Transforming the Practices and Rationale for Educational Programs to Aid Academic Researchers in Translating Research into Innovations and Ventures

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Abstract

The translation of basic scientific research to practical and deployable innovations that benefit people and the planet is as old as human history itself. From the discovery of the uses of fire to the transformative basic research that is the basis for space exploration, humans have translated scientific research into technological innovations that have advanced society. The National Collegiate Inventors and Innovators Alliance (NCIIA), a 501c3 founded by The Lemelson Foundation in 1996, develops and funds experiential learning and conducts research in STEM innovation, invention and entrepreneurship to create viable and socially beneficial businesses. This paper provides background information and describes NCIIA's approach to help address the innovation challenge in the U.S., which is to provide training, education and financial support that fits with both the venture's needs and the innovator's personal and professional aspirations.

I. The innovation challenge

Overview

One of our hopes is that… there will be full employment, and that the production of goods and services will serve to raise our standard of living… Surely we will not get there by standing still, merely by making the same things we made before and selling them at the same or higher prices. We will not get ahead in international trade unless we offer new and more attractive and cheaper products… There must be a stream of new scientific knowledge to turn the wheels of private and public enterprise. -- Vannevar Bush, 1945 [1]

The translation of basic scientific research to practical and deployable innovations that benefit people and the planet is as old as human history itself. From the discovery of the uses of fire to the transformative basic research that is the basis for space exploration, humans have translated scientific research into technological innovations that have advanced society.

To address the complex challenges faced by our planet and its inhabitants, many studies over the last fifteen years have pointed to the need for those formally trained in the science, technology, engineering and math (STEM) disciplines to be more broadly and flexibly educated to meet the demands of the 21st century. It has been suggested that this broader education consist not only of greater depth in a given STEM discipline [1] but also include additional interdisciplinary scientific skills [1-3] the ability to participate in the translation of research into innovations that

become products and processes that address societal problems [4], and the desire and skill to work collaboratively in developing and implementing those innovations [5].

Engineering education has traditionally been focused on preparing students to effectively apply scientific principles in order to design and develop useful products [6],[7]. While this remains the essence of engineering training, there is an urgent need to equip engineers with better translational skills and the ability to see opportunity in and translate scientific research into practical applications. This is even more important in the increasingly interdisciplinary environment of science and engineering. The once clear demarcation between scientist and engineer has become less sharp. Biologists engineer life forms and engineers increasingly pursue research that is at the boundary of interdisciplinary engineering knowledge, but engineers often remain key mediators of discovery to useful and commercially viable applications [8],[9].

The U.S. is consistently recognized as the global leader in research, but has recently struggled with the challenge of realizing its potential to successfully translate technological and scientific knowledge into commercial value. In this paper we develop an approach and provide background information to help address this critical challenge. Specifically, we suggest that:

1. academic researchers must be equipped with skills and tools to help them participate in translating their scientific and engineering knowledge into commercial innovations. Further, this skills development should optimally happen as an integrated part of the educational process for engineers and scientists at the undergraduate, graduate and even post-doctoral levels rather than after academic preparation has been completed;
2. it is not a simple "either/or" proposition requiring university researchers either to become entrepreneurs or stay in the lab and focus primarily on basic research. Intermediary roles of innovator are also present and as such
3. it is essential that those who support the research translation process understand, respect and address the *personal* change process that occurs as university-based engineers and scientists begin to take part in research translation activities.

Components

First, in order to understand how to improve research translation to commercial innovations, it is necessary to identify the core components of the research translation process that have been cited as key reasons for the U.S. falling behind in the commercialization of innovations. The four key components that any educational process must then address are:

1. Upgrading basic and advanced engineering and scientific skills, inventions and innovations;
2. Developing new skills that can enable engineers and scientists to translate their technical knowledge into real world innovations;
3. Defining different ways university-based engineers and scientists can engage with the process, including clarifying whether their professional goals and personal characteristics match those needed to take an idea to commercialization; and

4. Encouraging academic institutions and the fields of engineering and science to formally support, reward and recognize commercial and economic outcomes as much as scientific uniqueness and discovery.

Yet, successfully addressing each of these components individually is only one element in the equation. The key to success is training and skills development that synthesizes these components into a pedagogic and sequential whole that can be used as the basis for enhancing personal worth and creating commercial value.

