

**AC 2008-1601: ENTREPRENEURIAL BUSINESS FUNDAMENTALS FOR
SCIENTISTS AND ENGINEERS**

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Entrepreneurial Business Fundamentals for Scientists and Engineers

Abstract

Traditional engineering approaches to technology transfer and venture creation tend to be based on the technology push principle. These evolve from long term government support for the research, culminating in potential patents and licensure agreements. Research indicates that for every successful company there is a two order of magnitude of failed or unsuccessful entrepreneurial ventures.

Failure is often driven by the overemphasis on technology, in the absence of understanding market needs, unawareness of strategic principles that help positioning the technology-based product in the context of existing industries in this innovation space, and a fiscally-sound value proposition for investors or partners to enable the venture. Entrepreneurial market innovations need to address:

- technological uncertainties (robustness, scalability, cost-effectiveness, existing solutions)
- market uncertainties (value proposition, competing solutions/approaches, distribution network)
- business uncertainties (startup vs. corporate, fiscal sustainability, models for value capture)

The premise of “*Entrepreneurial Business Fundamentals for Scientists and Engineers*” is to help the students understand a business framework of science and technology with emphasis on (i) positioning technology-based ventures in the appropriate value chains, and (ii) assessment of value capture (business) models relevant to product positioning.

Technological entrepreneurs (and research managers) have two challenges: Finding the appropriate market application for currently discovered technologies and finding appropriate technologies that can create and capture value for a emerging market opportunity. This course focuses on the latter. The business fundamentals are taught in the context of identifying an emerging market opportunity. Industries, derived from the student team’s research area, are analyzed. These industries are then dissected in order to determine potential opportunities for new business or new lines of business. Once the opportunity is identified, the question of what technology may be required to enable this technology is determined. The content-driven lectures on strategy, marketing, financing and innovation are illustrated using video clips and case studies drawn from entrepreneurial and corporate examples. The hands-on experience focuses on homeworks, a team-based project in a technology space selected after a student competition, and a presentation to business developers. It is our observation that the main challenge for the students is to be able to reassess/modify their original technology-based solution to one informed by strategic, market and financial criteria.

Teaching Philosophy

Technology-based entrepreneurship, regardless of whether it takes place within a large organization or in a startup, requires a mixture of technological and business skills. Our aim in developing a joint graduate-level entrepreneurial curriculum between engineering and business is

to enhance the blended strengths of the two parties, not turn each into the other. Building the bridge between the two disciplines is the goal, not creating an engineering school within the business school or vice versa.

Most entrepreneurial curricula begin with a course on some form of writing a business plan. The message to students is that all their ideas are worthy of converting into detailed operating documents. They are not. These ideas must be screened and assessed. The entrepreneur’s time, after all, is the most precious resource of all. There is no sense wasting it on an idea that has no chance of being economically successful. The good news is that there is increasing attention being paid to—determining the feasibility of the business. More and more institutions are beginning to look at teaching methodologies to assess the feasibility of a proposed new business.

Our courses take the steps necessary to show students how to create entrepreneurial ventures with significant business potentials (Figure 1). Further discussion of the phases laid out in this figure can be found in a series of Inc. articles (Faley, 2005abc, Faley and Kirsch, 2005, Faley and Porter, 2005). Starting from either a new technology or identifying a market opportunity that could be transformed by a new technological discovery, our courses provides students structure and experience linking science and business. The course discussed in this paper, *Entrepreneurial Business Fundamentals for Engineers and Scientists*, provides the basis for business opportunity identification and concept development. This course then ties into a rigorous market opportunity assessment course, *Driving the Innovation Process*, which can then be further leveraged into a *Business assessment* and a *Business Planning* course. To be sure this is no paint-by-numbers deterministic process. It is highly stochastic and highly iterative. But it is a process nonetheless. One that can be articulated, taught, and effectively implemented. Perhaps even more importantly, the courses teach student how to exchange ideas in teams with diverse backgrounds and perspectives.



Figure 1. Entrepreneurial Skill-set and Business Formation/Development Phases

Course Format

To address the need for having the student understand the value of early entrepreneurial business assessment, and to allow the engineering student to de-emphasize the technology-based perspective of entrepreneurial business development, the course is organized in teaching modules. These modules include (i) strategy, (ii) marketing, (iii) finance, and (iv) innovation, and are supplemented by cases from *Harvard Business Review*, live cases from entrepreneurs, student-led projects that are weaved throughout the entire course, and a select number of

homeworks to allow the student time to learn the specific subject matter. The course requirements are graded either in team or individual format (Table 1), which also indicates the deliverables for each task.

