Synergistic use of private and governmental resources in Science Technology and Innovation to leverage industrial development: a proven model of success with ten years of excellent learning experiences

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Abstract – ***This document describes how a group of researchers concerned about financing high impact graduate level engineering projects and attract top talents to work in solving them, founded in 2008 the "Industrial Consortium to Foster Applied Research and Enhance Regional Economic Growth in México". This program, after running for ten years, was able to graduate 85 Masters and 5 PhDs students who worked in projects provided by twelve industrial companies and were mentored by faculty and leading industrial engineers. Most of these new graduate are now happily working, in Mexico, at the companies that supported their research projects. To make this program sustainable for the school of engineering, the companies were requested to financially support the program. At the end of the first 10th years of running the program the amount of money received from the industrial sector, and eventually from the Mexican Government, was in the order of five million dollars. With this financial support the program was able to convene top Mexican talents, independently of their own economic resources, to pursue graduate studies and provide innovative solutions to the specific engineering projects proposed by the industrial sector. Furthermore, a good percentage of these graduate students were able to publish their research work in international journals and conferences. The program also proved to be an excellent tool for talent retention, enhance industrial research and foster high tech continuous education at the participant industrial companies. With the aim to help other researchers to replicate this experience, this document present the main steps and barriers encountered during the first ten years of experience of this program and leaves opened several aspects that can be improved in any future replication.***

Keywords—Industrial consortium to foster applied research, talent retention in developing regions, innovation to leverage industrial development, "Educational Innovation" and "Higher Education"

I. Introduction.

Engineering research in higher education institutions has been traditionally financed by government grants to fulfil the university research needs, including that of their PhD students who need to publish two articles in international journals as a usual requirement to get their doctoral degree. As the economic resources to conduct research are provided by the governments, most of the prestigious research centers in Latin America are found in large public universities. Besides, public and private universities struggle to get economic resources to support their research and improve the quality of the education they deliver, and to be well positioned, by the number of scientific publications, in the many university ranking systems. Moreover, defining priorities in the research lines becomes a very hard task for deans and research directors and most of the time these budgetary discussions affect the organizational climate that is needed to ensure good results in scientific production that finally will have significant impact in their students and society. Tecnológico de Mon-terrey is the largest private university in Mexico with a top ranked engineering school, see [1]. It is well known by the quality of their graduates and by the excellent connection with the Mexican industry. In fact, it was founded 75 years ago by a group of industrial leaders. In particular, Monterrey is a large industrial city, located near the United States of America border, with two large and prestigious uni-versities, among others. The availability of a significant number of well-trained bilingual engineers and qualified labor force in the Mon-terrey´s area is attracting a large number of high-tech companies that are moving their manufacturing facilities and, most of all, their engi-neering design centers to this region. The fast-growing engineering demand of well-trained people, create a niche for an Industrial Consortium of Companies and University. This growth, in turn, attracts top engineering talents from all Mexico to Monterrey. A few of these young talented engineers are selected by the Consortium partner ´s companies and supported to be enrolled in a full-time graduate pro-gram with tuition and fees fully paid by the companies. Since the admission of the first generation of students, August 2008, the pro-gram experimented a steady growth, in the number of students and sponsor companies, and since 2016 the Mexican Government has been sponsoring 32 master and 4 PhD students to focus their studies in the national critical areas related to the new energy market trends. The grant received from the government, SENER-CONACyT, has had direct impact in the academic activities of the students covering tuition, fees and leaving expenses, plus a small stipend for expenses related with the preparation of their thesis, like electronics compo-nents, special software and eventually some field travels that may be absolutely necessary to accomplish good results in their research projects. Additionally, the government´s grant allocated funds to establish a sound relationship with two American leading universities in the field of engineering, Arizona State University and University of California at Berkeley, to joint efforts in two large research project: Interconnecting USA and Mexico with Direct Current Power Lines HVDC and High Penetration of Renewables Injected at the Distribution Level. Thanks to this grant some students had the chance to spend one semester abroad, at the previous mentioned institutions, to acquire international experience.

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This paper describes, in details, the origin, motivation and implementation of the "Industrial Consortium to Foster Applied Research and Enhance Regional Economic Growth" before and after receiving government support. In summary, it is a well-rounded program where all the stakeholders: universities, private companies and government, win. Additionally, it is our belief that it can be replicated in many regions in Latin America with success.

