

Designing a Bachelor in Nanotechnology Engineering at Mexico

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Abstract: - We present an Undergraduate Program in Nanotechnology that takes on account the Nanosciences, Biotechnology and Information Sciences convergence model. Nevertheless state of the art infrastructure and Human resources specialized in Nanotechnology are major factors for attaining success when an Undergraduate Nanotechnology program is installed. In the case of Mexico, PROMEP scholarships for faculty improvement have been helpful for increasing the number of faculty holding diplomas on advanced studies in Nanoscience and Nanotechnology. Societal and Environmental studies on the impact of Nanotechnology are also considered.

Key-Words: - Undergraduate Program in Nanotechnology, PROMEP scholarships, NBI model, Nanotechnology faculty, Mexico.

1 Introduction

Nowadays many universities and institutes in the world have academic programs in MS and Ph.D. in Nanotechnology or Nanosciences. However, current developments in nanotechnology require increasing the opening of Bachelors in nanotechnology. The first university program involving nanotechnology was offered by the University of Toronto's Engineering Science Program, and then Flinders University in Australia offered the Bachelor of Nanotechnology. Today, a lot of Universities around the world offer BS and B. Eng.in Nanotechnology or Nanoscience, and Mexico is no exception, although opening this degree is not so simple [1-3]. National Science Foundation solicited this year Proposals for enhancing Nanotechnology Undergraduate Education (NUE) in Engineering [31]. In recent years several Mexican companies have been distributing and producing products based on nanotechnology, therefore a workforce trained in nanotechnology should be available in the following years at Mexico. Viral threats have been a major concern for Mexico

in 2009 and this year a new disinfectant based on Mexican nanotechnology is being successfully tested on many viral and bacterial strands namely influenza H1N1, E. Colli, etc. Using this kind of nanotechnology products requires the development of new industrial methods of production where sound undergraduate training in Nanotechnology will be imperative. The superiority of nanotechnology will solve strategic national problems which will lead to a so called Nanodivide where Nanotechnology may bring lot of benefits to the countries that participate as agents but that may also relegate those countries that will play the role of spectators in the Nanotechnology Revolution. A successful Undergraduate Program in Nanotechnology should be based in the well known group of convergent technologies namely Molecular Biology, Information Technology and Nanoscale Science. Undergraduate training in Nanotechnology will develop the new skills required by the novel nanotechnology Mexican industries which will lead to a better distribution of wealth. Nevertheless, governmental funding for Science and Technology is

in the low range of 0.4% to 0.3% since 1997 which has been criticized by Nobel Prize Joseph Stiglitz. as The lack of proper funding of education, science and technology leads to a loss of competitiveness responsible for the acute loss in the GDP of 6.7% experienced by Mexican economy this year [32]. Mexican funding of experimental research in 2005 was about 5000 millions of Purchasing Power Parity units compared to 14000 millions of Purchasing Power Parity units invested by Brazil at that time. In spite of this low level of governmental support, more than 100 Mexican Nanotechnology patents are registered each year since 1997 [33].

2 Problem Formulation

We identify three fine points in the opening of a Nanotechnology Engineering Program.

2.1 Infrastructure

Nanotechnology necessarily requires experimentation based on synthesis and characterization equipment, and usually these are too expensive. This equipment may be obtained via research projects funded by Consejo Nacional de Ciencia y Tecnología (CONACYT), Secretaría de Educación Pública (SEP) and both Local and Federal Governments. Another instance is financial support of large private companies either national or from abroad. Also, it can be done collaborating with large universities and institutes whose infrastructure is extensive in Mexico namely UAM, IMP, UNAM, IPN, CINVESTAV, CIQA and CIMAV. Besides the above, projects could be financed by the Incubator for Nanotechnology Research and Innovation in the Technology Park at Monterrey [4] or through bilateral programs as the International Cooperation Program between Mexico and the European Union [5]. Undergraduate training in this kind of equipment can lead to efficient support of the local nanotechnology companies where the quality of products based on nanotechnology can be certified with the help of these expensive and sophisticated instruments. Once more a strong relation between the local companies, the universities and governmental institutions can help to attain a proper funding of the Nanotechnology Undergraduate Education Program as well as to enhance the competitiveness of local Nanotechnology companies as well as to the development of a safe regulation of Nanotechnology. A recent survey has detected the involvement of large and medium Mexican companies on nanotechnology production and commerce. CEMEX and Vitro are in this group of

Mexican companies that apply nanotechnology in the industrial fields of painting, ceramics, cement, steel, electrical materials, plastics, clothes, metals, chemicals and cosmetics. 449 were identified in this survey as well as 100 technicians, 87 postgraduate programs in 27 universities, with 44 Ph.D. programs, 43 MSc programs and 12 Undergraduate Nanotechnology Programs in Mexico. Ph.D. enrollment in these Nanotechnology Programs is 257 and MSc enrollment is about 216. Labs related to Nanotechnology are about 157 with 17 pilot plants with a total of 190 nanotechnology research projects detected in that survey [36]. NanoforumEULA also evaluated in 2007 the advancement of nanotechnology in Mexico, visiting several Mexican cities and detected several private companies, universities and consultants involved in nanotechnology although this evaluation indicated a lack of networking with other Mexican groups and with other international groups. These recent years several networks have been developed into the universities and with research groups from abroad and a linkage of the Undergraduate Nanotechnology Program with other universities should be built using the financial funds for Educational Exchange such as the one instituted by the National Association of Mexican Universities (ANUIES) [37] or the Summer School of the Mexican Academy of Sciences [38].

