



A Sequence of Technology Commercialization Courses for Science and Engineering

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Introduction

The transition of new products from conception to proof-of-concept to commercialization is the hallmark of technological progress, and it is essential for sustaining competitive advantage. Various business methods and funding mechanisms have been introduced and explored since the implementation of the Bayh-Dole Act in 1980 to facilitate technology commercialization¹. The federal government has been a leader in promoting technology commercialization through agencies such as the National Institutes of Health, National Science Foundation, Department of Energy, and Department of Defense. A number of state governments, universities, non-profit organizations, and for-profit institutions have also played an important role in enabling technology commercialization by offering guidance and assistance to entrepreneurs². These efforts have helped many new technologies to come to fruition, including life-saving drugs and medical devices, consumer products, communication devices, clean energy, and safe food products³.

In order to succeed, technology commercialization must involve properly trained scientists and engineers not only at the birth of a technology but also during the subsequent phases of its commercialization. The importance of incorporating elements of entrepreneurship and technology commercialization in engineering education has been noted by the National Academy of Sciences⁴ and echoed in the “Engineer of 2020” report of the National Academy of Engineering⁵ and more recently in President Obama’s strategy for American innovation⁶. Following the lead of the NAS and NAE, several universities have launched a variety of technology commercialization and entrepreneurship programs – short courses, workshops, cross-disciplinary courses, commercialization projects, and others⁷.

This paper describes a sequence of three technology commercialization courses in the Master of Biotechnology Program at Northwestern University. We developed these courses based on recommendations of our industrial advisory board, our interactions with business development professionals, previously reported research on entrepreneurship education, and advice from faculty members at our School of Business. The implicit challenge in developing technology commercialization courses is the integration and balance of business and technology. Our task was to familiarize students with a host of new business concepts, but also make them comfortable with embracing uncertainty in data and encourage them to make judgments based on incomplete information. The latter two tasks are challenging given the mostly deductive and converging mode of thinking of science and engineering students.

In the end, we believe that we have created a solid foundation for teaching technology commercialization to master’s level students. This course sequence has been offered every year starting with academic year 2011. Thus two cohorts of students have taken this course sequence and the third cohort is currently taking it. This course sequence extends over a period of three quarters – fall, winter, and spring and each course has a credit value of 0.5 units. One unit

corresponds to a course load of four lecture hours per week, so each course in this sequence has a course load of two lecture hours per week.

Throughout the sequence of three courses, we used a variety of pedagogical approaches to engage the students. In addition to teaching business concepts, we managed team dynamics. We also invited a significant number of guest instructors from industry, who brought a truly multi-disciplinary character to these courses. Finally, we gave students numerous opportunities to practice their critical thinking skills by answering non-trivial questions, formulating decisions, and reflecting on their actions.

Motivation for the sequence of technology commercialization courses

A recent survey of engineering students showed that 41% of them wanted to start their own businesses, and 66% thought that entrepreneurship education would strengthen their career prospects and improve their learning experiences^{8,9}. Another survey showed that 50% of faculty and administrators believed that access to entrepreneurship programs would improve engineering education¹⁰. These statistics show that many people realize the importance of entrepreneurship education in the undergraduate engineering curricula, but, perhaps not strongly enough to require it. These statistics are also mirrored in how universities deliver entrepreneurship and technology commercialization education – by way of optional minors, certificates, or electives. In most engineering curricula, a senior design course is typically the only required experience that includes some aspects of technology commercialization. Although this is a good start, it is far from what is required to grasp the complexity of technology commercialization.

Table 1. Graduate degrees awarded in the USA.

Type of degree	Number of degrees	% international students	Refs.
Engineering MS*	46, 940	44.4	11
Professional MS [#]	1, 758	18	12
Engineering PhD	9,582	54.2	11
Our master's program ^{\$}	180	40%	NA

* Data for the year 2011, the latest available.

[#] Data for the year 2012, the latest available.

^{\$} Our program is a hybrid between Engineering MS and Professional MS programs.

