TEACHING ENTREPRENEURSHIP TO SCIENTISTS AND ENGINEERS

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ABSTRACT

The article describes the outcomes of teaching the course: Entrepreneurship for Scientists and Engineers, to freshmen, senior and graduate students at the Colleges of Science and Engineering at the University of Texas at El Paso, during 2006 to 2020. In parallel to studying the topics to commercialize emerging technologies, from market analysis and marketing plan, to the legal structure, operations, costs and investments, financial statements, the intellectual property valuation, and the Prospectus for venture capitalists, the students formed working teams to write business plans on technologies by them selected. The outcomes demonstrated that teaching entrepreneurship in science and engineering, allows students expanding their overall view on how technological advances, and their future professional development, should be oriented on solving real life problems. During the period 2019-2020, out of ten business plans written by student teams, it was estimated that most of them were patentable and some of them keep pursuing filling the patent. A short version of the course was offered to professors from the Technology Institute at Juarez, Mexico, to discuss commercializing their research, following the same business plan writing model. Out of six business plans, it is estimated that five are patentable. These results demonstrate that training science and engineering professors on entrepreneurship, allows focusing their research on developing patentable technologies to solve real life problems. A call is made to professionals on entrepreneurship dissemination to focus on science and engineering schools, not only to follow the example of top universities like Stanford, MIT and Harvard, and their financial success, but to contribute to the technology expansion that should be oriented to solving the many problems the humanity faces nowadays.

Keywords: Technology entrepreneurship; business plans; science-based entrepreneurship education.

PREFACE

During the last three decades the United States lived the "entrepreneurship craze" due to the explosion in the demand of entrepreneurial learning and practice by different population's segments: business students, mom-and-pap small business, individuals not willing to be employees but to start up their businesses, even professionals like engineers, architects and physicians that needed to start practicing their careers in their own offices, but did not know how to start and run a business. This craze arrived to the University of Texas at El Paso (UTEP). A grant was received from the Kauffman Foundation to make entrepreneurship education widely available on campus, changing the way entrepreneurship was viewed, taught, and experienced. A Research Center was created to pursue this objective. The author became part of the initial group of six persons that started the grant's operation. All the members of this group were long time professors in the college of Business Administration, with the exception of the author, who was not a professor of business, but a physicist with a M. Sc. and a Ph. D. in Materials Science and Engineering from Stanford University. The author had experience on start-ups and operating tech-based companies in Mexico and the USA. The author's contribution was participating in the design of the new programs, and to teach a course called "Entrepreneurship for Scientists and Engineers", as described as follows.

1. INTRODUCTION

Can entrepreneurship be taught? This question has been on the table for decades ever since the 90's. Several questions arose: Is entrepreneurship an innate ability or an acquired skill? Can the entrepreneurial knowledge be acquired and enhanced through education? Entrepreneurs are "born" to be entrepreneurial? How being entrepreneurial is based on personal instincts and not on training?

The published literature pretends to answer these questions, most of them resulting on contradictory results depending on who provided those answers: economist, business administration experts, management theorists, social scientists, even human behaviorists. Klein and Bullock (1) mentioned that in management literature, entrepreneurship is associated to certain psychological characteristics of the entrepreneur, where some individuals are particularly well equipped to perform and specialized in communication (2). For labor economists, entrepreneurship is identified as self-employment. The economic theory of entrepreneurship focusses not on the individual or the business, but on the role entrepreneurship plays in the economy.

2. INNOVATION AND ENTREPRENEURSHIP

Schumpeter, a Marxist? Joseph Schumpeter's economic theories are intimately linked to the conceptualization of innovation and entrepreneurship. His intellectual legacy still causes controversy among scholars. Croitoru (3) pointed out that hundreds of papers are annually published about his theories, and citations of his works exceed 10,000 per year. While his view on entrepreneurship is considered dominant, there is still a stream of papers against the Schumpeterian mainstream. Nevertheless, Schumpeter is still considered "the Father of Entrepreneurship", but why?

Croitoru (3) comments that although "Capitalism, Socialism and Democracy" (1942) became Schumpeter's most cited book, "The Theory of Economic Development" (4) has emerged as his *magnus opus*, because in this book Schumpeter establishes how economic development is dependent of "change", ln which the enterprises present "adaptive responses" to the market conditions. But another business strategy can be based on "creative responses" where innovation and novelty are key elements for understanding successful strategies in the market. Creative responses are the results of conducting research and development to create products and services to satisfy the market's needs.