2.2 Human Resources

The number of universities offering a Nanotechnology Engineering Program in Mexico is growing at a rate of approximately one per year, and there are 87 academic programs related to nanotechnology [6-12]. There are more than 400 Mexican specialists in nanotechnology, and most of them have an excellent position in research within and outside the country, making it difficult to recruit them in new universities as teachers. For example, Dr. Mauricio Terrones was considered in the global top ten of Nanotechnology in Physica Status Solidi number 245, in late 2008. Mexican Nanotechnology Research Groups have a mean size of 5 and networks of these research groups have been created recently although a Mexican Nanotechnology Initiative needs to be created in the near future [34]. The difficulty of hiring faculty trained in nanotechnology can be overcome with the help of the PROMEP Program for Faculty Improvement [35], but relies on the preferences of faculty which not always is interested in doing postgraduate studies on Science and Technology.

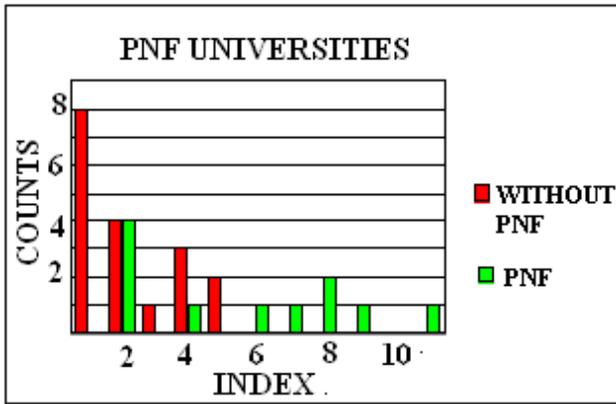


Fig. 1.-Correlation between the number of universities with PROMEP Nano Faculty (PNF) and an index that multiplies the percentage of PROMEP scholarships granted to that university times the percentage of these scholarships dedicated to Science and Technology.

Fig. 1 shows a correlation between the number of researchers funded by PROMEP and the number of PROMEP scholarships granted in engineering and basic sciences to the university where these researchers are based. These statistics prove that in several universities, faculty has participated actively in Mexican Nanotechnology. But some Mexican States are not involved yet in Nanotechnology. PROMEP program has consolidated several Nanotechnology research groups in Mexico. Postgraduate Studies in Nanotechnology can be pursued by faculty and others at universities and institutes in Mexico such as Universidad Autónoma Metropolitana which has a Nanotechnology Network and a Nanotechnology Laboratory unique in Latin America; Universidad Nacional Autónoma de México which has a General Network of Nanoscience and is classified between the 50 best universities worldwide; Instituto Potosino de Investigación Científica y Tecnológica which has a National Nanotechnology Laboratory I; Centro de Investigación y Estudios Avanzados with the National Nanotechnology Laboratory II; Instituto Mexicano del Petróleo with the Laboratory of Ultra High Resolution Electron Microscopy; Instituto Nacional de Astrofísica, Óptica y Electrónica with the National Laboratory of Nanoelectronics; Instituto Politécnico Nacional with the Nanoscience and Nanotechnology Center; Centro de Investigación y Estudios Avanzados with a PhD. Program in Nanosciences; and Centro de Investigación en Química Aplicada, among others [13-20]. In the other hand there are universities from abroad such as Erlangen-Nürnberg, Toronto University, Cambridge, Sussex, Oxford, Rice, and Waterloo who offer graduate courses in Nanotechnology and

Nanosciences [21-28]. Another way to obtain a degree in Nanotechnology is an online course in Nanotechnology offered by Oxford University who was the pioneer in these kinds of courses [29]. Notwithstanding, statistics prove that the number of nanotechnology researchers does not depend neither on the GDP of the State where the university is based (Fig. 2) or on the excessive expenses by State Government (Fig. 3). This means that involvement in Nanotechnology relies always on a personal choice as well as on priorities of local companies and the development plan of the local government.

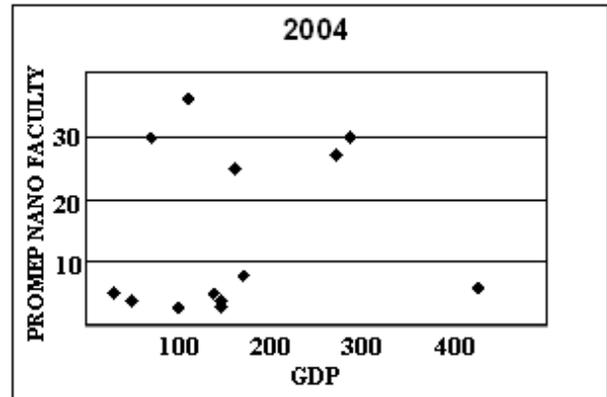


Fig 2.- Number of Nanoresearchers in a PROMEP nano research group versus GDP of the State where these groups are based.