The situation with teaching technology commercialization is not much different at the graduate level, despite the fact that MS and PhD graduates have more research experience than undergraduate students and, hence, are more likely to be at the forefront of technology commercialization. The situation is further complicated by the fact that about 45% of students in engineering MS programs are non-resident aliens, who are even less familiar than domestic students with the technology commercialization processes in the United States. Given the substantial number of graduate degrees awarded in the USA annually (Table 1), we think that more rigorous education in technology commercialization is not just beneficial, but it is necessary for graduate students' career growth and the future success of technology

commercialization. This education should be designed to bridge the knowledge gap between researchers and entrepreneurs (the so-called “valley of death” of technology commercialization)¹³, which has been attributed to several technology failures at the commercialization level. Our version of this education is a three-part sequence of 0.5-unit technology commercialization courses (amounting to a total of 1.5 units) required for all students in our master’s program. A total of 13 course credit units and 7 research credit units are required to graduate from our master’s program.

Our strategy for teaching technology commercialization can be represented in the form of a triple Venn diagram that has three key categories: Technological superiority/uniqueeness, a market-driven business opportunity, and regulatory considerations (Figure 1). A successful business opportunity is located in the overlap of these three categories. Each of these elements has their own sub-elements that can influence the business opportunity.

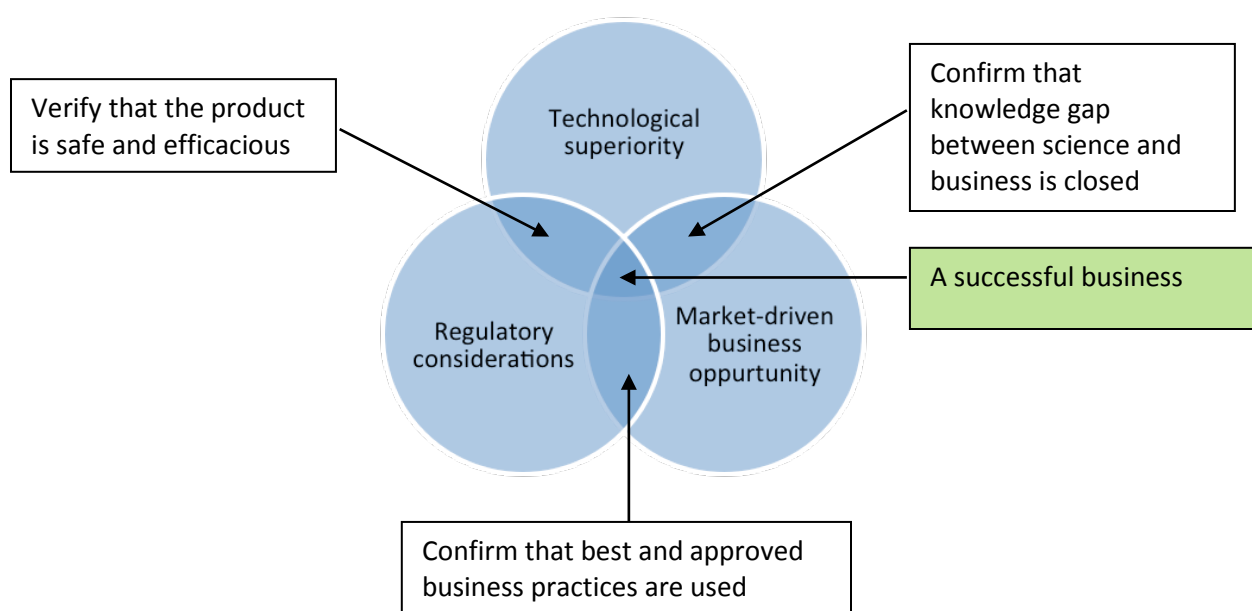


Figure 1. A Venn diagram representing the three key categories that determine a successful business.

Additional motivation for the development of this sequence of courses came from the opinions of the NAS and NAE, the recommendations of our Industrial Advisory Board to educate engineers with business acumen, and the new focus on learning and innovation skills (collaboration, communication, critical thinking, and creativity) that we adopted in our curriculum. In developing these courses we also sought to capitalize on the diversity of the technical knowledge and scientific background of our students. Our students are almost equally divided between life science majors (primarily biology or biochemistry) and engineers (primarily chemical or biological) plus biotechnologists. This diversity should enable students to learn from each other and enrich their experience in our program.