This value is created by training, educating and developing a next generation of technology innovators who can and want to develop solutions to technological challenges by translating their technology into successful commercial reality in order to create the "stream of new scientific knowledge to turn the wheels of private and public enterprise" envisioned by Vannevar Bush in 1945 [1]. But it does not require changing university-based engineers and scientists into entrepreneurs. It does require a step-by-step approach to support students, post-docs and faculty in developing both personal value and commercial value. The research basis of the work described in this paper draws upon literature in the areas of individual change and career development, innovation studies, and NCIIA research and practice in entrepreneurship education and funding. These bodies of knowledge serve as a foundation for supporting professional development pathways for innovators that are in alignment with the skills they require at the time they require them for innovation development (specific references are cited in the body of the text where appropriate).

The National Collegiate Inventors and Innovators Alliance (NCIIA) has developed such a sequential set of offerings encompassing both grants and training that synthesizes the components of successful translation of research to commercialization. This is accomplished with offerings that are aligned both with skills and needs of the university engineer or scientist, on one hand, and the stage of readiness for commercialization of the given technical or scientific innovation on the other.

Science and technology

While it can be argued that technological innovation has always been a hallmark of the U.S., this has been especially apparent since WWII. Since that time, the U.S. has become the premier destination for advanced scientific and engineering education and the leader for much of the world. Yet it is now argued that the U.S. has lost ground relative to other parts of the world. The World Economic Forum's *Global Competitiveness Report 2006–2007*, shows the U.S. fell from first place to sixth. The U.S. ranking was based on the World Economic Forum's analysis of the country's weaker performance in all the diverse steps of the innovation process. At the same time, other nations' performance, such as Switzerland, Finland, and Sweden were boosted because of their top-notch educational systems and focus on technology [10].

Examples of this perceived decline in technology innovation have been documented in many areas:

- K-12 education: The data on U.S. global standing is well known and, with the support of other initiatives at the local, state and federal levels, eventually led to the Governor's Association's report: "Building a Science, Technology, Engineering and Math Agenda" [11].
- Healthcare: Recently, the *The Hill* [12] reported that "Government and business officials called for greater investment in medical research as a way to keep the U.S. competitive, create jobs, and even lower healthcare costs." Notably, the "officials made the case for greater medical innovation which argues that the United States is losing its competitive edge because of deficiencies in science education, public investment and regulatory processes."
- Research funding: The U.S. has seen a sharp decline in funding for research, at both the basic and industrial levels, prompting the National Research Council to develop and release the report "Research and Development: Essential Foundation for U.S. Competitiveness in a Global Economy" [13], which underscores the need for competitive improvements not only in R&D funding but also in the value-added outcomes of that R&D.

Translation of innovation into commercial solutions

An estimated 90% of high tech translation ventures fail [14]. The high prospect of failure can be discouraging for scientists, their universities and also for funders. This is despite the fact that (a) many academic programs in engineering and science have identified the need to develop commercial innovations as the basis for institutional and state economic growth; (b) the infrastructure to support innovation and commercialization at the local, regional, state and national levels has grown substantially; and (c) there are a plethora of tools and techniques to aid in determining the value of a business idea (one example: "Take This Test To See If You Actually Have A Million Dollar Idea" posted on the Innovation Daily website).

Studies have examined the reasons for high-tech start-up or tech transfer success and failure. These studies [15-18] have shown that while there is no exact formula for success, some practices are strongly associated with failure—and it can be argued that they are all dependent for success to a greater or lesser extent on the skill sets of the innovator and the team. These include:

- Focusing more on the technology and less on market requirements,
- Relying on extreme optimism and a distant, unknown use,
- Underestimating the hurdles of translation, implementation and collaboration (believing the "hard work" is in the conception rather than the execution);
- Building ineffective strategic and translation plans and failing to revise the plan based on accurate and evolving market input;
- Underestimating the competitive technologies or global issues; and
- Not having an engaged, effective and collaborative team to affect the research to innovation to commercialization process.

The value such skill sets create—for individuals, nations and the planet—is undeniable. In the Kauffman Foundation report, "Where Will the Jobs Come From?" authors Litan and Stangler analyze census data to show that two-thirds of new job growth comes from firms that are between one and five years old. They state that, "New and young companies and the entrepreneurs that create them are the engines of job creation and eventual economic recovery" [19]. Further studies [20] also show that startups retain, on average, 80% of their initial total

employment to age five, and while startups initially hire fewer people during a recession, they catch back up to the same levels of employment at age five. So it is little wonder that universities, states and nations look to new innovation and the businesses they create for growth and sustainability.