Table 1. Tasks, Deliverables and Grading Structure

Task	Deliverable	Evaluation	Timeframe	Grade (%)
1. Project pitch	Short presentation	Class	Week 1	Ungraded
2. Homework 1. Strategy Assessment	Application of strategic frameworks to evaluate project idea	Team	Week 3	1/3 rd of 20
3. Homework 2. Entrepreneurial finance	Investment and market capitalization table applications	Team	Week 7	1/3 rd of 20
4. Homework 3. Value chain analysis	Construction of value chain and presentation	Team	Week 10	1/3 rd of 20
5. Midterm	Strategic and market analysis of technology opportunity	Individual	Week 6	15
6. Final paper	Revised strategic/market positioning of company following value chain analysis	Team	13	15
7. Oral participation	In-class discussion of business cases	Individual	Entire term	30
8. Contribution to course/project wiki	Project organization	Individual	Entire term	10

The course modules and project are taught in accordance with the sequence outlined in Figure 2, which starts with a technology-based idea. Hence, the course addresses the gap of understanding between the original idea and the development/assessment of the final product that has a reasonable chance for value creation. Since all students are engineers or scientists, they come to class with a technological solution or research idea that was previously defined by funding organizations, interactions with engineering professors, or resulting from their own creativity or observation of opportunities. The question that needs to be asked here is: what is the product concept that will be brought to market, or allows for value capture from this solution?

The students need to understand that for a technological solution to become valuable, business (How are you going to make money?) and market (How do you strategically position your business?) uncertainties need to be addressed. We start out with the question: what is the product concept (hardware or software) that is based on the technology, and that the students think addresses a need. This concept is then evaluated from a strategic, financial and value chain (innovation) perspective, until a final product offering is iterated as the likely value capturing opportunity. Lastly then, the students need to extract the key technological enabler this product can't do without. This technology is then the invention or technology that the entrepreneur ought

to invest time and finance in to maximize his/her chances to capture value in the marketplace. In short, the following questions need addressing:

Industry: What is the competitive differentiator of the new technology or concept, and how does a company based on this product compete in the macro-industry?

Market: What is the unmet need for a target market, and what is the broader growth market?

Finance: Can you build a sustainable business on your product, with attractive returns for investors?

Innovation: What is your strategy to sustain new product development and growth?

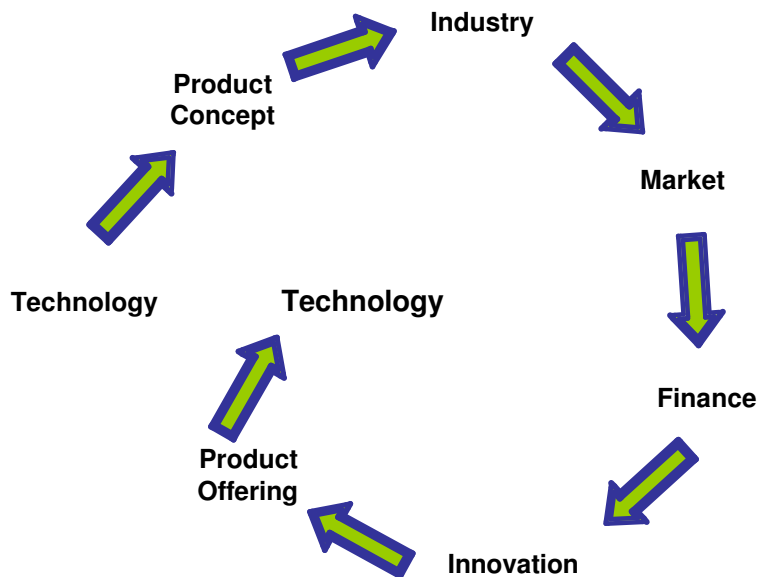


Figure 2. Course evolution and project modules

Strategy Assessment. The course employs a number of strategic assessment tools, to evaluate the market (buyers) and industry (sellers) positioning of an idea, as well as the strength of its intellectual property and impact of complementary assets (Teece, 1986). Mullin’s framework (Mullins, 2003) allows the students to evaluate the micro (initial target) and broader (macro) markets from a needs-based perspective. Where is the pain? What are current solutions to meet the need? How narrowly defined are the market segments? Concurrently, the micro- and macro-industries are assessed, in terms of the current offerings to assess competitive strength and bargaining power. Here

the students learn to apply the Porter’s Five forces paradigm (Porter, 1979) to evaluate the strategic position and strength of the industry and the proposed new venture. In particular, time is spent on assessing the strength of intellectual protection (IP), the dependence on other complementary assets to realize the venture, and the differentiation of their prospective companies from the competition. The students apply these frameworks to their project to strategically position their opportunity.