Intent and learning outcomes of the technology commercialization course sequence

Our overarching intent was to improve the knowledge of technology commercialization of science and engineering students. The key objective was to teach students the principles involved in transitioning a technology from bench research to an economically viable, market-oriented business. The expectations were that at the end of this sequence of courses students would be able to:

- (i) View the scientific background of a technology from a business perspective and answer questions such as “How is the technology scientifically superior to other competing technologies?”
- (ii) Assess the nature of a business opportunity (e.g. whether it is sizable, real, immediate, and has a first-mover advantage).
- (iii) Develop a business model and strategy for technology commercialization.
- (iv) Apply the Porter’s five forces analysis¹⁴ and SWOT¹⁵ analysis to a problem.
- (v) Identify and rank critical business issues and develop risk mitigation strategies.
- (vi) Write a succinct business development proposal targeted at either venture capitalist (VC) or internal corporate venture (ICV) funding.

It should be noted that this sequence of courses was not intended to convert every student into an entrepreneur. Students interested in a more in-depth study of technology commercialization have access to advanced courses in entrepreneurship and related areas offered at our University.

Course content

All topics covered in our sequence of the three technology commercialization courses lay at the interface of technology and business. Briefly, the first course focused on technology assessment and feasibility studies, commonly accepted as the initial phases of technology commercialization. The second course focused on business development and product launch, which are the intermediate phases of technology commercialization. The third course involved a team project, in which students unified the knowledge of science, engineering, and business acquired in the first two courses to evaluate the commercialization potential of a product. Comprehensive contents of the courses are given in Table 2.

More specifically, students received instruction on patents, copyrights, trademarks, costing and economic evaluation, and applied the SWOT analysis (Strengths, Weakness, Opportunities, and Threats) to several business and managerial scenarios. Students also received instruction in project management, regulatory compliance, business strategy, and the use of Porter’s five forces framework. It is essential to note that the courses featured eight guest lecturers, all subject matter experts (SMEs) in their respective fields, who added credentials to the course and provided unique non-academic perspective on the course topics.

Table 2. Contents of the sequence of technology commercialization courses.

Course number	Topics covered	Key skills acquired	Instructor
Course #1	Careers in business and management	Ability to understand business career opportunities for science and engineering graduates.	SME
	Intellectual property	Ability to understand patentability requirements, read claims, and perform patent search.	Course co-instructor who is a patent agent; plus SME in patent searches.
	Project management	Ability to write a project charter; ability to organize a project and manage risk.	SME in project management
Course #2	Engineering Economics	Ability to calculate costs and revenues; ability to use NPV and IRR to compare projects.	Course co-instructor who has experience in teaching senior engineering design courses.
	Statistics pertaining to development of bioproducts	Ability to understand sampling distributions, hypothesis testing, and randomization techniques.	Course co-instructor who has experience in teaching probability and statistics.
	Business strategy and frameworks	Ability to perform the Porter five forces analysis and SWOT analysis.	SME in strategy and operational consulting
	Regulatory considerations	Ability to understand regulatory constraints during bioproduct development.	SME in designing and managing clinical trials
Course #3 (team project)	Integration of all topics above	Ability to develop a business proposal and recommend a 'go' or 'no-go' decision for the technology commercialization.	Course co-instructors and SMEs

Pedagogical approaches

The sequence of technology commercialization courses described in this paper involved a combination of lecture-based, interactive, and project-based instructional methodologies (see Table 3 for more details). As mentioned earlier, the technology commercialization courses featured a substantial number of guest instructors. Since the guest instructors did not have experience in teaching and grading, the course instructors were deeply involved in guiding them through establishing the right learning outcomes for each seminar and providing a grading rubric. The course instructors normalized the grades to account for difference in grading between instructors. However, some subjectivity in grading was unavoidable.

