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Bridging the Valley of Death: Lessons Learned From 14 Years of Commercialization of Technology Education

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We argue for the increasing importance of providing graduate students with skills in technology entrepreneurship and the commercialization of technology. We describe the lessons we have learned from 14 years of developing commercialization of technology pedagogy and adapting it for use on four continents and within numerous corporations. We demonstrate that the theory-driven approach that we use to shape the curriculum improves our ability to learn from our mistakes and to structure small experiments to improve the curriculum and pedagogy.

Interest in the commercialization of technology and technology entrepreneurship has increased significantly in the past decade. In many increasingly knowledge-based economies, effective managers will need better training in dealing with technologists and in creating business growth and advantage through commercializing technology. Innovative new technology ventures will require entrepreneurs who are skilled at collaborating effectively with scientists and engineers as well as with financial managers and venture capitalists. Technical education faces new demands as well. For example, the National Academy of Sciences (COSEPUP, 1995) issued a statement calling for rethinking graduate education for scientists and engineers to include the skills to promote the commercialization of technologies that they create. More recently, the European Commission (2008) concluded that "the teaching of entrepreneurship is *not yet sufficiently integrated* in higher education institutions' curricula" (European Commission, 2008: 7, *emphasis in original*) and that far too little of existing entrepreneurship education efforts target students engaged in technical and scientific studies.

As interest in commercialization of technology (COT) has increased, so has academic research interest in this area. The *Journal of Product Innovation Management* (2008) recently published a two-issue special topic volume on technology commercialization and entrepreneurship. Commensurate with this increased academic interest, there has been an increase in the number of university education programs that provide instruction in COT. These programs provide education and experience in using emerging technologies to start a new business organization (*new venture focus*) or to create entities within existing firms (*corporate venture focus*).

There are multiple institutional reasons for universities to exhibit increased interest in new business start-ups based on technologies created at the host university (Jelenek & Markham, 2007). Markham et al. (2002) describe the increasingly

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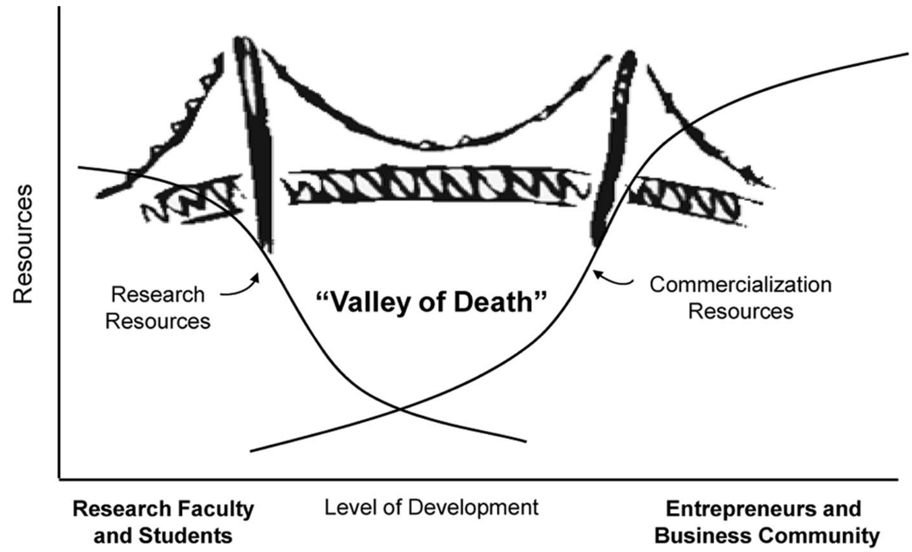

FIGURE 1
The Valley of Death Bridging the Gap Between Research and Commercial Application

vital role of university research in providing new technology platforms and products. Kirby (2005) discusses the development of a "dual role" model for universities to contribute to society by educating students but also by creating research that can be commercialized into new products and services. Some universities are attracted to COT because of the potential for gain due to royalty or equity positions. Breznitz, O'Shea, and Allen (2008) also note the potential importance of university commercialization in developing regional economies. Many other studies support claims for the increased importance of new business start-ups for universities' long-term success and survival (Debackere & Veugelers, 2005; Kirby, 2006; Kondo, 2004; Litan, Mitchell, & Reedy, 2007; Nicolaou & Birley, 2003). Blumenstyk (2007) reports that more than two dozen universities had revenues in excess of $10 million each from licensing revenue from university technologies in 2005. Siegel, Waldman, and Link (2003) report that licensing has been the strategy most often used by universities to commercialize university-created technologies, but Siegel, Waldman, Atwater, and Link (2003) also report an increase in universities' use of start-ups as a commercialization strategy. Even for the many universities that do not generate large profits from commercialization, it is both a means to enhance their social impact mission as well as to provide a forum for interested scientists to see their research have additional positive impact.

This increased interest in technology-based new business ventures at universities has not translated into a defined body of knowledge that addresses the education paradigm and process of university COT education programs. There is a paucity of research and information directly related to the actual education of university students in the area of commercialization of technology. Historically, significant research funding has been available from the National Science Foundation (NSF) and other sources for the creation of technology. Processes that facilitate the creation of new technologies have been researched (e.g., Cooper, 1983, 1994) and "best practices" have been identified (e.g., Barczak, Griffin, & Khan, 2009). There is some understanding of the process of matching public and private funds to promising technology start-ups with business plans and management teams in place. Universities have created and enhanced technology transfer offices to facilitate this process.

The missing link in these efforts is the transition from an existing or emerging technology to the creation of a compelling new market-driven business. This institutional, financial, and skill gap is referred to as the "valley of death" in COT (Auerswald & Branscomb, 2003; Markham, 2002; Marczewski, 1997; Wessner, 2005). Figure 1 depicts the "valley of death."[1] As a result of this gap between development of science and development of commercial products, many opportunities to create technology ventures remain undeveloped and unexploited (Kirzner, 1997). The remainder of this paper reports on the development and lessons of a

[1] Please note that all figures in this paper are versions of figures used in teaching the TEC program in the United States and elsewhere.

university-level program that is designed to train students to bridge the valley of death in COT. This program is *not* designed to facilitate the creation of technologies, a major university effort. Rather, the goal of this program is to increase student skills in technology entrepreneurship.[2]

The article is organized as follows: First, we briefly describe prior work on COT education. Next, we describe a COT program we have developed over more than a decade. We then describe a number of lessons we have learned from varying and adapting elements of the program over time. Finally, we assess our program against the five criteria recently suggested by van Burg, Gilsing, and Reymen (2008) to enhance new ventures from university-driven science and technology. We conclude with lessons learned from 14 (shows longevity) years of COT instruction and provide suggestions for COT education.

COT EDUCATION

We differentiate between teaching general entrepreneurship and teaching high technology-focused entrepreneurship, the latter being our focus here. While COT education efforts are based in part on general entrepreneurship education pedagogy and practices (readers are referred to the 2004 special issue of *Academy of Management Learning and Education* for a full discussion of topics of interest in general entrepreneurship education), COT education creates specific challenges given its reliance on existing and emerging technologies as the platform for entrepreneurship learning. A smaller body of existing research is pertinent to the particular challenges of teaching entrepreneurship within a COT framework.