Personal change and acquiring the skills to translate research into commercial innovations

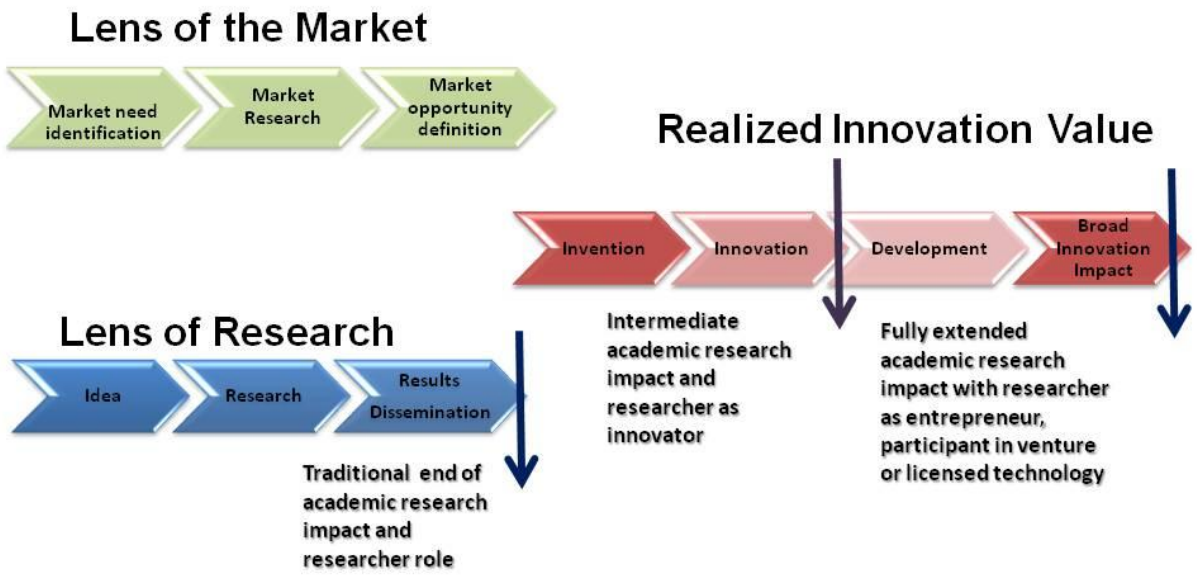


Figure 1: Fully Extended Academic Research to Broad Impact (Market) Value Chain

Since the publication of *Rising Above the Gathering Storm* announced, "In a world where advanced knowledge is widespread and low-cost labor is readily available, U.S. advantages in the marketplace and in science and technology have begun to erode" [3], government agencies at all levels have endeavored to develop legislation and fund programs to help our current and next-generation engineers and scientists develop the skills to conduct scientific research as well as to translate that research into innovations to help people and the planet.

To provide incentive to universities and their researchers to embrace this wider role, Bayh-Dole legislation was passed in the U.S. to lead the way for universities to become commercializers of technology and commercial technology brokers. The success of this concept relies heavily upon the traditional role of the academic researcher evolving into that of either an innovator, one who is actively engaged in translational endeavors, or a full-fledged entrepreneur, one who develops and commercializes innovations that can solve challenges of human and environmental

sustainability [21-26]. The success of this concept also involves the university embracing an extended mission beyond education and research (Figure 1).

Yet, accomplishing the transformation of university researchers into technology entrepreneurs has not been without controversy, nor has it been easy [27],[28]. Research on the behaviors and attitudes of academic researchers toward embracing a role that includes commercialization and embracing a role for themselves as the "entrepreneurs" who will commercialize such research has indicated that unless a structural and cultural change takes place in academe to reward and support this expanded view (Figure 1), the incentive for academicians (most of whom were trained and promoted in a system that rewarded a more traditional view of measuring accomplishments, e.g., publications, citations) to do so is not clearly evident [29]. Research by NCIIA [30] shows this bimodal idea of researcher or entrepreneur to be too simplistic. Indeed a more complex set of roles appears to have emerged, with a more nuanced role of innovator being defined by researchers for themselves in this evolving landscape.