Table 3: Pedagogical approaches used to deliver course contents

Topic covered	Instructional methodology	Student assessment method	Contribution to final grade
Course 1			
Intellectual property	Lectures and seminars	Individual and team homework assignments	50%
Project management	Workshops	Team homework assignments	50%
Course 2			
Engineering economics & statistics	Lectures	Individual homework assignments	60%
Regulatory considerations	Workshops	Student team interactions	
Business strategy & frameworks	Seminars and case-study discussions	Student team presentation	40%
Course 3			
Technical assessment of a technology	Biweekly meetings with student teams and PBL	Weekly student team presentations	0% (Pass/No pass)
Business assessment of the technology using frameworks	Biweekly meetings with student teams and PBL	Mid-term team presentation to a consultant from the industry	40%
Economic assessment of the technology, including risk mitigation strategies.	Biweekly meetings with student teams and PBL	Weekly student team presentations.	0% (Pass/ No pass)
Cumulative analysis of the commercialization potential of the technology	Small group coaching in writing a business development report and making an investment pitch.	Final presentation to consultants from the industry	60%

General format of the 1st technology commercialization course

The intent of the first two courses is formal, first-level education in various aspects of technology commercialization. The first technology commercialization course was taught in lecture and workshop format. The first class in this course was a guest lecture on business career opportunities for engineering majors. This was followed by a three class module on intellectual property (IP) management. The IP module was taught by one of the course instructors who is also a registered patent agent. Students received instruction on tools for patent search, evaluating the strength of patents, and writing patent claims. The IP module was in lecture and workshop format. Students were assessed by way of individual and team homework assignments which tested their ability to do patent searches and write patent claims.

The IP module was followed by a four class project management module which was taught in workshop format. The broad goal of this module was to learn the steps in planning and running a project. A project management consultant was the guest instructor for this module. Each workshop had a brief lecture followed by hands-on activities by student teams. Students were taught the essential elements of project management such as project charter, communication plan, scope statement, and work breakdown structure. Student teams were assessed through a mini-project which was given out as a homework assignment. Teams were allowed to choose a project that they can relate to and found enjoyable. The guest instructor coached students over a period of four weeks to complete their projects. Weekly presentations and meetings with student teams were used to evaluate team's progress. The final product of this module was a project management plan prepared by student teams.

General format of the 2nd technology commercialization course

The second technology commercialization was taught in lecture, workshop, and case-study discussion format. First part of this course covered topics on engineering economics and statistics related to product development (see Table 3). Three lecture hours were used for engineering economics and two lecture hours were used for statistics. Traditional lecture-homework format was used to teach these topics. Students were assessed through individual homework assignments.

Next in this course was the regulatory compliance module. Many commercial enterprises are required to operate within certain regulatory boundaries and the intent of this module was to make the student cognizant of these boundaries. Three lecture hours were devoted to instruction on regulatory compliance which was done by way of brief lectures and workshops. Student teams were assigned exercises which were completed for the most part in class. If exercises were not completed in class, teams completed it as a take-home assignment. The exercise involved developing a product profile that will conform to regulations that influence the product's market space. The products chosen were mostly in the areas of drugs and medical devices. Student teams were assessed through interactions and oral evaluation of the product profile.

The last part of this course was the business strategy and frameworks module which was covered in three lecture hours. Lecture and case-study format was used. Students were taught to perform the Porter's five forces analysis and SWOT analysis. A SME in operational strategy was the guest instructor for this module. Students were assigned cases to read which were then discussed during class. Student teams critiqued the Porter's five forces analysis and SWOT analysis provided in the cases. Student teams were then assigned business scenarios for which they performed their own Porter's five forces analysis and SWOT analysis. Student teams were evaluated through a presentation of their Porter's five forces analysis and SWOT analysis.

General format and framework used in 3rd technology commercialization course

The third course in the technology commercialization sequence was taught through project-based learning (PBL). Students worked on projects for a total of 10 weeks in groups of 4-5 people. The topics for the projects were selected by the instructors based on the their perceived impact on society, ease of commercialization, and availability of relevant data. Selected characteristics of these projects are given in Table 4.

Table 4. Characteristics of technology commercialization projects

Project	Application areas	Current state of commercialization	Suggested investment mechanism ^{\$}	Regulatory considerations
Cardiac stem cell therapy	Chronic cardiac disease	Emerging [*]	ICV	High
New breast cancer drug	Metastatic breast cancer	Emerging	ICV	High
Media storage using DNA	Any place that needs enormous data storage	New [#]	VC	Low
Nanopore technology for DNA sequencing	Medical diagnostics and biomedical research	New	VC	Low to High

^{*}Emerging technologies are defined as those undergoing commercialization; commercialization data of such technologies are not available to the public.

[#]New technologies are defined as those reported in research publications only; no commercialization efforts are known for these technologies.