Entrepreneurial innovation is, for Schumpeter, the central cause of economic development, and capital accumulation is a major result. For Marx, by contrast, capital accumulation is itself the primary force in the development process. This is the main difference between Marx's and Schumpeter's economic development doctrines. Economic development is caused by "entrepreneurial innovation". This is the answer to the question why Schumpeter is *the father of entrepreneurship*, and why he is not a Marxist.

Schumpeter's distinction between innovation and invention is noted in his book: "(…) *the inventions of the antique world and the middle ages for centuries failed to affect the current of life. As soon, however, as an invention is put into business practice, we have a process which arises from, and is an element of, the economic life of its time, and not something that acts on from without. Therefore, invention is an external factor*." (4).

When teaching entrepreneurship to scientists and engineers, the difference between innovation and invention should be completely clear. Scientists in many instances claim to be involved in the innovation process, but pure research is the process of invention, which may turn into an innovation when it is launched into the marketplace.

Schumpeter establishes that the "methods of supplying commodities" are directly associated with innovation: "*Technological change in the production of commodities already in use, the opening up of new markets or of new sources of supply, …, improved handling of material, the setting up of new business organizations such as department stores – in short, any 'doing things differently' in the realm of economic life – all these are instances of what we shall refer to by the term of* ***Innovation****."* (4).

Schumpeter conceptualizes innovation as the driving force of the economic evolution: *"In a system in which the process of evolution goes on strongly, it is presumably not very far from the truth to say that practically all new plant that is being constructed beyond replacement, and much of what is being constructed by way of replacement, either embodies some innovation or is a response to situations traceable to some innovation."* (4).

Schumpeter's "Theory of Economic Development" (4) emphasizes that between innovation and entrepreneurship there is an indissoluble relationship: *"For actions which consist in carrying out innovations we reserve the term Enterprise; the individuals who carry them out we call Entrepreneurs. This terminological decision is based on a historical fact and a theoretical proposition, namely, that carrying out innovations is the only function which is fundamental in history and essential in theory to the type usually designed by that term* (4). The paternity of entrepreneurism belongs to Schumpeter.

Again, it is very important to have these concepts clear, since this course assumes that **innovation happens when entrepreneurs launch into the marketplace the inventions, to become innovations.**

Schumpeter (p. 102) introduces several elements which deserve a special attention by the entrepreneurs-to-be: *"the entrepreneur performs but also routinized tasks or 'non-entrepreneurial work' within the company framework"; "the entrepreneur is not necessarily 'the inventor of the good or process he introduces', but s/he is the one who imposed it in the market context"; "the entrepreneur may, but need not, be the person who furnishes the capital. This is a very important point…* ***It is leadership rather than ownership that matters****"*. Innovation consists in: a) Introduction of a new good, b) Introduction of a new method of production, c) The opening of a new market, d) The discovery of a new source of supply of raw materials or semi-manufactured goods, and e) Introduction of a new organization in an industry.

Schumpeter states that the economic and social foundations of capitalism will crumble on account of the decay of the entrepreneurial function: "*The decay of the entrepreneurial function decays when the entrepreneurs make their business grow so big, that innovation itself becomes a routine, and technological progress now becomes the province of specialists; marketing and administration become automatic. Innovation thus degenerates into a depersonalized routine activity carried on in big business through a bureaucracy of highly trained managers*" (4). We question: Are we living this phenomenon by observing Google and Apple?

When teaching entrepreneurship the students must understand basic economic theory from where entrepreneurship derives, to develop a panoramic view on the role they play in the economic framework of capitalism and society. Schumpeter states that in capitalism, innovation continually displaces things: "*the opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory…illustrate the same process of industrial mutation,* ***that incessantly revolutionizes the economic structure from within, incessantly destroying the old, incessantly creating a new one. This process of <u>Creative Destruction</u> is the essential fact about capitalism"*** (5) (p 83).

3. ENTREPRENEURSHIP EDUCATION

Teaching Entrepreneurship. The teaching of skills and cultivation of talents that students need to start businesses, identify opportunities, manage risk, and innovate in the course of their careers, is now an essential of USA higher education. As recently as the 90's, that was far from true. In the past two decades the university teaching of entrepreneurship has shown an unprecedented explosion.

Evolution. Teaching entrepreneurship is not new. Observers trace it back to 1947, when Harvard University offered a course in "**new enterprises**" for returning veterans (6). The field entered its start-up phase in the 70's, began developing curricula in the 80's, and a rapid growth in the 90's.