In addition to a perceived lack of support for an expanded role for academic researchers comes the question of a definition of innovation that is aligned with their value system. Further research by NCIIA [30] indicates that while there is openness to implicit inclusion of a commercial or societal value in the definition of innovation for many of the researchers participating in the research, few explicitly mention commercialization as a key part of innovation, while a larger percentage cites qualities of scientific uniqueness or discovery as innovative. This lack of consensus in definition can also lead to inconsistent actions and behavior toward commercial endeavors from academic researchers. This work shows the need for ensuring that any training or intervention aimed at assisting academic researchers in technology commercialization respects their definition for and value of their role.

Institutional support

As indicated in Figure 1, the role of the university and university researchers is impacted by the explicit and implicit behavior of university leadership and the perceived role of researchers. It is just this tension of defining the role of higher education and determining how this definition differs by department or discipline that is cited as a key challenge for institutional leadership [31].

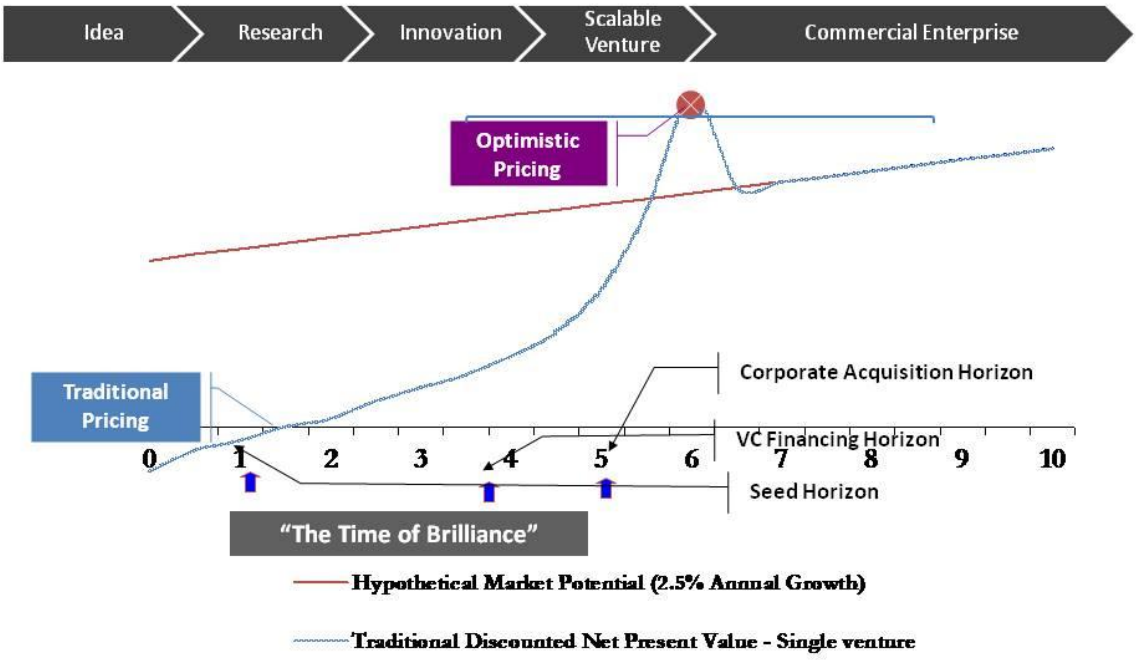
A 1996 work by Lee [32] concluded that U.S. academics in the 1990s were more favorably disposed than in the 1980s toward closer university-industry collaboration, but were concerned about the impact of close university-industry cooperation, which was viewed as likely to interfere with academic freedom—the freedom to pursue long-term, disinterested, fundamental research. The findings indicated the challenge to creating the right balance between these two competing concerns. The NSF report "Impact of Transformative Interdisciplinary Research and Graduate Education on Academic Institutions" cited the need for institutional support of faculty, new mechanisms for promotion and tenure collaborations, and better ways of organizing the institution to take advantage of funding. As one participant stated, "Future STEM graduates must be able to explain why science matters to society and how basic science and technology relate to each other" [29].