COT education programs in universities are found primarily in engineering and business schools. Kingon et al. (2001) reviewed the curriculum of both general entrepreneurship and COT courses in engineering and business programs. They noted an increase in the number of faculty positions dedicated to general entrepreneurship education and in the number of entrepreneurship courses, consistent with results noted by Finkle and Deeds (2001). Most of this growth was in business schools, followed by engineering schools. Kingon et al. also note a more recent increase in entrepreneurship courses offered by engineering schools, primarily directed toward technology-oriented engineering students and containing evaluation of existing or developing technologies as part of the pedagogy. One reason for the increase of these engineering programs focusing on COT is the desire to link the development of technology and the commercialization of technology into a more seamless process. Engineering education has traditionally focused on the creation or development of technology, resulting in the creation of many technologies that, while having potential application, lay dormant due to lack of follow-through on the possible commercial applications of the technology. There is also increasing recognition among science and engineering students and faculty that some type of business or management education is required to prepare technology-based students for typical career paths. This point was stressed in the COSEPUP report of the National Academy of Sciences (1995). Most of these graduates, both MS and PhDs, follow careers in industry. In both cases, a high percentage of science and engineering graduates transition into management or business roles early in their careers.[3]

Although business school and engineering department entrepreneurship offerings have developed in parallel, a number of arguments support the potential benefits of bringing together content, faculty and students from these disciplines into strong cross-disciplinary curricula. A major conclusion of the Kingon et al. (2001) review is that both engineering and business COT education efforts contain elements important to teaching students how to develop commercially viable technology start-ups or licenses, and both would be appropriate for COT education programs. Similarly, Wright, Piva, Mosey, and Lockett's (2008: 13) field study of "the challenges that [business schools] face in relation to the development of academic entrepreneurship in eight UK universities" uncovered a number of issues regarding the practical value of business school faculties' engagement in efforts to promote COT. It has been observed that little research conducted by business school faculty, including entrepreneurship faculty, is derived from practice or intended primarily to provide insights useful to the day-to-day struggles of creating and nurturing a thriving technology

[2] In this paper, we use COT and technology entrepreneurship interchangeably, but we acknowledge that some technology entrepreneurship is not primarily COT and that some COT cannot easily be labeled entrepreneurship. In our experience, the primary skills of technology entrepreneurship work well in creating new ventures outside of or within existing organizations.

[3] Readers seeking a fuller comparison of engineering and business school COT curriculum content and processes are referred to Kingon et al. (2001).

venture (Drucker, 1985; Gibbs, 2002; Wright et al., 2008). This may translate into a lack of relevance of faculty research to the practice-oriented demands of teaching entrepreneurship and to inappropriate overreliance on nonresearch faculty to teach based on personal experience and anecdote (Baker & Pollock, 2007; Gibbs, 2002; Whittington, 2003). One proposed corrective measure is for entrepreneurship faculty to "significantly increase their involvement in cross-disciplinary research and teaching, with faculty from engineering and applied sciences" (Gibbs, 2002, quoted in Wright et al., 2008: 10).

Such mixed groups benefit students by affording practice in role-spanning behaviors that are likely to be useful in organizations in which both business and technology skills play important parts. Another advantage is that this makes training in fundamental business skills, known to be important to entrepreneurial survival (Shane & Delmar, 2004), available to a broader range of students, including scientists and engineers (European Commission, 2008; Wright et al., 2008).

Overall, we still lack well-developed theoretical and conceptual frameworks to direct the teaching of general entrepreneurship, and this is a more pointed limitation for COT. Until recently, this lack of theory-driven approaches mirrored the status of entrepreneurship research in general (Aldrich & Baker, 1997; Shane & Venkataraman, 2000). Fiet (2001) and Bechard and Toulouse (1998) have noted the importance of "theory-based" approaches to the teaching of entrepreneurship. Despite these calls, and despite substantial recent improvements in theory-driven entrepreneurship *research*, there has been little attention given to the theoretical development of entrepreneurship *education,* especially in COT. We propose that a more fruitful approach is to develop pedagogies that draw on theoretical frameworks for design guidance, as this provides a context for evaluating how the program is working and for cumulative learning from experience.

Recently, van Burg et al. (2008) proposed a science-based design approach to creating university spin-offs as a framework for crossing what we referred to as the "valley of death." They note the importance of linking scholarly knowledge in a technology area to new venture creation using that technology. This satisfies the university's dual role of knowledge creation and economic development, which are often in competition (Bird, Hayward, & Allen, 1993; Clark, 1998). They propose that a science-based design approach provides a way to enhance both future scholarly research in the area as well as new business creation (Di Gregorio & Shane, 2003). Van Burg et al. (2008) conclude that to enhance start-ups from university science, five factors are critical. First, universitywide awareness of entrepreneurship opportunities must be increased, thus encouraging the development of entrepreneurial ideas. Second, a mix of technology knowledge and venturing skills must be provided through coaching and training. Third, a collaborative network of advisors, managers, and investors must be established to support start-up teams. Fourth, spin-off processes should be separated from academic research and teaching. Finally, a university-level culture must be created that motivates and rewards entrepreneurial behavior. Below we evaluate our design and "lessons learned" against these five factors.

In the next section we explain the education model and processes used in the COT program that is our focus here. We refer to this model as the Technology Entrepreneurship and Commercialization (TEC) Algorithm. We then briefly describe the primary theoretical perspectives that have shaped development of the pedagogy and use this as the context to explain the lessons we have learned.

THE TEC PROGRAM

The Technology Entrepreneurship and Commercialization program (TEC) was initially developed at North Carolina State University from 1995 to 1999. Development was supported by the National Science Foundation (Kingon, Markham, & Zapata, 1999), the Kenan Institute for Science and Engineering, and the North Carolina State University College of Management for total development funding of approximately $1 million. Since this time, TEC has been refined and adapted through trial-and-error learning in classrooms at NC State, The Ohio State University, University of Ljubljana (Slovenia), Loughborough University (UK; Boocock, Frank & Warren, 2009), a consortium of 12 universities in Portugal, 6 universities in South Korea, the University of Cape Town (South Africa), and many corporate training facilities. TEC has been taught in formats ranging from 3 full semesters to a series of 9 brief modules.

In North Carolina, TEC projects by student teams and entrepreneurs have resulted in the creation of over 450 new jobs and have attracted over $170 million in investments. Similar, and in the case of Portugal somewhat superior results, are being seen as TEC is adopted elsewhere. A recently awarded grant from the joint US-EU "Atlantis" program will allow creation and support of "TECnet," which is an international network of technology entrepreneurship educators.

Pedagogy

The baseline pedagogy (from which many adaptations continue to be made for varied circumstances) involves a 2-semester course sequence in which students apply a clearly structured *process model* of creating businesses that sell products and services based on novel science and technology. The process, which is labeled "the algorithm," is designed specifically to embed sets of skills and behaviors that allow technology commercialization novices to operate as competent technology entrepreneurs or as technology-product champions (Markham & Griffin, 1998) within existing firms. While appearing to be a "technology-push" process, the algorithm is designed to systematically explore connections between a wide variety of market needs and the unique attributes and product features enabled by new and emerging technologies.