A *Kauffman Foundation* research report found in 2008 that "*Entrepreneurship* i*s one of the fastest growing subjects in today's undergraduate curricula*" (6). In 1975, colleges and universities in the United States offered over a hundred formal programs (majors, minors, and certificates) in entrepreneurship. The number had more than quadrupled by 2006, reaching more than 500 (6). "*Studies suggest that college campuses in the United States offered approximately 250 entrepreneurship courses in 1985. By 2008, more than 5,000 entrepreneurship courses were being offered in two-year and four-year institutions*" (6). Today, well over 400,000 students a year take courses in the subject, and almost 9,000 faculty members teach it. Universities have become correspondingly important to the nation's start-up infrastructure (7). Of the 1,250 or so business incubators in the United States, about one-third is based at universities, up from one-fifth in 2006 (8). During the 90's to 2000's period, entrepreneurship programs traditionally were the domain of the business school. Schools became inspired by the 2003 launch of the "Kauffman Campuses Initiative (KCI)". The Ewing Marion Kauffman Foundation launched $25 million program in matching grants to eight U.S. universities that committed to make entrepreneurship education more widely available on campus, changing the way entrepreneurship was viewed, taught, and experienced (9). Out of fifteen finalist schools the eight winners were: Florida International University, Howard University, the University of Illinois at Urbana-Champaign, the University of North Carolina at Chapel Hill, the University of Rochester, **the University of Texas at El Paso (UTEP)**, Wake Forest University, and Washington University in St. Louis. And here is where the story begins.

Upon winning the contest, UTEP started working on implementing the means to accomplish the objective. A highly specialized Research Center was created to pursue this objective. The author became part of the initial group of six persons that started the grant's operation. All the members of this group were professors in the College of Business Administration, with the exception of the author, who was not a UTEP professor, neither in business nor in another college, but had a B. Sc. in Physics from the National University of Mexico (UNAM), and a M. Sc. and a Ph. D. in Materials Science and Engineering from Stanford University. The author had the experience of starting-up and operating several tech-based companies in Mexico and the USA. The author's participated in the design of teaching, research and developing programs, and teach a course he designed and called "Entrepreneurship for Scientists and Engineers".

Universities all over are trying to become more effective at entrepreneurial education**,** by generating new income from commercializing research and intellectual property. Important initiatives to fostering entrepreneurship are patenting and licensing**,** creating incubators**,** science parks**,** university spin-offs**,** and investing equity in start-ups.

4. SCIENCE, TECHNOLOGY AND ENGINEERING ENTREPRENEURSHIP

Technology Entrepreneurship. Technology has gone from novelty to necessity, empowering speed and effectiveness in the workplace, and reducing the potential for human error. That happens when knowledge generation (invention) is launched into the marketplace to become an innovation. Entrepreneurs are those that commercialize technologies. Accordingly, teaching entrepreneurship to those individuals in charge of technology development, fosters creativity and enhances the ability to develop commercially viable ideas.

Engineering Entrepreneurship. As Nelson and Byers pointed out (10), it is no longer enough to come out of school with a purely technical education; engineers need to be entrepreneurial in order to understand and contribute in the context of market and business pressures. For engineers who start companies soon after graduation, entrepreneurship education gives them solid experience in product design and development, prototyping, technology trends, and market analysis (10). In many US universities, entrepreneurship is no longer confined to business schools. It is one of the fastest growing subjects in undergraduate education, with formal programs from 1975 to 2006 (11). High impact

entrepreneurial ventures have three characteristics: they are innovative; value-creating and growth-oriented. These are the premises that lead the educational programs of those universities that offer Technology and Engineering Entrepreneurship.

Science Entrepreneurship. University-industry technology transfer has long been perceived as the Holy Grail in science and innovation policy. Universities and companies strive to collaborate in research projects, enhancing their mutual innovative potential. Innovation policies assume that a lack of university-industry technology transfer is due to a lack of collaboration between scientists and external parties (12). University to industry technology transfer has been based on the research done by professor and students. However, in the last two decades, it became clear that in order accelerate this process; universities should teach entrepreneurship to their science and engineering students to learn to develop an entrepreneurial attitude in the mindset of the students, and how to turn scientific innovations into business opportunities.

This was the motivation of the author to offer a course on entrepreneurship to science and engineering students, through the Colleges of Science and Engineering at the University of Texas at El Paso (UTEP). Ever since the first course, the results were not only satisfactory, but astonishing.