^{\$}Instructors' suggestions; student teams were free to choose a different investment mechanism.

ICV = Internal corporate venture

VC = Venture capitalist

In our implementation of project-based learning, students collected and analyzed data, debated the implications of their findings, and pondered the viability of the selected technology. Multiple iterations of ideas and plenty of opportunities for interaction with the coaches (the course instructors) were implemented. The instructors strove to create a nurturing environment that fostered creativity and gave opportunities to fail and to learn from these failures. Since the very nature of technology commercialization is iterative, the third technology commercialization course included several opportunities for the teams to reflect on the decisions they had made earlier and reiterate.

Student teams and coaches met biweekly – once to review students' ideas and next for a semi-formal 30-minute project update. Feedback to teams was provided during project update meetings. Minutes of project update meetings including action items for next week and beyond (which was approved by all team members and the team coach) were used as a record of project progress. Outside these scheduled meetings, students met to brainstorm ideas the coaches were available to moderate these brainstorming sessions. Online meeting and document sharing tools

such as Google Hangout and Google Docs were used for student-coach and student-student interactions. However, teams were required to give the weekly update presentation in person to the coach and to other teams working on the same project. It should be noted that one-on-one meetings and the presentations took the instructors 3-4 hours per week per team.

Tentative goals and mid-term milestones were given to students as a guideline, but the students had to come up with the final goals and milestones and document them using a Gantt chart. A broad technology commercialization process template was also provided (Figure 2), but students were given significant freedom to change the template based on process needs. The crucial parts of the technology commercialization process template were the decision-making steps, where the ‘go’ or ‘no-go’ decisions were made.