The process begins with the creation of multidisciplinary teams of 5–8 graduate students from business and engineering/science disciplines. Teams frequently include graduate students from other fields such as technical writing or design. Teams are given access to a portfolio of technologies that have been disclosed to any of 20 university technology transfer offices or corporate R&D offices. Each team chooses at least two (and no more than five) technologies to begin the 5-phase process. An overall summary of the phases in the process is presented in Figure 2. In the following sections we review each phase.

The first 4 weeks are dedicated to the "ideation" phase. The objective of this phase is to develop a set of prioritized product concepts with strong hypothesized linkages between the unique capabilities of the technologies and customer/market needs, with these linkages described in terms of initial product concepts. The ideation phase is described below and summarized in Figure 3. Ideas are generated, prioritized, slightly refined, and written into preliminary initial statements describing the product and the markets they might serve. Students first investigate the technology and discover how it works and what unique capabilities it may create or enable. They engage in structured rounds of "creative imagination" during which they are taught to use individual and joint creativity tools to imagine solutions to problems or needs that might be achievable through products or services based on the technology. Recently, we have relied heavily on the "nominal group technique," which we have found to be particularly useful for diverse, interdisciplinary groups (Van de Ven, 2007). Students are introduced to Pauling's notion that the best way to develop good ideas is to generate numerous ideas and learn which ones to discard (Crick, 1996). They are encouraged to use a wide variety of sources to generate ideas, including written documents, the large network of local

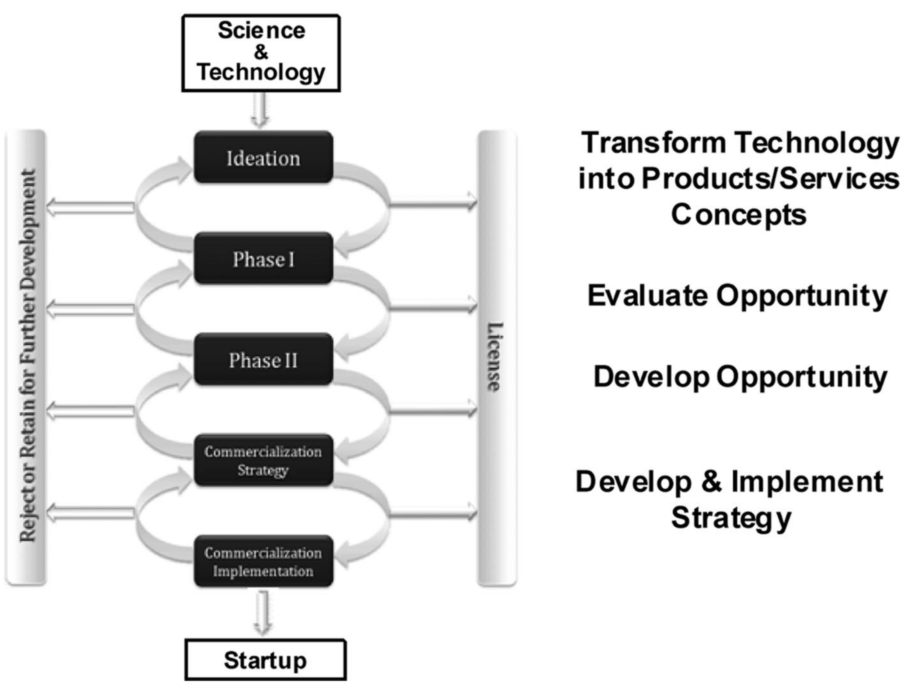

FIGURE 2
The TEC Algorithm

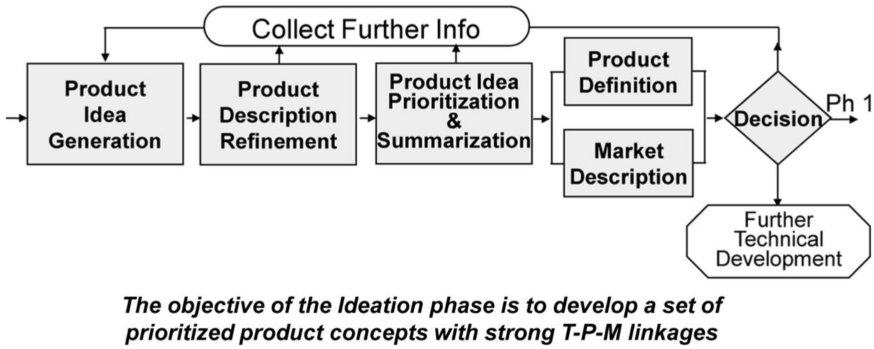

FIGURE 3
Ideation Phase

executives eager to help the teams, and their own social networks. We validate the role of "prior experience" and "knowledge corridors" (Hayek, 1945; Shane, 2000) by introducing students to academic work in this area and encouraging them to make use of what they know from prior experience about needs they might address.

The key construct we introduce to generate and capture "lots of ideas" is called "T-P-M," which refers to "technology–product–market" linkages. Student teams are required to generate multiple product ideas that might be developed for each technology and multiple markets for each product (or service). For example, students recently applied T-P-M to a single patented chemical compound to describe product ideas as diverse as a fluid to prolong the useful life of transplant organs, an antiaging skin cream, and an energy drink. Then students are asked to identify multiple market opportunities for each product idea. Identifying diverse market needs guides the process of further specifying product attributes and—if the initial technology appears incomplete or inadequate—guides the search for technologies with the needed performance characteristics.

A major benefit of the pedagogy is that students become more comfortable with interdisciplinary tasks and demands. Science and engineering students are typically comfortable with the "concrete" nature of the science and technology and are initially less comfortable with the "made-up" nature of the product and market needs they envision. By the end of the program, products and market needs are more concrete and relatively more important to these students. Similarly, during the program MBA students become more comfortable dealing with novel technologies and discussing and evaluating their intricacies with the scientists and engineers who have created the technology. We have found it is useful to address these patterns of student comfort up front, thereby making both science/engineering and business students' initial discomfort feel more "normal" to them.

The remainder of the first semester is dedicated to "Phase 1" and to the first iteration of "Phase 2" (see Figure 4). These phases are described below. During Phase 1 and Phase 2 students improve and select among their product concepts by grounding and challenging in market and technical realities what was previously mostly "imagination."

Phase 1 and Phase 2 are elements of opportunity evaluation structured around series of questions and analytical tools that guide technology commercialization neophytes to ask fundamental questions about a variety of topics covering technology, legal, marketing, organization, manufacturing, financial, industry and competitive issues. We refer to this as the functional and strategic assessment. These guiding questions distill for investigation the primary issues considered by experts to be important to entrepreneurial success. The questions are updated through periodic reviews of new literature, through the regular input of members of the local entrepreneurship community, and through our experience with the courses. We also adapt standard business analysis tools to the evaluation process. For example, students are required to apply standard industry analysis tools based on Porter's (1980, 1985) work.

