBSU phase. This extends the literature on university spinoffs and also on innovation, as prior research has shown that initial commercialization takes a long time (e.g. Golder et al., 2009), while studies on the academic venture process are relatively silent on the duration of each phase (e.g. Rasmussen et al., 2011; Vohora et al., 2004).

Furthermore, the study adds insight on funding sources, particularly during the long RBSU phase. The NAEs collectively raised about $120 million in financing through grants and equity investment. Of this, over $70 million was raised before the TBSU phase and over 80 percent came from various grants, such as the Small Business Innovation Research (SBIR) program. This adds to the literature on public funding of innovation and on a recognized funding gap between scientific invention and commercialization often referred to as the “valley of death” (Barr et al., 2009).

Additionally, this work adds to research on entrepreneurial opportunities, a central issue in the entrepreneurship literature, in several ways. First, there is considerable debate about whether opportunities are created, a Schumpeterian view, or discovered, a Kirznerian perspective. In all but one case in this study, the technology was the result of a discovery through research by a PhD student. The study demonstrates that a range of potential entrepreneurial opportunities sprang into existence at the moment the new technology was invented. This adds to the literature by providing insights into the genesis of technology-based opportunities. Additionally, the findings provide additional support to Stokes’s (1997) proposition that scientists can be driven by both the quest for fundamental knowledge and the pursuit of future practical applications of that knowledge.

Next, the study also found that the NAEs in seven out of eight academic ventures primarily were motivated by scientific goals and technological opportunities in their decision to launch startups based on their research. They all concluded that the technology could not yet be effectively used or licensed by others, and that unless they started a venture to continue to advance the research, it would never see the light of day. They all believed they were the only ones that could do it—that it was their responsibility. They also described a desire to see how far the science could evolve. At that point in the process, the participants described economic gain as further down the list of drivers: not completely out of mind, but not a key determinant. This is in contrast to the conventional view that individuals become entrepreneurs to exploit entrepreneurial opportunities for economic gain (e.g. Cassar, 2007; Shane, 2004; Schumpeter, 1934). The study did find that NAEs later must shift to adopt this view and target specific market opportunities to successfully transition to the TBSU phase and

reach commercialization. However, the initial driver of scientific curiosity was not extinguished, as reflected in a comment by Founder7 made after he had led his venture to an extremely successful outcome: “Someday, somebody will have to run this place who just wants to, like, make some money, and I’ll probably just keep being the curious guy.” Hayter (2011) and Lam (2011) found that scientists considering startups may be driven by varied goals, with personal financial rewards as a minor and secondary consideration. This study extends those findings by illuminating how the motivations of NAEs may evolve and how they arrive at their decisions.

This research also found that nine of the ten NAEs were students when they began their venture activities suggesting that students are a significant vector for academic venture creation. This is in contrast to much prior literature that indicated that faculty are the dominant actors creating academic ventures. Although there is strong evidence for the entrepreneurial involvement of faculty in creating many ventures, being entrepreneurial is not the same as being the driving entrepreneur responsible each day for moving the academic venture forward. This requires a full-time commitment. The intention here is not to diminish the importance of faculty entrepreneurship, but rather to uncover and explore the experiences and challenges faced by certain academics that do act on their ideas and intentions and become committed to driving the idea forward. By adding two words to the definition of an NAE—full time—the study was able to look at an important population that had received little attention. These findings provided support for recent studies that had questioned the role of faculty in academic ventures, such as those by Boh et al. (2012) and Astebro et al. (2012), adding to the literature on USOs. The data also revealed that serious conflicts between student NAEs and faculty can arise, as well as among team members. These issues and the surrounding circumstances have received limited research, and this study adds to the conversation concerning entrepreneurial universities and academic capitalism.

Practical Implications

This study indicated that NAEs face a different process and additional challenges in their ventures compared to regular TBSUs. The researcher offers the following practical insights drawn from a better understanding of the major issues, questions, and inflection points these inventors encountered in their journeys: (a) that prospective and current academic entrepreneurs can make more informed decisions leading to more effective and efficient venture outcomes, and (b) that policymakers and institutions may be able to structure resources more appropriately to support any unique needs of NAEs.