II. Creating value

Transforming the "Valley of Death" into the "Time of Brilliance"—mitigating risk and maximizing value for innovators, investors, stakeholders and the country

It is in this dynamic and unsettled climate for translation of research into innovation and the changing rankings of countries in this regard, that university startups and would-be innovators and entrepreneurs must exist and thrive. Startup teams launching new ventures face formidable challenges. One of the most common of these challenges has been given a name: the Valley of Death, that exhilarating stretch of time for company and personal value creation between innovation/proof of concept and the beginning of production and significant sales. It is the time when large infusions of energy, luck, optimism, teamwork, creativity—and, often times, cash—are needed to survive. Ventures that survive this arid landscape pass through to a successful, greener pasture of revenue growth. It is a formidable time, made even more so in today's financial climate, where recent data from Dow Jones shows venture capital raises at a seven-year low, citing as the reason that investors are "still haunted by the industry's lackluster returns over

Figure 2:
Stage Dependent Value of Research to Commercial Enterprise – years versus arbitrary $



the last decade" [33].

Figure 2 illustrates an example scenario for a given research to venture [34] enterprise. In this example, the Traditional Pricing scenario shows the desired hockey-stick growth in value performance. It is during the "Time of Brilliance" that the most value—and risk—are incurred.

The objective is to gain this value and exit with as close to optimistic pricing as possible. The comparison curve is a standard value appreciation curve, assuming 2.5% annual growth for the industry into which this venture becomes integrated. Despite the challenges, we contend this is not the Valley of Death, but the Time of Brilliance. It is the time when the greatest rate of creativity to value conversion occurs—both for the researchers and the enterprise—but only if navigated carefully and strategically, taking into account both the needs of the researchers and the enterprise. Transforming the Valley of Death to the Time of Brilliance requires addressing each of the components outlined earlier that can hamper economic and cultural success. The Time of Brilliance requires:

Researchers who are:

1. Excellent in their disciplines while being capable and desirous of working with other disciplines to solve a problem with both the tool of basic and interdisciplinary research and the tool of market research.
2. Well-educated, informed and conversant in the process of research translation to commercialization, a process that requires both market and research skills and one that respects opportunities for basic research to be tuned, refined or influenced by market requirements.
3. Cognizant of the varying yet important roles they can play in the process, ranging from researcher to innovator to entrepreneur.
4. Supported by their institutions (and faculty advisors if they are students or post-docs) to embrace the broader role the university can play beyond basic research and dissemination (Figure 1).

Support ecosystems to:

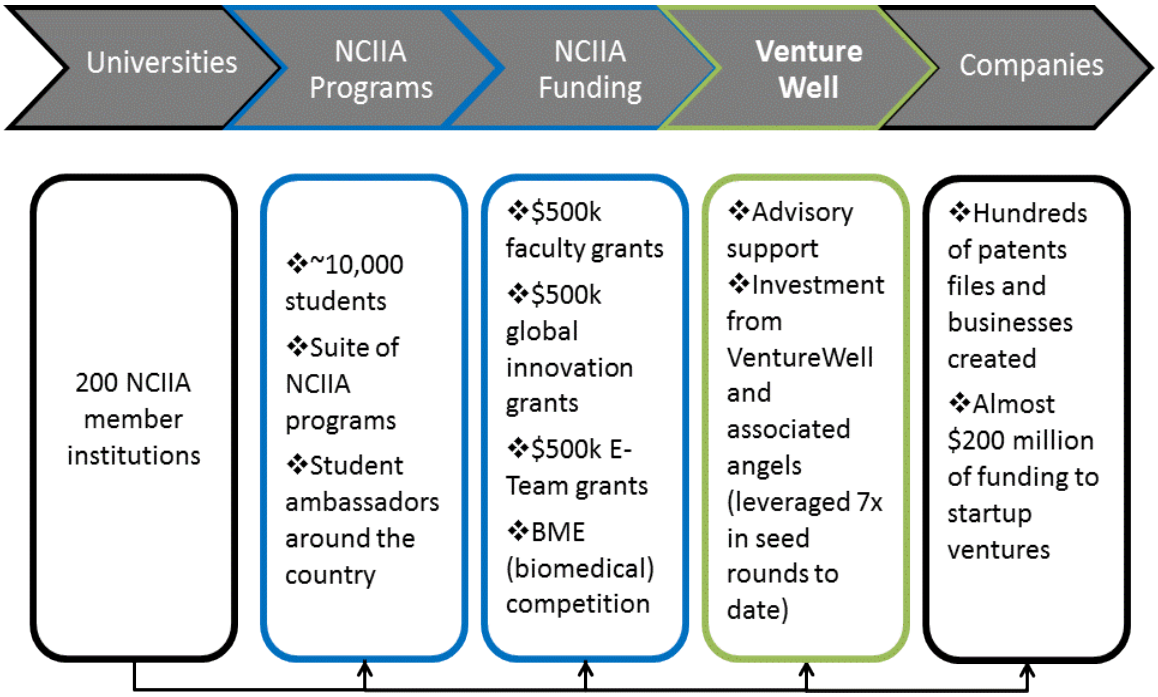
1. Provide logical and sequential training and advising timed to and aligned with the needs of both the researcher/innovator/entrepreneur and maturity and stage of research to innovation to venture progression.
2. Ensure students, post-docs and faculty are rewarded and recognized for engaging in an extended view of the value of academic research (Figure 1).
3. Provide a network of expert and sector/market structured advice to navigate all aspects of the business.
4. Align financing timed to business growth requirements.