In both Phases 1 and 2 students use the guide questions and analytic tools to direct their research into whether they have identified a valuable opportunity. There are three primary differences between the two phases. First, the primary purpose of Phase 1 is to identify "fatal flaws" of any sort that would warrant setting a technology or product idea aside at least for the time being (Paulings' "which ones to throw away"), while the primary purpose of Phase 2 is to begin building the business case and becoming expert in the technologies, products, and markets that have survived Phase 1 (the presumptively good ideas). Most "fatal

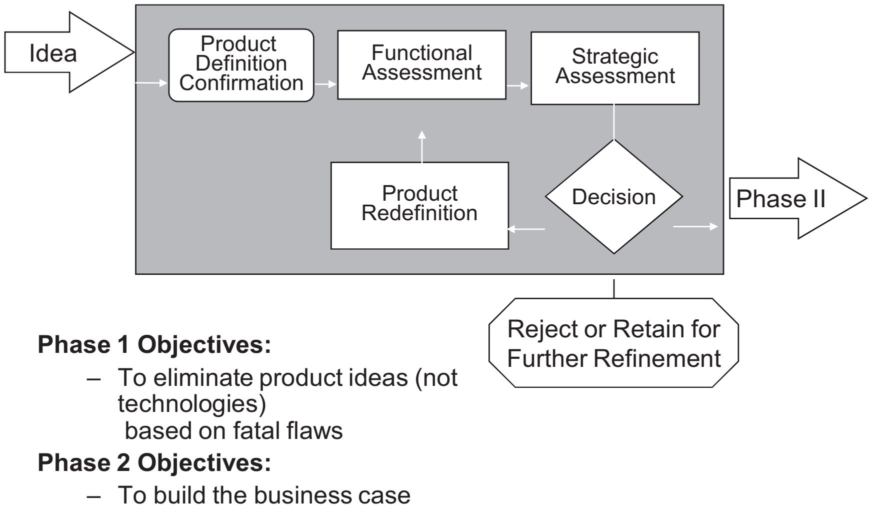

FIGURE 4
Phase 1 & 2 Assessments

flaws" discovered during Phase 1 fall into one of two categories: technology flaws or market flaws. In a technology flaw, the students discover that the technology cannot do what has been claimed or will not be able to do it without massive and uneconomical infusions of research funds. For example, students recently discovered a fatal flaw when an outside expert they contacted pointed out that the video signal data reduction and recovery technology they hoped to exploit violated a law of physics and could *never* achieve the intended performance. Flaws may also be judged fatal when early stage technologies *might* work but appear highly unlikely to do so, or when intellectual property the students need is legally protected and the students appear unable to gain the license they require on reasonable terms. In market flaws, the students sometimes discover that superior technologies and products are about to be introduced, obviating the need for their innovations. For example, this happened recently when a team excited about a set of substantial advancements over goggles then available for viewing videos privately learned about a new product introduction that leapfrogged their own advancements. In every case, categorizing something as a fatal flaw is based on the student team's judgment that there is no opportunity *for them* worth considering or developing further from the T-P-M linkages they have created between a technology and a particular market.

As a second difference between the first two phases, Phase 1 consists of a few dozen questions and some cursory analytic tools, while Phase 2 consists of several hundred questions and requires rigorous application of a variety of standard tools—e.g. "five forces" analysis—with which the MBA students are in principle familiar but which the science and engineering students must learn in the context of the project. The purpose of having so many questions is to guide inexperienced business and technical students to gather the wide variety of information needed to make informed decisions.

Third, while Phase 1 requires some limited interaction with external experts, Phase 2 requires students to interact with and begin building relationships with dozens of external parties, including scientists, managers at potential competitor firms, suppliers, and especially customers. In Phase 2 students make heavier use of product development and market research tools such as "voice of the customer" (Griffin & Hauser, 1993) and "lead user" analysis (von Hippel, 1986). By the end of the first term, groups have typically reduced their portfolios to no more than two technologies and three sets of related product ideas, most targeted at several market segments. They are aware that by early in the second term they will be forced—typically against their will as they have *"fallen in love"* with more than one set of T-P-M linkages—to choose one technology "platform" and one initial set of start-up product ideas.

The second term of the 2-semester sequence begins first by deepening the Phase 2 research and analyses, resulting in the choice of "which company we are going to start," including, importantly, the industry within which it will be started (Shane, 2005). The choice of venture/industry does not follow automatically from the Phase 2 analysis. Instead, the teams are required to develop a set of criteria that they consider most important for making this fundamental decision, to assign weights to the criteria, and then to assess each opportunity for which they have developed T-P-M linkages against these criteria, resulting in a quantitative ranking. This ranking then becomes the primary basis for the selection of what opportunity will be carried forward. Typical criteria include not only industry attractiveness, but also the degree to which the students are passionate about the venture idea, the degree to which the team has the skills to meet early milestones, and, on the negative side, the projected capital intensity of the venture, the required further development of the underlying technology, and the projected time to profitability. Also of interest, although many of the criteria the teams adopt fit with those that scholars identify as appropriate (e.g., Shane, 2005), some of the criteria adopted are instead expressions of idiosyncratic team desires. For example several teams have recently placed a high value, beyond "market" consideration, on "green" technologies and products.

Phase 2 is followed by development of a commercialization/start-up strategy. Throughout the course, students are challenged to develop "value propositions" for their products using a simple prescriptive format. This forces the students to answer "*what* is this product, *who* will buy this product, *why* will they buy it instead of doing nothing, and *why* will they buy it instead of buying something from the (inevitable) competitors?" In addition, they build a "business model" that answers questions about *how* the business will bring the product to market and *how* it will do so profitably, including initial financial projections. Finally the students propose answers to strategic questions of *where* and *when* the business will operate and market its products and services. The result is a modular "business proposal" that can be easily updated and which students subsequently adapt to create proposals to recruit executives, raise financing, and market their services to early customers. The actual launch of the business typically takes place after the end of the formal coursework. Two additional integrated courses are also offered to interested students, "Launching the Technology-Enabled Growth Venture" and "Managing Venture Growth."

Teaching Format

Primary course instruction is provided by two or more full-time tenured faculty, one with entrepreneurship research and new venture creation experience and one with significant science or technology research experience. Numerous additional "technology" and "new venture" creation experts are available as needed. These include academics, entrepreneurs, and venture capital experts. In its basic format, the course meets once a week for 3 hours. A little less than half this time is spent on lecture/discussion, introducing students to each element of the algorithm in a "just-in-time" manner. The remainder of the class is spent in group meetings. These are run by the students, but are facilitated by "executives in residence," volunteer coaches from the business community, who work with the student teams through both terms. Often, for those student teams that launch businesses after graduation, the coaches become either members of the entrepreneurial team or stakeholders in the business. Student teams are required to meet in-person as a group at least one other time each week. The teams are required to produce a variety of documents throughout both terms, including many "worksheets" that provide step-by-step guidance to each element of the algorithm and also provide evidence of team progress and decision making.