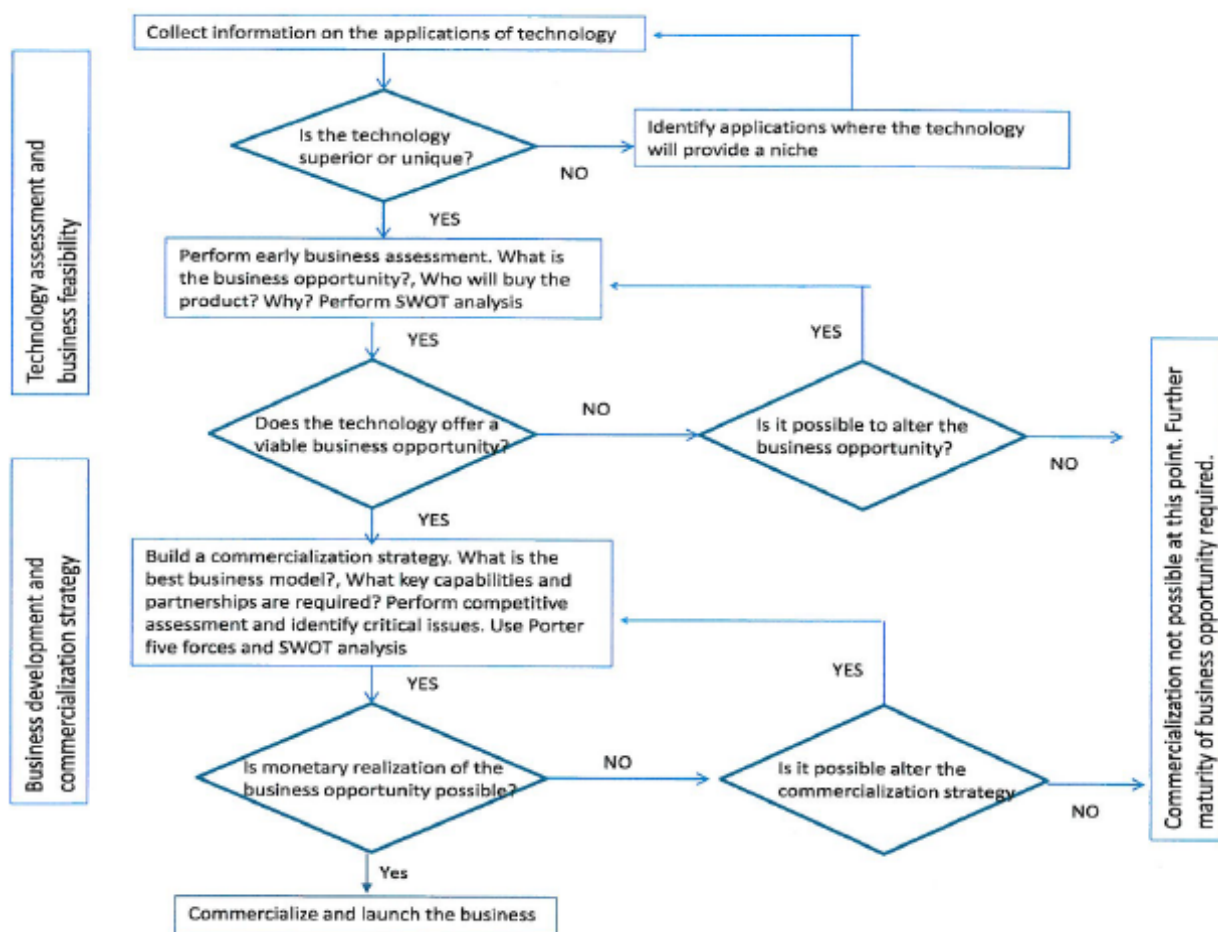


Figure 2. The technology commercialization template provided to students.

To sharpen their decision-making skills, students received instruction in two widely used business frameworks: the Strength, Weakness, Opportunities, and Threat (SWOT) analysis and the Porter’s five forces analysis. They used these frameworks to organize and analyze patent searches, secondary market research, and economic and clinical trials data. As the name implies,

the SWOT analysis is a tool used to identify strength, weakness, opportunity of a particular technology and threats that it faces. The SWOT analysis helps to place all business aspects of a technology in the form of an easily readable matrix and facilitates greater insights into strengths that can be capitalized on and weaknesses that should be fortified. It can also help in identifying new business opportunities and critical issues for the technology. The five-forces analysis invented by Michael Porter in 1979 provides a simple model for evaluating a competitive position of a business organization, and it is routinely used in conjunction with the SWOT analysis. The five-forces framework stipulates that managers must look broadly at the competition and consider not just their direct competitors (one force) but also buyers, suppliers, new products and substitute products (the other four forces). The combination of these forces determined the profitability of a business organization. Detailed explanation of the SWOT analysis and the five forces analysis can be found elsewhere¹³⁻¹⁷.

Our experiences and challenges

As pointed out earlier, the MS students who took this sequence of technology commercialization courses had backgrounds in life science or engineering. They also had a varying level of interest in entrepreneurship. A recent informal ‘show of hands’ poll indicated that about 50% were very interested in technology commercialization, close to 35% saw some utility in learning it, and roughly 15% opined that it was irrelevant to their plans. Thus, the students were substantially heterogeneous in their perceptions about this course. Given this heterogeneity, our intention was to provide firm foundation to students with a strong desire to become entrepreneurs and build awareness of technology commercialization among those who wanted to pursue other career paths.

Significantly, our sequence of technology commercialization courses gave students an opportunity to practice semi-quantitative and critical thinking, in which decisions must be made based on incomplete information within short periods of time. This *modus operandi* is much less common in the academia than it is in industry. Due to the analytical nature of their education, science and engineering students tend to struggle when dealing with ambiguous, poorly defined problems that do not have a unique and/or best solution. The differences in operational thinking between science and engineering and business fields are listed in Table 5.

Students were also wary of making wrong decisions, since they did not have many theories, equations, or boundary conditions to rely upon. To remove this pressure, we provided opportunities for the students to fail. Weekly presentations were graded on a pass/no-pass basis. If a decision could be substantiated and defended adequately, a passing grade was given. Otherwise, the team was asked to rethink their decision or further substantiate it. Some decisions required multiple iterations, and we tried to accommodate additional meeting with the students (in person or via videoconferencing) as much as we could.

Table 5. Science and engineering vs. business modus operandi.