NCIIA and its VentureWell initiative—vision and offerings to create value, address the innovation challenges and create the Time of Brilliance

Background on NCIIA, engineering education and offerings

NCIIA is a 501c3, founded by The Lemelson Foundation in 1996. Its mission is to develop and fund experiential learning and conduct research in STEM innovation, invention and entrepreneurship with the aim of creating viable and socially beneficial businesses. With over 200 universities as members, NCIIA has provided millions of dollars in grant support primarily to engineering and business faculty to develop experiential curricula in innovation and

entrepreneurship; it has provided millions of dollars in grant funding through faculty advisors to support teams of students in venture development, with a substantial amount of funding directed to undergraduate engineering and in particular biomedical engineering. In addition to funding, NCIIA has provided educational programs on the basics of entrepreneurship (one-day Invention to Venture workshops, and four-day Advanced Invention to Venture workshops for nascent ventures). This has resulted in close to 100 companies that have raised over $180 million in funding. Figure 3 provides an overview of the NCIIA ecosystem, including the new VentureWell initiative.



However, in looking at the challenges to and requirements from university research for economic development coupled with the results from its own research in entrepreneurship and that of others, NCIIA has defined the need for an expanded programmatic vision to help ensure a greater success rate for university research translation to commercial innovations and the Time of Brilliance.

University STEM entrepreneurs

Historically, the traditional process for developing value or the value chain for educational and grant offerings in entrepreneurship education has been focused on providing the skills required for the translation of ideas into research into innovations and then, with support, into scalable ventures and potentially commercial enterprises (Figure 4)—a traditional venture development value chain. This primary focus on training for translating the engineering or science into a venture takes into account the skills of the researcher in the innovation process, but not necessarily the role the researcher aspired to in the process or where they were personally in embracing a changed role from basic researcher to innovator or even entrepreneur. While this often works with undergraduates, data have shown that this is not the case with faculty, post-doctoral or graduate researchers in an academic setting.

Figure 4: Traditional venture development process

With the requirement for university researchers to become key leaders in the venture development process coupled with an evolving understanding of their requirements for personal success (especially for faculty, graduate students and post docs), offerings in venture development training must be designed to take into account a personal development and value building process that is occurring in concert with venture development. Based on personal change processes well known in the organizational change space [35], Figure 5 shows an example personal value building chain in alignment with the venture development value chain.