It is essential to note that the entire TEC process is explicitly "iterative" (see Figure 2), based on the epistemological assumption drawn from entrepreneurship theory that some of what teams need to know to make appropriate decisions is uncertain and unknowable (Knight, 1929) or simply undiscovered (Kirzner, 1997). When a team learns anything that makes a prior decision appear suspect, they are required to "iterate back" to the appropriate part of the algorithm and enact the process again. Indeed, the typical team experience is one of repeated iteration as new discoveries are made, which helps to explain why at the end of the year most students are well-practiced at the algorithm and have internalized many of the skills and practices it requires. Finally, the entire "group" element of the grade for both terms is based on discipline and explicitness in applying the TEC algorithm and the resultant quality of decision making. Failure to iterate and "go back through the process" upon the late discovery of contradictory information or of a substantially superior opportunity is the primary error that teams can make. As we make clear from the beginning, "Nobody said this would be easy or quick." Two normal outcomes of the algorithm, besides starting a new firm, are reject (from further consideration at the current time) and retain for further development and licensing (see Figure 4). In the former case, scientists and engineers associated with the technology are given guidance as to what developments might make their work more commercially valuable, and the door is left open for future engagement. In the latter case, technology transfer and research and development offices are given leads on firms likely to want to license a technology if it proves inappropriate for a start-up venture.

LESSONS LEARNED

In the following sections, we first describe two primary theoretical frameworks guiding continued development of the pedagogy and then describe some of the most important lessons we have learned. Major pedagogical design lessons are presented first, followed by more specific issues.

Theory and Design

Because we take seriously the potential benefits of cross-disciplinary mixing of students, the design of our program needs to accommodate widely varying student backgrounds and experiences. Our students include both full- and part-time MBA students, along with master's and PhD students from a wide range of science and technical disciplines. Most important, our students vary in the extent to which they already intend to become entrepreneurs, in the extent to which they feel they are capable of becoming entrepreneurs, in the extent to which they have already developed various skills useful for engaging in technology entrepreneurship, and in the extent to which they have been conditioned by prior education (Gibb, 1987) and employment to think of entrepreneurship as an option (Sorensen, 2007). While a wide variety of genetic (Nicolaou et al., 2008); family (Aldrich & Cliff, 2003); and other factors in students' pasts may affect their desire and capabilities to engage successfully in entrepreneurship, we operate on the assumption that for most students, we can provide learning experiences which open up entrepreneurship as a reasonable option.

Our primary goal is not to turn the greatest number of our students into entrepreneurs. It is, instead, to get our students to understand that entrepreneurship is an option for them and to increase their confidence and self-efficacy in regard to making this career choice (Boyd & Vozikis, 1994; Chen, Greene, & Crick, 1998; Tabak & Barr, 1999). We provide them with skills, knowledge, and behaviors, that is, entrepreneurial management *practices* (Drucker, 1985), that will help them to succeed if they choose to engage in technology entrepreneurship. Prior research provides evidence that entrepreneurship training can substantially increase cognitive and motivational precursors to entrepreneurial activity, which suggests that the training may open up entrepreneurship as a choice to students who would otherwise remain closed to it.

For example, in an interesting set of arguments, Gibb (1987) suggests that entrepreneurs may be characterized according to a set of useful personal attributes. Rather than arguing that this constrains entrepreneurship to only a limited group of people with specific personality types, he instead argues and adduces evidence in support of three claims: First, that the task demands of entrepreneurship are so varied that few people, regardless of their personal attributes, are likely to be incapable of entrepreneurial activity; second, that the task demands of entrepreneurial endeavors may themselves stimulate and strengthen particular useful attributes and behaviors among individuals engaged in entrepreneurship (Busenitz & Barney, 1997); and third, that many of the attributes and behaviors useful to entrepreneurship are amenable to development through experience and training. Focusing specifically on the effects of entrepreneurship training on undergraduate science and engineering students in the UK and France, Souitaris, Zerbinati, and Al-Laham (2007) found that the training increased both attitudes toward and intentions to engage in entrepreneurship. Also of interest, the most important trigger to these changes appeared to be the degree to which the students were emotionally aroused and inspired by the entrepreneurship modules.

In general, it remains unclear how tightly later entrepreneurial activity is linked to entrepreneurial attitudes and intentions at the end of a curriculum, in part because there are often substantial time gaps between the completion of an entrepreneurship program and attempting to engage in entrepreneurship (Gibb, 1987; Luthje & Franke, 2003; Ronstadt, 1990). However, Charney and Libecap's detailed analysis of the effect of entrepreneurship curricula at the University of Arizona suggests that the effects of entrepreneurship curricula may be lasting, as it showed that over the period from 1985 to 1999, compared to members of a control group of nonentrepreneurship graduates of the college, graduates of the entrepreneurship program were more likely to start ventures, more likely to grow them successfully, more likely to commercialize technologies, and more likely to create technology-based firms.

We have shaped the ongoing development of our curriculum and pedagogy and, therefore, our design of the student educational experience primarily in accordance with two fundamental theories: cognitive theory and the theory of planned action. Both theories are consistent with our assumption that technology entrepreneurship can be usefully taught. Social cognitive theory (Bandura, 1977, 1986) explains learned behavior as a reciprocal interaction of cognitive, behavioral, and environmental factors. The primary ideas we take from Bandura are the notions of self-efficacy and enactive mastery. *Self-efficacy* refers to one's beliefs regarding "how well one can execute courses of action required to deal with prospective situations" (Bandura, 1982: 122), and it is shaped primarily by one's prior experience with similar situations. Numerous studies have shown that "enactive mastery experiences," experiences in which success required persistence and learning from failure and setback, increase self-efficacy and make it more robust, thereby allowing individuals to maintain their self-efficacy in the face of future hurdles (Bandura, 1997, 2000). In our program development, enactive mastery experiences have to be perceived as authentic and real to have the desired effects.

It is worth noting that the need for enactive mastery experiences is also consistent with many published observations that effective entrepreneurship education needs to be "hands-on." For example, the European Commission Expert Report (2008) suggests that traditional teaching methods, such as lectures, tend to be ineffective in entrepreneurship teaching and that "there is a need for more interactive learning approaches, where the teacher becomes more of a moderator than a lecturer" (2008: 8). Gibb (1987:19), adopting a critical perspective on both business school research and teaching, calls for entrepreneurship education to utilize "learning by doing—gaining insight as well as knowledge by involving students in problem solving in real-world situations right up to, and through, the solution and action component." A similar insight underlies Ronstadt's (1990: 80) suggestion that entrepreneurship programs should proceed "from being more structured to extremely unstructured—to the point that individual initiative ultimately becomes the critical variable shaping the project and the outcomes." Consistent with this insight, very loosely structured hands-on engagement with trying to move a project forward, which may provide both skill development and enactive master experiences, becomes the core of later stages of the TEC curriculum. The last several weeks of the program are designed on the fly to accommodate and respond to questions and demands that arise in the students' work on their projects. As Ronstadt emphasized, this approach is in strong contrast to many traditional pedagogical approaches built around the often largely reflective, analytical and highly structured construction of a "business plan."

The second primary theoretical framework that affects our program design is the theory of planned behavior (Ajzen, 1987), which builds on classic work on attitude formation and behavior (Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1977). At the core of the theory of planned behavior is the notion of "perceived behavioral control," which in many ways resembles Bandura's notion of self-efficacy. This theory explains behavior that is calculative and planned to be consistent with the relative likelihoods (probabilities) and consequences (outcomes) associated with each behavior under consideration. It undergirds the more calculative and predictive elements of our program (see Souitaris et al., 2007 for a complementary recent application of the theory of planned behavior to entrepreneurship).