Practical implications for management. Academics who either are contemplating a startup or currently engaged in an emerging venture based on their university research may achieve superior outcomes from a better understanding of the process and the sequence of key challenges. First, they may be able to calibrate their expectations about the process and their efforts better before starting. Second, this knowledge may help them be both more effective and efficient in the use of their available resources. Third, they will be more likely to reach an informed and desired outcome—even if it is

abandoning the effort—as opposed to continuing until the venture fails due to running out of resources. NAEs should consider the following:

1. Recognize that science-based ventures are different from regular high-tech startups and understand the phases, as well as their current status in the sequence. NAEs should concentrate their time, energy, and resources on the key objectives within each phase in order to extend their runway as long as possible. For example, to find funding, efforts should be focused on the most likely sources within that phase.
2. At the outset, NAEs should use the available entrepreneurial ecosystem, especially resources such as business plan competitions and mentoring, to fully explore the venture idea and learn about the entrepreneurial process, become familiar with business thinking, and gather evidence to validate the likely existence of future entrepreneurial opportunities.
3. More importantly, NAEs should use that information to understand requirements relative to their technology regarding performance, maturity, and capabilities needed to satisfy those potential applications. This will enable them to assess the gap between the technology's current state and the target to define the additional research work needed.
4. NAEs should understand that when they launch, they first will start off in the RBSU phase, during which they will need to continue to do the research in order to advance the technology to those targets. They should expect and plan that the RBSU phase likely will span a number of years and probably take longer than expected at the outset.
5. During the RBSU phase, the NAEs should get out of their labs and offices and engage with the market and potential customers. Not in a sales mode, as they won't have a product yet, but to remain connected to the technology targets and monitor other changes affecting customers. They should recognize that the opportunities identified during idea exploration likely will not be the ones eventually exploited, as the market and other technologies will have evolved. However, the technological targets will lead them to emerging new opportunities that they can exploit.
6. Recognize that the transition from research as an RBSU to becoming a product company as a TBSU will be a major challenge, as this shift requires both significant reconfiguration of the venture's resources and organizational change in multiple respects. This will require careful advance planning and effort along with strong leadership, since major tensions can be expected.
7. NAEs should make sure to carefully discuss and agree on expectations with any prospective team members, including those participating in a business plan competition. NAEs who are students should understand the potential unique conflicts that may arise and proactively find ways to prevent them. One way is to continue to work toward a venture but hold off on creating a company and launching the startup until after graduation.

Practical implications for policymakers and institutions. Universities are increasingly facing societal demands to become more entrepreneurial and serve as vital engines of economic progress. This trend also has been driving an increase in scholarly research concerning the roles and contributions universities play at many levels. Early research tended to focus on institutional and policy-level activities at the macro level. However, there is increasing focus at the micro level, such as the role of individuals like the academic entrepreneur, to understand how broader policies impact actual firms and individuals. The findings from this research fit this trend in a number of key respects: First, by illuminating how important early stage support mechanisms are in enabling the NAE to acquire the learning, confidence, and market evidence needed to make an informed commitment to launching an academic venture. Second, by explaining how NAEs can use early market information to identify the additional research needed to meet product requirements. Third, by demonstrating how critical public funding is to advance these technologies in the early stages. Fourth, by revealing that students are a significant pathway for new science-based venture creation. Finally, by forewarning that NAEs and other stakeholders may encounter conflicts.

University faculty and leadership, including directors of support programs and activities that serve NAEs, should consider the following to improve technology transfer through entrepreneurship and reduce potential conflicts:

1. Trends indicate a continuing increase in science-based academic ventures. Furthermore, environmental forces such as declining academic career options, along with an oversupply of PhD graduates, likely will mean greater numbers of students leading these startups. Universities and other officials should prepare by reviewing and evaluating objectives, policies, and procedures specifically related to student entrepreneurship to ensure desired outcomes are supported.
2. Recognize that science-based ventures are different than regular high-tech startups. They do not start with the same issues and challenges, and therefore the guidance that NAEs need is different. Policies and support mechanisms should not conflate the two, but rather should be designed to identify NAEs and deliver assistance targeted to their requirements. Programs should evaluate whether additional or different resources are needed to support NAEs.
3. NAEs obtain information and guidance from multiple sources, both formal and informal. Some of these may be external to the university. The guidance may not always be consistent. The development of a clear set of unified policies and principles communicated to guide all parties including students, faculty, administrators, and leadership would help increase clarity and transparency. This includes helping NAEs understand all intellectual property issues and the licensing process to properly align their expectations. One mechanism to consider is a regularly scheduled seminar open to all potential NAEs wherein these topics are presented and discussed.
4. The findings suggest that the idea exploration process is critical in providing the learning and evidence needed for students to alter their career plans and commit to creating new ventures. Universities should identify ways for NAEs to participate in events and activities allowing them to fully explore and develop

their ideas without having to form a company or make ownership, equity splitting, and role decisions before they are ready or graduate. A related recommendation is to investigate potential methods for including ways to obtain options, even if nonexclusive, to licenses for their technology during this period. Reducing the barriers for NAEs to investigate their ideas likely would lead to increased innovation based on university technologies.

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