II. BACKGROUND AND MOTIVATION.

In modern times, industrial companies struggle to reduce costs and remain competitive in the market. The fast changing technologies and product innovations are also threatening them and, to survive and stay in business, they have to introduce new innovative products in the market to stay ahead of their competitors. China and India are countries with excellent offers of cheap labor and well trained reverse design engineers, capable of reproducing most of the occidental products at a lower price. However, direct design of new products requires another type of personal ability, like deep knowledge of basic engineering fundamentals, new emerging technologies and modern engineering design tools. Monterrey grew up as an industrial city, mostly devoted to manufacturing products in large industrial companies in the area of steel, glass, beverages, power electric transformers and, industrial products in general, with a solid demand for exporting due to an excellent commercial relationship with large economic markets.

The Mexican companies, which must compete with China and India, started to introduce added value to their products, manufactured in Mexico, incorporating new designs and innovations to transform their products from "Made in Mexico" to "Designed and Made in Mexico". This trend soon required better trained engineers to design new products, and this sparked the idea of founding a Consortium with companies that have similar requirements for skilled people and to train all of them under the umbrella of a full time engineering graduate program. However, faculty know that real industrial experience seldom comes in books or scientific papers, so a decision was made to ask companies to support the students, and faculty, with their top engineers as mentors for the students in their thesis projects. On the other hand, the university understands that there is a need to attract top talents from all over the world willing to work hard in applied research to get new patents, publish scientific papers and create wealth for the sponsoring companies. With all these objectives in mind a group of five companies founded the Industrial Consortium to Foster Applied Research in Mexico in February 2008 and this document share part of the experiences acquired since them.

III. UNIVERSITY-INDUSTRY PARTNERSHIP, THE SYNERGY THAT MAY CHANGE THE INDUSTRIAL FUTURE

It is well known that most of the top engineering students receive good work offers from leading companies at the time of their bachelor graduation, but a few of them reject these offers, as they are willing to pursue graduate studies. These students are not attracted by just a good salary; their driving force is to acquire new theoretical knowledge that they can apply to design new high tech products. Hard workers, innovators, strong in math, physics and engineering fundamentals are common characteristics of this small group of people. Additionally, most of them look at well-known international universities as the place to continue their education and perhaps, after graduation, emigrate to get more challenging working positions.

The challenge for México is to retain these talents in the country and keep them working in local companies applying their knowledge to create new innovative products and improve the international competitiveness of the region. In the long term, those countries that will be able to retain their talent, will experience a steady economic growth that will warranty sustainability.

In response to these facts, Tecnológico de Monterrey created the Industrial Consortium to Foster Applied Research and attracts top talent, searching for a high ranked graduate program, and asked the companies to first select and second retain the students that best fit their needs. After selecting the best candidates the companies assign them to a full time graduate program that will prepare the students to face the challenges and solve the problems that the company assign to them the very first day of the students in the program. The Industrial Consortium started academic activities in August 2008 with thirteen students, selected by five companies. Before that time, about one year of negotiations was spent by the founding group to establish the engineering areas that the Consortium should focus on and to work out the legal framework, especially with intellectual property issues.

Even before the first generation of students graduated, all five companies were convinced that the Consortium´s original idea was working very well for them and synergy among companies was found which enhanced the program. The young talents were happy working with experienced engineers, provided by the sponsoring companies, and closely assisted by faculty in finding new areas to develop/improve products in an effective way. This relationship always enriches the educational process and provides tangible benefits for all stakeholders. Their impact to the business was clearly a successful indicator that the solution to the challenges that led to the foundation of this Industrial Consortium was appropriate.

IV. ENERGY THE BEST FIT TO FULFIL THE INDUSTRY NEEDS

One of the great challenges during the inception of the Consortium was searching for an area that would fulfil the needs of most companies willing to invest in training new talent, and at the same time, sharing educational resources to cut cost. It was clear to the sponsor companies that the selected area should be sufficiently attractive for all of them, but not too specialized, to allow the synergy of sharing common computer platforms, expensive software packages, courses, seminars, and other educational aids like laboratories. In addition, a "design center" was recreated with adequate office space to accommodate the students in a real industrial setting. An atmosphere of hard work and collaboration among students was immediately created.

Energy Engineering and Energy Efficiency were finally the selected research areas. All partner companies agreed that under this umbrella they were able to accommodate many different engineering projects, ranging from those heavily oriented to electrical power systems analysis in presence of large nonlinear loads, like Electrical Arc Furnaces for the steel making industry, to combustion in large Steam Power Plants or Combined Cycles.

Design of new electrical devices, electronics converters, thermal equipment, chemical processes, and renewable energy systems are active areas were the students are currently working sponsored by the partner companies and under the advice and supervision of their respective company mentors and faculty. More recent projects can be found in Reference [2].

Several scientific contributions, like patents, new products and indexed publications, were recently produced by this group of talented people. Additionally, significant energy savings were reported by a company that focuses their research in the area of Electric Arc Furnaces for the steelmaking industry.