Together, social learning theory and the theory of planned behavior suggest a number of prescriptive elements for design of a program to teach students the skills, behaviors, attitudes, motivations, and self-efficacy required for the sorts of entrepreneurial undertakings that graduate students in both business and science/engineering often find highly daunting. Through almost 14 years of developing this program, and more recently, through helping people in other institutions and nations adapt it to their environments and students, we have engaged in a great deal of trial-and-error learning: We have made a number of mistakes and attempted to learn from them. In addition, we have engaged in intentional manipulation and variation of the curriculum in order to see what works. The "lessons" learned and described below are the results of these learning processes.

Four Fundamental Elements

We have learned that the pedagogy falters when any of four key elements is weakened. The program must be *real, intensive, interdisciplinary,* and *iterative*.

Real

As we noted above, "enactive mastery" experiences must be perceived as "authentic" if they are to strengthen self-efficacy. The only way we have found to let students experience the program as a real and authentic experience of technology entrepreneurship is to have the real and explicit endpoint of the program focused on creating real companies. Not every student wants to or will follow an entrepreneurial path. Each year, students in the U.S. program start 2–4 new ventures that involve about 25% of the enrolled students and projects. The percentage of class projects transitioning or transitioned to commercial ventures is similar in Portugal, at around 33%.

This history of starting ventures is enough to make most students experience the entire year-long program as "real." Indeed, each year, the current students are interested in knowing about prior start-ups and in meeting the students behind them. Even with this history, however, students are still highly attuned to any statement or action that might trigger doubt or concerns such as "we are working this hard for an *academic exercise?"* Running the course *"as if"* it were focused on creating companies is not good enough to engage the students fully.

This lesson was reinforced recently when we reflected on the fact that some students are simply not interested in starting a business at the moment; they just want to learn some skills. We decided to stop pressing the issue and instead to share and discuss with students why it was important that we "act as if" we were in the process of starting businesses in order to get them to "act as if" they were starting businesses. Several of the students who were most eager to engage in trying to start new ventures (or taking on different challenges with an employer) clearly felt somewhat "duped," while other students displayed evidence that they were just "going through the motions." During the last 2 years, we have returned to and strengthened the message that the class focus is on developing opportunities and actually enabling and launching new ventures. The trade-off, which we accept, is that while most students appear to be very engaged, a small group of students that would prefer a less "authentic" experience and are unhappy when "going through the motions" is not enough to generate a good start-up. We have also learned to provide a highly realistic preview of the courses in order to allow students who know they do not want to do this sort of work to opt out early.

Intensive

Self-efficacy is enhanced by the experience of working hard against obstacles, overcoming them, slipping back, staying with the effort, and eventually succeeding. We have experimented with "how hard" we make the course (varying things like the size and composition of the technology portfolio, how quickly different tasks need to be accomplished, how much directive guidance we provide, etc.) based on student self-reports of spending excessive numbers of hours in the courses and a general sense of the program as overwhelming, especially during the first 6 weeks. Experiments with making the course easier, such as forcing teams to carry only two (rather than their more typical choice of 3–5) technologies through Phase 1, have backfired. Easier pedagogical demands seem to undermine the enactive mastery experience and result in students responding less positively to setbacks later in the course. When students have lived through the experience of the very difficult first 6 weeks, however, it appears that the gains in self-efficacy become robust against the more serious technological and business setbacks that could otherwise surprise them much later in the year.

One function of the "modular" nature of the course (Ideation, Phase 1, Phase 2, etc.) is to modularize the enactive mastery experiences. That is, students experience success with one module and gain self-efficacy on those tasks before they move on to the next. In practice, this also means that when students "iterate" back to an early step in the algorithm on the basis of "surprise" information, they are remarkably better at it the second time than the first time. For example, the first time students run through the questions on the Phase 1 functional and strategic analyses, the tasks typically require 25–35 person hours. By the second or third time the teams do a Phase 1 analysis, time spent is often reduced to 6–10 person hours. From an initial daunting task, it has become just another tool they can apply with increasing efficiency and confidence.

Interdisciplinary

There are myriad benefits to interdisciplinary teams. The most obvious are that the students learn to work well with people from different backgrounds and that the projects are "staffed" with many different skills. We discuss the value of diverse teams, including our next planned experiment, below. But the most important element of the interdisciplinary teams, based on our experiments with creating disciplinary-focused ones, is that teams that include graduate scientists, engineers, and managers create a situation in which everyone is ignorant about something. They therefore find it easier to admit to their ignorance in the group setting. Individuals' shock at the level of their own ignorance in the face of the size and scope of the tasks to be accomplished creates an openness to learning and cross-disciplinary cooperation.

Iterative

The algorithm attempts to put a somewhat linear framework around what is otherwise a seemingly chaotic process. However, the technology entrepreneurship process is not inherently linear. This is very difficult for many students to understand. The modularity of the curriculum provides a structure in which students can understand this nonlinearity specifically through experiencing the need to "go back" one or more steps as surprises occur. During a typical year students strongly resist "iterating" early on, they iterate fluidly through the middle part of the process, and by the end, iteration has become largely second nature. These multiple iterations and experiences of enactive mastery create a high level of self-efficacy in which students develop a profound sense that "I can do this" and an equally profound sense that they should not expect it to be easy.

More Specific Issues and Recommendations

In addition to the four primary design considerations above, we have also experienced other pedagogical issues and tried various experiments around several other design features.

Create Temporal Checkpoints

The modules and stages described above provide important checkpoints to assess project status and process. We have been surprised to find that these are not adequate, especially in the early stages of student learning. We have found that most students view the process (ideation through development of a commercialization strategy and business plan) as a daunting task with high uncertainty and many complexities. Breaking this long-term task into smaller tasks with regular deliverables due on specific dates is an effective way to keep teams' attention focused on the task at hand, and is consistent with guidance from social cognitive theory on the need to actively focus "attention." Moreover, the combination of modular and temporal checkpoints allows students to set and achieve a series of challenging but attainable goals, which is consistent with recommendations from the goal-setting and performance appraisal literatures (Latham & Wexley, 1981; Locke & Latham, 1990; Bretz, Milkovich, & Read, 1992).

De-Emphasize Business Plans

Many entrepreneurship curricula use development of a business plan effectively as the central organizing principle and primary outcome of one or more courses. Consistent with Ronstadt's (1990) critique of business plan-focused curricula, we have observed that this can lead to a form of goal substitution in which writing a business plan, which is a useful tool for some but not all businesses (Bhidé, 2000), becomes the primary learning target. We have experimented with having students develop a business plan as a year-long process in which a loose and somewhat impressionistic early plan gets revised many times as the students learn new skills and do research. This structure caused substantial problems. Students began to view the development of a business plan as an "investment" that should produce a rate of return. They developed rationales for the existing business plan and felt like they should try to "win" in their defense of the plan rather than viewing the plan as part of the process. As important, when students had in hand a business plan they wanted to defend, they exhibited a corollary resistance to iterating, to going back and revisiting earlier steps in the process, even when it was apparent that their opportunity needed further development (see also Alvarez & Barney, 2007, on the restricted place of business plans in the process of "creating" opportunities). As a result, we observed better performance in writing finely crafted business plans and poorer performance in following a disciplined approach to opportunity development and exploitation.