Financial Assessment. Successful ventures can be realized within a corporate or a startup setting, but in either a case needs to be made for value creation (i.e. Why should the company/venture fund invest in your idea or company?). On the other hand, the entrepreneur has to make a decision regarding the objectives for his company (e.g. growth-based with external funding, maximizing ownership, etc..). To accomplish this objective, the students learn to read, develop and evaluate cash flow analyses and learn to apply company valuation methods. Using various forms of startup capital, including venture capital, loans, and grants, the students develop capitalization tables for their ventures, calculate the weighted average cost of capital (WACC) to develop scenarios for various valuations of ventures. The students then apply these methods to

assess the value of their ventures, and iterate to achieve a reasonable rate of return (ROI) for investors. This iterative evaluation does require them to go back to basic assumptions about the funding objectives, and even the product and its embedded technology.

Innovation and new business creation. Sustained growth of a value creating entity depends on the ability to continuously innovate, and to do so along the value chain of an industry where most of the value is created. Alternatively, strategic value creation may occur when the product/company has the opportunity to restructure the value chain with the objective of improving the company's position in the industry. To address this need, a section of the course is dedicated to value chain analysis, and the opportunities for venture creation. Value assessments of industries along the chain are based on web-based knowledge of the industry, or via financial analysis of proxy companies. For example, operating margins may provide relative indicators of the intrinsic value of a service or product along a given value chain. The students apply these principles to their ventures to evaluate where their putative product offering captures value along the industry's chain, and reassess venture opportunities, products, and enabling technologies based on this information.

Case Example

An example is presented in figure 4 for the valuation of business segments in the green building industry. Based on profit margins derived from proxy companies as researched in the public domain (hoovers.com), it appears that the highest value-creating opportunities (based on profit margins) exist in operations and maintenance or as a developer. Certain specialty materials also capture high margins, but value creation from general construction materials is marginal. So for example, if the original idea for the company was to capitalize on the development of new plant-based materials for construction, a business challenge is presented by the existence of industry standards and thus the strength of incumbent industries in this segment. In addition, the development costs required to adhere to these standards, the low margins from outsourcing of mass production, and the general conservative nature of the industry may impact successful introduction of new materials.

Following along the course modules and iteration towards a sustainable business solution by using the strategic, financial and innovation screening tools results in the following assessments:

Industry: The product differentiator (micro-industry) is based on a value proposition of equal strength and quality to existing materials (e.g. wallboard), but less energy-intensive manufacturing processes. At the macro-industry level (Porter's Five Forces), competition is substantial. Established construction standards, and need for certification, will make it difficult to enter the industry with substitute materials. In addition, strong incumbent industries present additional barriers of entry.

Market: The target market is aimed at architects designing LEED (Leadership in Energy and Environmental Design) – certified buildings. Certification is based on a rating system implemented by the US Green Building Council (<http://www.usgbc.org/>). With ratings impacted by the lifecycle and energy required for material use, plant-based materials present an opportunity to increase LEED points for remodeled buildings. The macro-markets include new construction and additional materials replacement of traditional structural components.

Finance: The cost (at low volume) of production is higher than that of currently used materials. Scaling of manufacturing presents a major business and technological uncertainty. In addition, non-specialty (e.g. for aesthetical applications) construction materials have low profit margins and, hence, return on investment (ROI) will be long-term and not very attractive to investors.