5. ENTREPRENEURSHIP FOR SCIENTISTS AND ENGINEERS AT UTEP

Origins. The Kauffman Foundation launched the **Kauffman Campuses Initiative** (**KCI**) in 2003 to encourage new, interdisciplinary entrepreneurship education programs throughout American colleges and universities. As mentioned before, eight universities were part of KCI when it launched in 2003. In 2006, five more universities and five Northeast Ohio liberal arts colleges were selected. UTEP formed the Center for Entrepreneurship, Development, Advancement, Research and Studies (CEDARS) on 2004.

By 2006 there were at UTEP three undergraduate courses in entrepreneurship (entrepreneurship, franchising, small business management), one masters level course (corporate entrepreneurship), and one doctoral level (international entrepreneurship), and some experimental course, among them **Entrepreneurship for Science and Engineering Majors**, and several sections on the **Entering Students Program** on various entrepreneurship topics.

The Course-First Stage. The first course was proposed for the fall semester of 2006. This first stage was effective for three semesters at the College of Science.
Objectives: This course was designed to create in the student the awareness of the value of entrepreneurial education in the world of science and engineering, and to describe how the intellectual capital generated by university research, and the resulting new scientific and technological discoveries, can be commercialized. The attendees learned to identify opportunities derived from scientific and technological research activities, and working as teams will develop a profile of a technology venture.
Prerequisites: Senior-level undergraduate student, or graduate students status.
Team Project 1: Identifying a technology from university research. Senior Science and Engineering students are much aware and capable to understand the research and development projects in different fields. Students were asked to form teams to analyze the research in universities, or UTEP.
Team Project 2: Organizing a technology venture. Once the research project is selected, the student teams were asked to organize a technology venture by writing a *business profile* on how successful that product/technology would be if commercialized.
Content: The student learned the how to write a business profile: market analysis, marketing and sales plans, start-up legal structure, equipment for a manufacturing plant if such were the case, investments, plant lay out, operations, production and administration personnel, raw materials, inventories, packing and shipment of finished products, costs and expenses, financial statements, five-year pro-forma financial forecast, potential venture funding by equity position, owners and venture capitalists equity, company valuation, intellectual property filling and valuation, shares structure, and the Prospectus.

Evaluation and testing. As reported by Torrance, Wendy (13): "*The schools also created numerous centers for entrepreneurship, innovation, and creativity, and countless students were encouraged to share their ideas through competitions*." That was the case for this course. The course had no midterm and no final exam. The students were asked to give presentations of their work advances on the midterm, and a final presentation and a written report for the final exam. For the final presentation, business owners from the local community and professors were invited to act as jurors evaluating the quality of the work. But the final exam was also a contest. The jurors were asked to select the best presentation, and a price was given to the first place.
Course population: the course became popular among students in Electrical Engineering and Computer Sciences, College of Engineering, and among Biologists and Bioengineers, College of Science. During three semesters the total population had an average of 20 students per group.
Outcome: the course was offered for three semesters, student teams selected a wide variety of technologies as their team projects: In renewable energies, the students developed the business plan for a local company commercializing state of the art photovoltaics.
On two consecutive semesters international students coming from the neighbor city of Juarez, Mexico that were studying Computer Science, formed teams and prepared business plans of companies designing videogames. Upon graduation they started their companies in Juarez.
A student studying bioengineering developed a company that would develop computer simulation models for the medical sciences.

The Course-Second Stage. As reported by Torrance, Wendy (13) on the KCI "*Several schools incorporated entrepreneurship into courses required for all students. Campuses as diverse as UTEP, Arizona State, … introduced large numbers of students to the principles of entrepreneurship and innovation... UTEP, likewise, incorporated entrepreneurship into* ***University Studies 1301****, an introductory course that is required for all entering freshmen*". Accordingly, the second stage consisted on switching the course offering to senior science and engineering students, to the first semester for entering students; that is University Studies 1301, part of the "**Entering Students Program**".
Content: the Entering Students Program Course is divided into two parts. In the first part the student receives an introduction to the university on topics like "Academic resources"; "Money matters"; and so no. In the second part, the student received in parallel to the first part, an introduction to their major topics, in this case "**Knowledge Entrepreneurship" (**for Scientists and Engineers), following a similar content than then one described before, but not as detailed since these were students that were taking their first college courses, and they only had one half of the time available. However the content was enough for the students to prepare a business profile on their ideas.
Duration. This course was offered once a year to two or three groups of an average of 40 students per course per year, during the period 2009-2016.
Outcome. Since the students were registered on science and engineering mayors, it became evident that ever since the beginning of their college education, courses on entrepreneurship will perfectly supplement their technical and scientific orientation. There were several cases that after taking the course, the students decided to switch to a business mayor. Some of them decided to open up ever at their young age, their own small business, or to dedicate their energies to learning the management of the family business, since they would inherit it.