More generally, reliance on a premature business plan is likely to produce poor overall decisions. Consistent with behavioral decision-making literatures, early adoption of a business plan may result in an "anchoring" effect. Research consistently demonstrates that there is insufficient adjustment from initial anchoring in decision making. Decision makers seek and process information that supports the initial anchor and rationalize disconfirming information. Similar effects are noted frequently in the escalation of commitment literature (Staw, 1981; Bobocei & Meyer, 1994). When we encouraged students to write a business plan early and to revise it during the rest of the course sequence, we found that they were too anchored on the early version and that we needed to apply substantial pressure to induce the more radical revisions that were often warranted. More troubling, once the students have anchored on a written plan, they think they are close to the "right answer" and become less eager to continue to work hard on developing an opportunity.

Consistent with the iterative nature of the TEC algorithm, students learn that the business concept continues not just to evolve but sometimes to change radically as the process continues. Although by the end of the program we require every team to write and present a plan, we do not even introduce this topic until students have been working on an opportunity for approximately 18 weeks. We therefore *encourage* students to consider the business plan as a "sunk cost" that they want to avoid taking on until they must. Eventually, they learn that if they have done all of the work we have asked them to do throughout the program, actually writing the business plan becomes a very straightforward and (for some) enjoyable "last minute" task of writing what is basically the core of a document to "market the company," different versions of which they might use to attract stakeholders ranging from technology transfer offices, to early employees, to investors and to customers.

Structure Large Blocks of Time

Individual students and student teams need large blocks of time to gather and process information. We prefer that classes meet once weekly for 3 hours, rather than multiple shorter sessions. The Ideation, Phase1, and Phase 2 activities require significant amounts of uninterrupted time for in-depth consideration of the technology–product–market linkages, functional area assessments, and commercialization strategy development. As discussed earlier, the TEC algorithm process is highly recursive with multiple interdisciplinary relationships. Thus, it is a complex decision task. This process is similar to the demands of academic research, in that it often requires intensive time commitments to become immersed in the specifics of the research under investigation. Mitchell (2007), in a discussion of academic values, notes the importance of hours of uninterrupted time for the thinking, reading, and writing necessary for high-quality research. For many people, longer blocks of time are more effective in producing quality research than more frequent smaller blocks of time, even when total time is the same.

We encourage a small number of regularly scheduled "long" (minimum 2 hours) weekly team meetings outside of class and now require at least one such meeting weekly. Over the period that we have been teaching this program, students have become more resistant to structuring work this way because they are accustomed to multitasking and cycling quickly between activities. However, once they are forced to a structure requiring sustained attention, many students become converts to the value of uninterrupted time for improving their focus and creativity. Supporting this approach, our courses have been recently changed from 3 credit hours to 4. Our science/engineering students had noted that the course demands were easily equal or greater than the 4 credit hour format (3 hours course plus 1 hour lab) found in many engineering and science courses.

Emphasize and Balance Team Diversity

Projects requiring both management and science/engineering talent require a certain minimum level of functional diversity to work effectively. Beyond this requirement, our most extensive experimentation has been focused on trying to figure out the trade-offs in other forms of skill and background diversity. For example, for several years, we attempted to create teams in which the scientists and engineers had overlapping technical backgrounds (e.g., biologists, biochemists, chemical engineers, etc.) and in which the business students had experience in relevant industries (e.g., life sciences companies, agricultural chemical companies, clinical test firms, etc.). The primary goal was to create a team with strong interlocking complementary skills such as might be found in a good small firm in the relevant industry. We found that the teams were particularly good, once they had identified and initially developed an opportunity, at figuring out how to exploit it.

We then experimented with creating teams that were intentionally heterogeneous in terms of technical backgrounds and industry experience. In comparison with the earlier groups, the new groups were not as strong in their abilities to create strong paths to exploitation. However, they were substantially better in generating the T-P-M linkage ideas, the sets of opportunities that feed into the evaluation and exploitation processes. On balance, it became clear to us that the quality of opportunities that the teams develop is a much more important determinant of the quality of the student learning experience and of the firms that are created through the program. Therefore, we now construct teams around the primary criterion of skill diversity. Our next experiment involves creating a structure that allows students to reconfigure team membership during the second term, to see whether we can optimize for creativity and the quality of opportunities during the first term and optimize for opportunity exploitation during the second term. We anticipate that one problem will be the strong bonding that takes place as teams work closely together during the first term, and therefore, the personal reluctance of students to move from one team to another.

Generate Technology Flow

An important success factor in university COT education is the presence of significant volume and quality of technical assets or technologies to be examined. As noted, our approach initially involves "weeding out" technologies based on use of the algorithm. Most technologies are discarded for one or more reasons at this point. Thus a flow of new technologies is required for a COT program to sustain itself. Having access to a portfolio of technologies keeps the teams engaged in evaluating multiple options and helps keep them from prematurely foreclosing on one opportunity. We have found that settling on one technology too soon results in an overly optimistic bias toward the team's perceived one and only opportunity, similar to the optimism well documented in the research literature as entrepreneurs pursue one venture (Aldrich, 1999; de Meza & Southey, 1996).

Beware of Idiosyncratic Heuristics

Decision makers in general and entrepreneurs in particular operate in complex environments with high levels of uncertainty and often with time constraints. In situations like this, decision makers are likely to use heuristics or rules of thumb to reduce uncertainty and enable themselves to reach a decision (Tversky & Kahneman, 2004). This is true of entrepreneurs, who are especially likely to rely on heuristics and cognitive biases to maneuver through uncertainty (Busenitz & Barney, 1997). These heuristics develop based on prior experience and are exhibited strongly by experienced entrepreneurs. Most students in our program have limited or no prior entrepreneurial experience. Thus, we utilize the TEC algorithm to provide the students with a common platform as a basis for future entrepreneurship experience.

The goal is to have the students' repeated, intensive, iterative experience with the process steps of the algorithm create both explicit tools and useful heuristics that they will carry with them in their careers. A serious issue sometimes arises in the interactions between the students and the experienced entrepreneurs (i.e., the "executive in residence") serving as mentors to the teams. Each team is assigned two such volunteer mentors, who meet with the teams at least once a week for two academic semesters. As experienced members of the entrepreneurial community, these entrepreneurs "know" from gut sense and heuristics what the teams should do. They are tempted to pass their insights and implicitly their personal heuristics along to the students. This interferes with our ability to embed the skills and structured, process-based heuristics we are trying to teach. The problem is not so much that the mentors are "wrong" in their gut reactions (although, of course, they sometimes are) but rather that simply "hearing the right answer" from a mentor does not teach students approaches to figuring out an answer themselves. Handing an answer to the students undermines the applied, hands-on benefits of the pedagogy and turns learning-by-doing back into a "minilecture." We have found therefore that it is necessary both to put a strong effort into teaching new mentors the algorithm, and also to team novices with experienced mentors to minimize these issues. The rule of thumb we insist on is that a mentor should only violate the structured process of the algorithm when she or he sees that the students are completely spinning their wheels or in the unlikely event that they are about to do something potentially disastrous. When the students are themselves more experienced entrepreneurs or managers, the algorithm serves as a "checklist" to ensure a more thorough decision process.