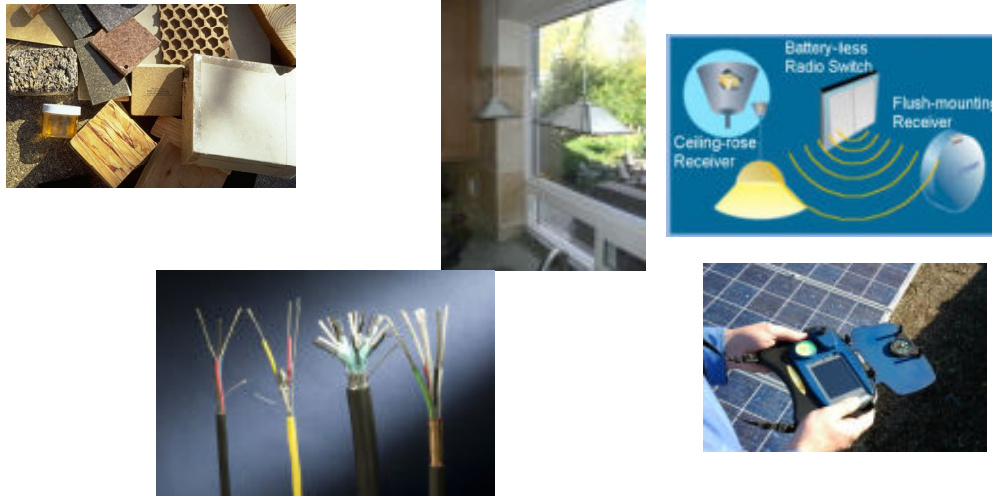
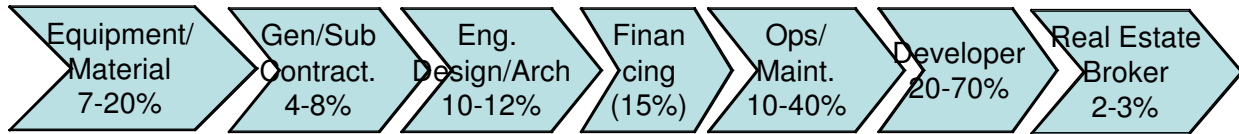


Figure 4. Value chain for green buildings

The result of this evaluation (supported by comprehensive strategy and financial analysis) indicates that the positioning of a new startup company based on manufacturing plant-based materials for LEED construction would be a challenging proposition. Yet, in this industry, higher value is captured if the product development would focus on applications not encumbered by industry standards, and by providing the architect creative design opportunities for which customers are willing to pay more (i.e. not price sensitive). Thus, competitive differentiation of the product would be based on ‘low energy-high quality-plant-based’ and versatility. The issue is not whether the technology is good or not, but whether the product that embeds this technology (construction materials vs. creative design componets) is properly targeted based on valuation methods.

Course Evaluation and Outcomes

The main objective of the course is to teach the students how to combine technological solutions with value capturing opportunities. The approach taken in this course is rather challenging to the paradigm of ‘technology push’, where market needs and industry or financial analyses are conducted after the technology has been largely developed or resources have been committed. The students learn that where you end up is the important thing, not where you start. Part of the endless debate in the formation of new technology-based businesses is whether one should start with the marketing side (so-called “market pull”) or the technology (so-called “technology-

push”). The way we teach this course shows that it simply does not matter. It is like walking; it simply does not matter which foot you begin with—right or left—the important thing is which foot you move next (the opposite one). It is when you move the same one over and over without moving the other (left-left-left or right-right-right versus left-right, left-right....) that you get in trouble. Similarly if you start with the technology, you need to move to the market side next and vice versa. So-called “technology-push” companies get in trouble when they try to walk technology-technology-technology. It is a balance of business and technology leads to successful technology-based business.

The assessment of the course meeting its goals, beyond the grading structure, is more anecdotal. The course has now been taught three times, and from an instructor’s perspective the challenge has been the relative positioning/order of the modules, and how to assess whether the materials were understood. Since there is no textbook for this ‘information that entrepreneurs should know before writing a business plan’, the challenge is to take the students away from the technology focus as soon as possible, and into the realm of ‘does this make business sense’ early on. The projects in the course provide the vehicle for skill development. It takes just a little more effort to make these projects “real” versus hypothetical. Whether we work with the graduate student’s own research, research from the technology transfer office, or business opportunities in emerging spaces (energy-water nexus, for example) we strive to forward something real. The reality is, of course, that not all technologies provide the kernel for great business nor can every market opportunity be reduced to a clear technological need. This is an important part of the students’ learning. Sometimes things just don’t work. The best thing an entrepreneur can do is to identify these issues early. Teams are rewarded based on the process they followed to determine the answer and not on the viability of the final outcome.

The biggest success thus far from the course has been the breaking down of silos between students across the engineering college and business school. Our business plan competitions now have lots of entries driven by teams made up of business and engineering students, while this was quite rare five years ago. The biggest challenge with the development of the curriculum has been communicating to would-be entrepreneurs that they need to do something between their invention and their business plan. The popular press constantly reinforces myth of the “shower idea” to “riches” phenomena. There are lots of steps in between that all successful businesses follow. Sometimes a business will pass through these intermediate steps very quickly, but they still pass through them.

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