V. THE STAKEHOLDERS: COMPANY, UNIVERSITY AND STUDENTS

The three main stakeholders in this consortium are: company, university and students. A successful program needed to address all their collective needs.

1) Companies have the necessity to develop technologies to compete globally. They cannot afford to keep all their engineers well updated with new emerging technologies. They cannot afford to have state of the art technologies, in computing platforms and design software licenses, to support the limited design capabilities of their production engineers. They have a hard time recruiting top young talent that will support their activities and keep them updated with new technologies.
2) Prestigious universities have graduate programs that attract talented people driven by their need to acquire new knowledge. All graduate students enrolled in the leading graduate program spend one third of the time conducting research in the field of their master/ PhD thesis or dissertations. Defining the area of research, at the beginning of their graduate program, becomes a hard task for the student due to his/her lack of industrial experience. Expensive computing platforms and software licenses are available and shared with many other programs. Faculty feels more comfortable lecturing the material in a textbook and facing, in class, problems with well-known solutions.
3) Top students like to devote all their time to study mandatory courses and conduct research in his/her area of interest only when time permits. They do not want to have the need to work while studying. They may ignore what is happening in the local industries and how their time devoted to research could have a positive impact in regional companies.

Considering the above facts, interest and preferences, the Industrial Consortium was the answer to all of them. Top company engineers are willing to improve their knowledge and share industrial experience with young students, additionally they know which are the company needs and the economic impact of many areas that require improvement, but they do not have the time and sometimes the knowledge to conduct a deep study using modern simulation tools. The faculty is sometimes afraid to work in solving real company problems, but when supported by company technology leaders, they will accept new challenges to establish good ties with industry. Students get their projects defined from the very first day in the program and have the certainty that their research work will contribute to the economic development of the region. Additionally, he/she will receive from the company an economic support, equivalent to the salary of a junior engineer, as well as full tuition and fees to pay the university.

The reader might be wondering why a company would invest money and time of their top engineers to support a program like this. Well, the answer was obvious after graduation of the program's first generation of students. All of them were hired by the companies that supported this initiative and many of them are still working in the same area in which they were trained in their time at university. The transition from university to industry was seamless for these students, as they spend two years working in solving company problems with continuous assistance of their engineers.

VI. COMPANY AND UNIVERSITY COMMITMENTS

To secure the formation of human resources, responding to the real needs of the industrial partners, specialized in the design of middle and high technology equipment, capable of performing research, generate and transfer practical knowledge, a Group of Committed Industrial Companies decided to strengthen the Engineering Graduate Programs, by strongly bonding them with the needs of local industry and agreeing in the following actions:

a) Integrate, as partners, a fellowship of companies oriented to design new high tech products and incorporate them in their manufacturing chains to nurture the economic growth of the region.
b) Participate in the student selection process of those who wish to enter the graduate program, identifying those who possess a suitable industrial profile to meet the requirements of their companies and those who also had a distinguished performance in their bachelor studies.
c) Support the best talent that, assisted by the engineering staff and human resources personnel of the partner companies may recruit at the top engineering schools of the country. The cost of the tuition and personal expenses, in present times (2019), is about 25,000 U$D/year per student at the host university.
d) Additionally, the program is assisted with economic support, only on very particular cases, for those students that after identifying top specialists in his/her area of research in leading institutions of the world, they manage to establish a sound working relationship with them, to spend one semester working abroad as visiting students.
e) Provide innovative research and development projects to involve graduate students and facilitate their top design engineers, to serve as mentors for them and follow closely their study progress and thesis.
f) To motivate their own engineers in participating in the process of forming graduate students by lecturing some classes in their field of expertise in team teaching with full-time faculty.
g) To define the basic areas of interest of the graduate program that will be used by the university and the companies themselves in the process of promotion and recruitment of new students.
h) To participate with their engineers in the periodic meetings of the Industrial Consortium to support in defining the courses which the selected students must take for the whole 18/24 months while they remain at the university.
i) To contribute economically with the student recruitment process, research activities and trips to conferences, by paying "membership fees" that are administered to cover said expenses. The cost of this membership was set to 2,500 USD per student for the whole duration of the students program.

j) To help the university widen its network amongst their contacts with the best engineering schools in the country, by jointly inviting talent to enter this graduate program and sponsor their graduate studies.