OVERALL POSITIONING AND ASSESSMENT

Although we have worked from a basic theoretical perspective in learning to shape and adapt our program, we note that its design is also largely consistent with the five high-level design elements suggested for creating university spin-offs described earlier (Van Burg et al., 2008). A major element of the Van Burg et al. perspective is that a mix of technology knowledge and venturing skills must be provided through coaching and training. The TEC algorithm combines an in-depth understanding of the technologies being evaluated coupled with development of potential technology–product–market combinations. The course content also includes functional analysis skills in areas like marketing, financial, and intellectual property.

A second proposed element is a collaborative network of advisors, managers and investors. The use of classroom instruction by multiple faculty, significant time in teams outside class, availability of the pool of executives in residence (content experts in both technology and venturing specialties), and presentation of final business proposals to leading members of the local entrepreneurial community provide multiple levels of support for the teams as they move through Ideation, Phases 1 and 2, and development of the commercialization strategy. A new experiment, which we have implemented this year, is to require that each team meet (preferably in person, virtually otherwise, involving each student member in at least four meetings) with at least 12 members of the long list of members of the local and national entrepreneurship communities who have expressed interest in supporting our students and program, choosing their contacts based on apparent match between contact background and project needs. This is in addition to the several hundred contacts students are expected to make as part of their ongoing project development and research. It is our hope that by implementing this requirement, we will give some students who appear shier in meeting new people the opportunity to learn that doing so is within their capabilities, while simultaneously improving every student's embeddedness in useful entrepreneurial communities.

A third design element of the Van Burg article suggests that spin-off processes should be separated from academic research and teaching. To a limited extent, our program violates this recommendation, because we are interested not only in optimizing the creation of spin-offs, but more important, in using this process to teach students technology entrepreneurship. We are also currently experimenting with ways to provide a better feedback loop to technologists by revisiting previously "rejected" technologies in subsequent years in order to provide continued guidance as to how the research might become more commercially useful. Nonetheless, the ultimate decision about any commercialization of technology (licensing, new business start-up) is controlled by the university through the offices governing technology transfer. Neither technology-creating faculty nor the TEC faculty influences this process in a substantial way beyond the individual projects on which we cooperate with technology transfer offices and through occasional mutual training seminars. However, as Wright et al. (2008) and Lockett and Wright (2005) demonstrate, the very challenges our students face and the very skills we try to help them develop are also some of the primary challenges faced by university technology transfer professionals. We believe that our efforts complement the ongoing efforts of the many technology transfer offices with which we work, and the directors of these offices have provided us with strong support.

The last two elements of the science-based design perspective for university COT efforts include development of university awareness of entrepreneurial opportunities and the creation of a university-level culture to motivate and reward entrepreneurial behaviors. These are organization (university) wide design prescriptions and are beyond the scope of the TEC pedagogy. However, the interdisciplinary nature of the student teams, the instructional faculty, and the executives in residence provide needed multidisciplinary expertise and perspectives, and have contributed to the campuswide and multicampus awareness of entrepreneurship opportunities for science and engineering faculty involved in the creation of new technologies.

CONCLUSIONS

A major advantage of the pedagogical approach we have described is that it addresses the factors that cause technology and innovation to languish in the Valley of Death, a critical problem in technology commercialization. The program is designed to bridge this gap between the creation of technologies and the commercialization of these technologies (see Figure 1). The use of real technologies in a team environment with content and functional experts that support the teams allow the students to be more fully engaged in the early stages of the COT process than does more traditional case-based education or the creation of business plans around an existing business concept. The added emphasis on these early stages through the identification and evaluation of possible technology–product–market linkages in a process-based comprehensive model provides significantly more value creation to the early stages of COT. The T-P-M construct allows students to begin with a technology but move quickly to understanding the decisive role in commercialization of product and market forces, thereby effectively integrating "technology push" and "market pull" commercial logics.

Earlier, we proposed that experience-based teaching (reliance on experience of the instructor) may not be the most effective pedagogy for COT education, although it is common. Neither theory, nor cases, nor engagement is sufficient. All are useful, but at the core, there needs to be a process to guide the COT education effort. We propose that *process-based* instruction, the modules of which represent significant steps in the commercialization process and also represent coherent sets of skills, provides a better means for students to understand and master the complexities of COT.

Given the current centrality in the entrepreneurship literature of debates about the nature of opportunities and whether they are "discovered" or "created," it may be worth noting how we have adapted our program to this scholarly discussion. At the most abstract levels, the debate involves fundamental ontological considerations: In simple terms, are opportunities objective, out there and waiting to be discovered and then exploited, or are they created through entrepreneurial action (Alvarez & Barney, 2007; Eckhardt & Shane, 2003; Sarasvathy et al., 2003)? However, the debate also embraces highly practical implications for practice, contingent on whether entrepreneurs are in a discovery or creation "context" and whether they rely on discovery or creation "assumptions" about how to behave in that context (Alvarez & Barney, 2007). At the level of ontology, our curriculum remains agnostic (although we never seem to run into opportunities just waiting to be plucked), but generally in agreement with synthesizing claims that the subjective and objective characteristics of opportunities are resolved through entrepreneurial action in the form of "enactment" (Baker & Nelson, 2005; Sarasvathy et al., 2003).

In terms of curriculum development, in response to the development of "creation" theory, our pedagogy has continued to reduce emphasis on "discovery" of opportunities, and has therefore, supplemented the attempt to teach appropriate search, analysis, and forecasting skills with behaviors more useful to "creation" opportunities such as the ability to *persuade others to visions* of products and markets that may not yet exist (Aldrich & Fiol, 1994; Alvarez & Barney, 2007). In addition to our traditional focus on teaching skills to attract and manage professional equity investments, we are now attempting to help students also learn how to make do through effective use of bricolage and bootstrapping behaviors (Baker & Nelson, 2005; Bhidé, 1992, 2000). Our curriculum has always emphasized the importance of "iterative" decision making, which has recently been identified as an important practical element of creation theory (Alvarez & Barney, 2007). More generally, we have found that incorporating "creation" behaviors and skills into the curriculum is both interesting and challenging, because there are fewer published tools and approaches available than exist for traditional "discovery" approaches and because to many students, creation behaviors seem more like the characteristics of "struggle," than like the characteristics of "analysis," to which they are more accustomed. Overall, our pedagogical approach presages recent conjectures that the behaviors required for creation opportunities encompass the full set of behaviors and skills required for entrepreneurship more generally (Alvarez & Barney, 2007; Sarasvathy et al., 2003).

Much prior research has examined factors that may affect COT in universities (Agrawal, 2006; DiGregorio & Shane, 2003; Siegel, Waldman, & Link, 2003; Shane & Stuart, 2002: Thursby, 2004). We complement these efforts, by studying the pedagogy and content of the education experience for the university's students. We believe this research is critical both in supporting universities' increasingly important roles in entrepreneurship and economic development and, more important, in providing students with the skills they need to create and lead technology-rich entrepreneurial ventures.

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