Figure 5: Personal development process

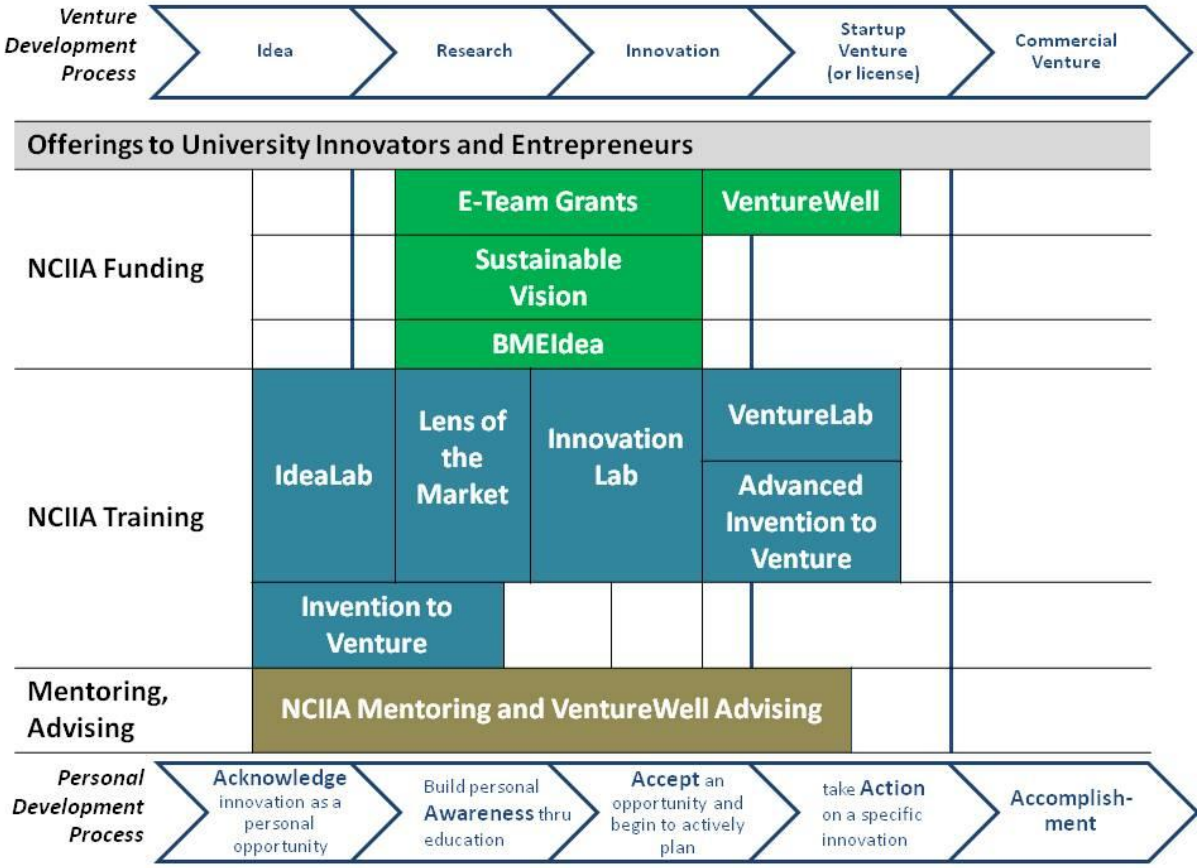
Our contention is that providing training and support that builds successful technology ventures must respect the place in the personal development process of the engineering and scientific researchers and innovators involved and begin from where they are starting.

With this as a starting point, NCIIA has developed and implemented an expanded set of training and educational offerings designed for researchers at different points in the continuum of both their personal development and the development of their research into commercial ventures.

1. Lens of the Market [36] is aimed at graduate students, post-doctoral researchers and faculty who have been conducting research and would like to determine the applicability of that work or determine ways to realign that work based on defined market need.
2. InnovationLab is also aimed at graduate and post-doctoral researchers and faculty who have developed what they believe to be marketable technologies that may be platform technologies and therefore applicable to many markets. InnovationLab uses proven industrial market assessment and prioritization processes in conjunction with structured guidance and advice from those with commercial expertise in the specific field to aid researchers in developing prioritized market paths and focusing technical developments to that market path.
3. VentureWell, which provides two offerings to innovators whose work is approaching investment stage: an Advising Offering and an Investment Offering.

Figure 6 shows the complete suite of NCIIA educational [37] and grant [38] offerings for university entrepreneurs, designed to provide step-by-step training, guidance and advice to would-be university innovators and entrepreneurs that endeavors to respect both their desire to commercialize their research and the personal role they wish, as an individual, to play in the process.

Figure 6: NCIIA Offerings for University innovators and Entrepreneurs



Summary

The U.S. is consistently recognized as the global leader in research, but has recently struggled with the challenge of realizing its potential to successfully translate technological and scientific knowledge into commercial value. In this paper we have developed an approach and provided background information to help address this critical U.S. challenge.

We suggest that the so-called Valley of Death can be transformed into a Time of Brilliance where value is built both in technology commercialization and for the academic researchers involved. This transformation will take place when all components of the challenge to the translation of research into commercial innovations are addressed in a holistic manner that supplies training, education and financial support to the innovators at a time and in a way that

aligns with both the needs of the venture and the needs and stages in the personal development processes of the researcher.

Based on findings from research in the literature and its own primary research, NCIIA has developed a sequential set of offerings (Figure 6) aimed at accomplishing the outcomes envisioned by Vannevar Bush.

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[37] For information on NCIIA offerings please see http://nciia.org/ventures, http://nciia.org/node/871 and http://www.venturewell.org.

[38] Please see http://nciia.org/grants.