The course-third stage. The third stage was on the 2019-2020 period. It was offered for three semesters having an average audience of 10 students per course. In this period, half of the students were in the M.Sc. and Ph. D. programs from the Department of Electrical Engineering and Computer Science. As graduate students were participating, some topics like business finances and Intellectual Property valuation were discussed in deeper detail.
Outcome. Having graduate students registered in the course significantly raised the level and sophistication of their projects. Out of ten projects presented, the judging committees and the students

agreed that most of them were patentable, so that some of the student teams proceeded to establish contact with patent law firms for filling preliminary patents. Some of those projects were:

1. "Dim-Brid, Inc.". An *Augmented Reality* company specialized in manufacturing **smart glasses** and **wearable technology** as applied to the Manufacturing Industry. The product "**Mercury I"** provides cost-effective solutions for applications like: Fast Communication, Inventory Management, Failure detection, and To-Do lists. **Mercury I** supports a range of accessories making it easily adaptable for operations within warehousing, field service, training and design. Features include two HD Cameras to provide "Stereo Vision"; microphones and speakers to allow communication; an AMLCD screen for AR functionality; an abundance of software to accommodate hardware. **Status**: students started negotiations with a patent law firm.
2. Multi_Key, Inc. a Company developing local control of multiple computers from a single mouse and keyboard. Features: Easily add multiple computers to the same keyboard and mouse. Configuration and setup handled by the keyboard, no need to install software or setup up the computer. Cross computer clipboard allows for easy transfer of smaller files as well as images and text. **Status**: initiated approach to patent law firms.

All the business plans presented on this Course-Third Stage included similar innovative ideas, and the financial projections demonstrated that they are not only financially feasible, but the Prospectus offered a very attractive alternative to venture capitalist. Unfortunately the course could no longer be offered due to lack of funding, since the grant available became to an end.

The course-fourth stage. A short 20 hr. course was offered to the Ciudad Juarez, Mexico, Technology Institute on March 2021. In this case, the audiences were the Professors, and some senior and graduate students, covering about the same topics, but focused on selecting the faculty research projects on technologies that could have a real life application and solve real life problems. Again, the outcomes were outstanding. The selected projects were prepared by professor-students teams, some of them on research already in-course. The course allowed them to acquire an overall view of their technologies' market opportunities and financial feasibility. Similar courses are offered to other Institutes in Mexico.

6. CONCLUSIONS

1. Evidence obtained from the experience of offering this course to students at different levels of their careers, demonstrate that teaching entrepreneurship in science and engineering, allows students expanding their overall view on how technological advances, and their future professional development, should be oriented on solving real life problems.
2. Bringing technology to the market place is not only a matter of forming profitable businesses that have a rapid growth and that create high-paid jobs to regional development, but is also a matter of social responsibility to raise the socioeconomic level of the communities where courses are being offered, because these technology-based start-ups have a concomitant effect in terms of products and services required for operation, a cascade of regional socioeconomic proportions.
3. When offered to professors, the course demonstrated that orienting their research to solve current problems, is a matter of social responsibility as well, because the investments done on grants and R&D programs are in this way focused to satisfy market needs.
4. A call is made to professionals on entrepreneurship dissemination to focus on science and engineering schools, not only to follow the example of top universities like Stanford, MIT and Harvard, and their financial success, but to contribute to the technology expansion that should be oriented to solving the many problems the humanity faces nowadays, and the potential collapse of our civilization due to natural phenomena like global warming, or the environmental degradation produced by humans in their efforts to profit without considering collateral effects.
5. Author contribution**.** The reported experiences on a 14 year period demonstrate that the course readily provides elements for students and professors to work on technologies that are designed to

solve specific problems, with the advantage of being eligible for filling the intellectual property either as patents or trade secrets.

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CONFERENCE'S QUESTION

1. **Q.** Are there any problems in teaching the course?
   A. There are problems when teaching the course to professors or researchers, since they are used to select their research topics in terms of available grants or on topics selected from previous research, and those topics do not necessarily are focused on solving real-life problems are their results to be launched in the marketplace. In those cases it is generally considered that the entrepreneurship training does not apply for their jobs. However, this is not necessarily true; pure research in many cases has turned to be useful for novel discoveries and technologies. Therefore, the researchers will find extremely useful to count with the entrepreneurial training for advancing their research to formal applications.