Process	Science and engineering	Business
Data collection	<ul style="list-style-type: none"> • Desire to collect <u>all</u> available information. This information is mostly public, and it is available online and in libraries. • Strong belief that more information will lead to better decisions. • Assumption that all necessary information will be available or can be obtained. 	<ul style="list-style-type: none"> • Desire to collect only the information that is necessary to make decisions. Some of this information is public, but most of it is available only by paid subscriptions. • Belief that decisions can be made with truncated information. • Assumption that some information will be unknown or unattainable.
Basis of data analysis	<ul style="list-style-type: none"> • Analysis is based on sound scientific theories. Some established empirical methods are used. • Belief that data analysis based on strong theories will lead to the best decisions. 	<ul style="list-style-type: none"> • Analysis is based on empirical methods or experience. • Belief that due to higher level of complexity and non-quantifiable data, best decisions can be made through established business process methods such as SWOT analysis.
Conclusions and decision making	<ul style="list-style-type: none"> • Based on established scientific methods. • Assumption that all parameters, which affect the process, will converge at a single optimum point. 	<ul style="list-style-type: none"> • Based on business frameworks, such as the empirical SWOT analysis. • Assumption that multiple decisions are possible but the current decision is best at the moment. Iterations are used when new information becomes available.
Consideration of variables that affect the process	<ul style="list-style-type: none"> • Start an analysis with all possible variables and scientifically eliminate insignificant variables. 	<ul style="list-style-type: none"> • Start an analysis with a limited set of variables, which obviously affect the business. Add variables as the analysis progresses.
General line of thinking	<ul style="list-style-type: none"> • Highly quantitative and guided by scientific theories • Unambiguous results are possible. • Even open- or loose-ended problems can be fragmented to well-defined problems. Solutions will be unique. 	<ul style="list-style-type: none"> • Semi-quantitative (at best) and guided by empirical methods. • Ambiguity will exist. Must learn to work with it. • Problems will always be loose-ended, even at the base level. Multiple solutions will exist.

The importance of finding the successful business opportunity at the overlap of technological superiority, a market-driven economy, and regulatory considerations was emphasized during the project (Figure 1). For example, in the cardiac stem cell therapy project, students initially

proposed that this therapy could become a standard of care (i.e., establish technological superiority) and thus capture much of the cardiac therapy market (around \$35 billion). However, further research revealed that regulatory considerations that govern healthcare providers (HMOs, Medicare, etc.) would make this hard despite very favorable clinical trial data. The students then looked for technological uniqueness and discovered that the cardiac stem cell therapy could improve the quality of life for patients who had survived a first heart attack. The clinical outcome was consequently changed from an improved lipid profile to improved quality of life to allow the cardiac stem cell therapy to deliver a unique therapeutic value. While this change resulted in a smaller patient base and reduced market size (\$19.8 billion), it also established a niche market with a minimal threat of substitutes.

Further analysis concluded that this technology will be a first mover in the stem cell therapy area and, hence, would require establishing new production facilities. From a business perspective, this requirement would result in a huge input of capital (untested technology). So, the students suggested that a prudent approach would be to either outsource, partner, or enter into licensing agreements with existing cell banking companies to launch the product. Such a step would reduce profit per unit product initially, but also significantly mitigate the risk by lowering initial investments. Through several iterations and taking all three elements into consideration, the team was able to find the best opportunity.

SMEs were given significant autonomy in lecture materials in their area of expertise. But they were only marginally involved in the design of this course sequence. The SMEs were usually receptive to the guest lecture but were cautious in participating in course design, primarily because of the time commitment. The instructors facilitated interaction between SMEs to improve continuity. Since the SMEs were recruited as available, the content of the first two courses, in some instances, was fragmented.

In the two years that these courses have been offered, students had the liberty to choose their own teams. We monitored team dynamics through informal discussions with students, particularly when we had suspicions of negative team dynamics. Students were given the opportunity to do a confidential mid-term peer evaluation. We intervened when there was a problem and in some cases reassigned students to different teams. Though a minority of students had some troubles with team work, many teams functioned very well during the projects course.

Assessment of the technology commercialization course sequence

Assessment of this course sequence is qualitative based on comments from students, and SME and industry personnel who provided feedback on student work and presentations. Our industry partners generally provided a positive feedback on the technology commercialization course sequence. They felt students were more aware of the business models and steps involved in commercializing a technology after taking this course sequence. Students were able to

confidently have a discourse on the commercialization potential of technologies other than the one they studied, such as their research project. The general improvements suggested were: (i) greater depth in topics even if it meant that the number of topics need to be reduced, and (ii) make the course more coherent, and topics in the 1st and 2nd courses should follow the actual sequence in the commercialization process.