Additionally, the university, as coordinator of the fellowship, commits to:

1) Attract the best talent, both in national and foreign universities, to fill the places that the Consortium defines for their needs. This implies same travelling to make presentations of the program with the sponsoring companies, at major events of different engineering schools.
2) Create a work environment, based on a culture of effort, dedication and collaboration, which facilitates knowledge generation and ideas that can be turned into products with a high added value for the member companies in the Consortium.
3) Provide adequate space for study, meetings and properly equipped laboratories so the students, teachers and the companies' mentors may perform their work in an efficient way.
4) Protect, in a secure and efficient way, the intellectual property of every company that takes part in the Consortium.
5) Recognize the companies supporting the program by including their names and logos in every promotional brochure of the graduate program.
6) Promote new research projects in areas which may benefit the regional economic growth by creating products and systems of high added value.
7) Organize annual meetings, with the participation of all Consortium members to evaluate the results of the graduate program, performance of the students and teachers, student recruitment, and define new goals and objectives for the next year. Finally, the consortium´s director must present an account audit for all funds received from the company and government.
8) As a recognition to the trust that these industrial companies place in the educational institution, the university assumes responsibility of paying the wages and assign the necessary academic load to this activity so their best professors may directly contribute to the formation of these students in the graduate program and to keep open communication channels to assure that teaching and research responds effectively to the companies' needs.

VII. KEY POINTS AND MAIN DIFFERENCES WITH TRADITIO AL ENGINEERING GRADUATE PROGRAMS

Thanks to the economic support provided by companies the students receive a monthly stipend equivalent to the starting salary of any good engineer in the regional companies. In addition, he/she gets tuition, fees and medical insurance expenses fully paid by the sponsor company. Several courses are taught in "team teaching" by faculty and leading engineers from the sponsor companies. Every week the students take part in technical debates/seminars, where they present the progress of their research work and an open discussion is generated to train them in collective learning techniques. In addition, they are trained to do high quality technical presentations and improving their communication skills. Those students that acquire excellent communication abilities and their research projects are relevant, are encouraged to publish the results in journals or present the work at international conferences to establish ties with world leaders in the area of their research.

The final admission in the program is granted by the sponsor companies. All suitable candidates must have outstanding records from his/her previous engineering studies, advanced English proficiency, sound knowledge in basic sciences, such us physics, math and computing, in addition to master their main area of expertise, like electrical, mechanical, electronics, etc. Students must adhere to rules of the Consortium specially those about intellectual property rights. All candidates must present and pass, with excellent grades, the admission graduate examination prepared by the educational institution.

VIII. LESSONS LEARNED

The Industrial Consortium is a successful program which has demonstrated that investing in applied research can be sustainable, cost effective and strategic for an international company willing to settle in a foreign country. A research center, associated to an industrial company, is like the roots of a tree, needed to be feed by innovations in new products and to monitor the evolution of disruptive technologies driven by competitors that could threaten the stability of the company.

In the herein presented Consortium, after ten/eleven years of hard work, the number of students remain limited by the number of faculty with time and willingness to work in this type of projects, however, the number of companies doubled from the original five. The complexity of the new engineering projects available from the industrial companies is increasing with time and new students are faced with more challenging projects. This requires more time and dedication from the students, mentors and faculty.

Company mentors are quite limited in time to assist their students and to attend the weekly session of debate organized by the consortium. However, several companies require that the faculty advisors spend more time, not only in helping the student, but also to be more involved with the company mentors by paying frequent visits to meet and discuss alternative solutions to the projects at hand with them. The number of graduate students that remain working with the sponsor company, after graduation, is directly proportional to the time the company mentors spent in helping the student while in the program.

A challenge, jet to be solved, is that the program does not have any extra funds to reward faculty and/or mentors for their overload and, as said before, the amount of time required to mentor these students is considerable, especially when is added to the daily working load of engineers and faculty. This is an aspect to review in any new attempt to replicate this program, academic load is heavy and must be recognized by university for their faculty and companies for their mentors.

IX. CONCLUSIONS

The Industrial Consortium is now a well-established and sustainable program. It is another solution to the old problem of connecting educational institutions with local industry. At the same time, it creates the bridge between the creativity of young talent and the needs of local industries to remain competitive in the international market: It also creates economic growth and new jobs, bringing benefits to the region. These stimulates student and faculty actions to have a better

understanding of real engineering projects and encourages the companies to invest in applied research. It also helps to keep company engineers updated with new technologies and faculty connected to real world problems. In addition, it contributes to retain talents in the country by offering them very challenging and attractive job positions after graduation. In ten years "The Industrial Consortium" graduated 85 Master students and 5 PhDs, most of them are today working for their sponsors companies in Mexico, which proves that this program is effective in talent retention and capacity building for the Mexican industry. In summary, it is a well-rounded program where all the stakeholders win. Finally, we believe that it can be replicated with success in many regions of the world associated with most of the engineering and science programs of research universities.

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REFERENCES

[1] "QS Latin America University Rankings 2020" https://www.topuniversities.com/university-rankings/latin-american-university-rankings/2020
[2] "Industrial Consortium to Foster Applied Research & Roberto Rocca Energy Research Chair" http://www.mty.itesm.mx/dia/consorcio/