Students overall had diverse opinions on this course sequence. About 80% of the free form comments we received from students indicated that they saw some value in this course. The rest indicated that this course did not fit well with what they wanted to do in the future (most of these students have plans to enter a Ph.D. program). About 25% mentioned that this course sequence has positively transformed their thoughts on entrepreneurship and that they are likely to pursue this career path. It should be noted that before this course sequence was offered barely one student from a cohort (in some cohorts none) chose commercialization-related careers, but after offering this course sequence that number has raised to about six students per cohort wanting to start careers in technology commercialization. Several students took advanced entrepreneurship courses as electives after taking this course sequence. Regarding the course itself, student mentioned three areas of improvement: (i) provide customized and easy to understand instructional materials that are different from those used by business management students, (ii) grading rubrics and criteria were confusing, and (iii) provide some formal help to handle team performance issues.

Future plans

As we move forward with improving this course sequence, we plan to implement the following changes to address the aforesaid challenges and comments from students and industry partners:

- (i) Create a web archive of instructional materials from SMEs.
- (ii) Implement course management strategies to improve coherence and continuity of topics covered in the 1st and 2nd courses.
- (iii) Develop clear grading rubrics and make the grading process more transparent.
- (iv) Implement peer evaluation among team members to get a better understanding of team dynamics. Hire consultants to coach students on team work. Use Meyers-Briggs personality type evaluation to develop teams and manage team dynamics.
- (v) Collect and synthesize feedback from industrial advisory board.

References:

1. Bradley, S. R. *et. al.* Models and methods for university technology transfer. *The UNC-Greensboro, Economics Working Paper Series # 13-10*, June (2013).
2. <http://www.federallabs.org/>, <http://esd.ny.gov/nystar/RegionalTechCtrs.asp> . Last accessed January 2014.
3. Federal laboratory technology transfer – A summary report to the president and the Congress. *A National Institute of Standards and Technology Report*, (2012).
4. Reshaping the graduate education of scientists and engineers. *Committee on Science, Engineering, and Public Policy of the National Academy of Sciences Report*, (1995).
5. The Engineer of 2020. Visions of engineering the new century. *National Academy of Engineering report*, (2004).
6. A Strategy for American Innovation: Securing Our Economic Growth and Prosperity. *National Economic Council Report*, (2011).
7. Besterfield-Sacre, M., *et. al.* Understanding the technical landscape in engineering education. *Proceedings of the 118th ASEE Annual Conference, Vancouver BC*, (2011).
8. Pryor, J. H., *et. al.* The American Freshman: National Norms Fall 2011. *UCLA Higher Education Research Institute Report*, (2011).
9. Duval-Couetil, N., *et. al.* Engineering students and entrepreneurship education: Involvement, attitudes and outcomes. *Intl. J. Eng. Edu.*, 28(2), 425-435, (2012).
10. Peterfreund, A. R. Epicenter baseline survey report. <https://www.dropbox.com/s/7z9hgp67t0mr9sk/Epicenter-Baseline-Survey-Report-FINAL315.pdf>. Last accessed February 2014.
11. Yoder, B, L. Engineering by numbers. <http://www.asee.org/papers-and-publications/publications/college-profiles/2011-profile-engineering-statistics.pdf>. Last accessed February 2014.
12. Enrollment and degrees in professional science master's programs. *Council of Graduate Schools Report*. http://www.sciencemasters.com/portals/0/pdfs/PSM_Enrollment_and_Degrees_Report_2010.pdf. Last accessed February 2014.
13. Barr, S. H., *et. al.* Bridging the valley of death: Lessons learned from 14 years of commercialization of technology education. *Acad. Mgmt. Learning and Edu.* 8(3), 370-388, (2008).
14. http://www.mindtools.com/pages/article/newTMC_08.htm. Last accessed January 2014.
15. http://www.mindtools.com/pages/article/newTMC_05.htm. Last accessed January 2014.
16. Menon, A. *et al.* Antecedents and consequences of marketing strategy making. *Journal of Marketing* , 63 (2), 18–40, (1999).
17. Porter, M. E. The five competitive forces that shape strategy, *Harvard Business Review*, 28-28, January (2008).