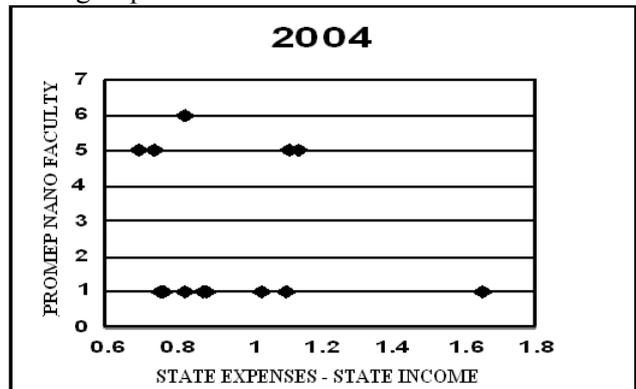


Fig 3.- Number of Nanoresearchers in PROMEP nano research groups versus Excessive Spending by the State Government where these groups are based.

2.3 Academic Programs

We believe that designing a Academic Program is essential for success of the Undergraduate Program in Nanotechnology. Such Academic Program must be consistent to new times, considering a comprehensive approach focused on technological and scientific research as well as involving students in the development of Nanotechnology Business. An example of a successful Academic program is the Program of B.Sc. in Nanoscale Science at Albany [30]. The academic Program (4.5 years) proposed by us hereby is shown in Fig. 3, based on Physics,

Chemistry and Biology. This academic program has an emphasis on synthesis and characterization of Nanomaterials with areas of concentration in electronics, biology and materials. Societal and environmental impacts of Nanotechnology are also addressed as required by the National Science Foundation since Nanotechnology may change our world and education in these dimensions is needed to attain an informed citizenry and a competitive workforce [31].

FOREIGN LANGUAGE I	FOREIGN LANGUAGE II	FOREIGN LANGUAGE III
CHEMISTRY I	CHEMISTRY II	CHEMISTRY III
PHYSICS I	PHYSICS II	PHYSICS III
DIFFERENTIAL CALCULUS	INTEGRAL CALCULUS	DIFFERENTIAL EQUATIONS
LINEAR ALGEBRA	VECTOR CALCULUS	MATERIALS SCIENCE
SOCIETAL IMPACTS OF NANOTECHNOLOGY	TROUBLE IN ENGINEERING	NANOTECHNOLOGY ENGINEERING

FOREIGN LANGUAGE IV	FOREIGN LANGUAGE V	FOREIGN LANGUAGE VI
THERMODYNAMICS	COMPUTATIONAL CHEMISTRY	ELECTRONICS I
SOLID STATE PHYSICS I	SOLID STATE PHYSICS II	PHYSICS-CHEMISTRY OF MATERIALS
FOURIER ANALYSIS	NUMERICAL METHODS	PROBABILITY AND STATISTICS
PROPERTIES OF MATERIALS	MOLECULAR MATERIALS AND NANOMATERIALS	ELECTRICAL CIRCUITS
SEMINAR I	CHARACTERIZATION TECHNIQUES I	CHARACTERIZATION TECHNIQUES II

FOREIGN LANGUAGE VII	FOREIGN LANGUAGE VIII	FOREIGN LANGUAGE IX
ELECTRONICS II	MICRO & NANOELECTRONICS	SENSORS & TRANSDUCERS
MOLECULAR MODELS	BIOLOGY	APPLICATION OF NANOTECHNOLOGY TO BIOLOGY
ALGORITHMS AND PROGRAMMING SOLUTIONS	DESIGN AND CONSTRUCTION EQUIPMENT	REVERSE ENGINEERING & BUSINESS
SEMINAR II	ENVIRONMENTAL PROBLEMS	SEMINAR III
CHARACTERIZATION TECHNIQUES III	NANOMATERIALS SYNTHESIS I	NANOMATERIALS SYNTHESIS II

Fig. 3.- Academic Curriculum of Bachelor in Nanotechnology Engineering proposed by us.

3 Conclusion

We conclude that the basis for future success for the opening of Bachelor of Nanotechnology Engineering in Mexico depends on three aspects: adequate

infrastructure of the laboratories, the challenge of hiring and training skilled human resources and a careful selection of topics of academic program. Faculty improvement funds have been crucial for developing Nanotechnology Academic Programs. Involvement with local companies and government can be also a major ingredient for success in terms of obtaining state of the art equipment for providing service to local industries and achieving a better distribution of wealth in the surroundings of the university where this Undergraduate Nanotechnology Program will be based. A.B acknowledges the support of a Postdoctoral Fellowship at CINVESTAV granted by CONACYT-48795 Fund.

References:

- [1] Sweeney, A.E., *Developing a viable knowledge base in nanoscale science and engineering, Nanoscale science and engineering education*, American Scientific, 2008.
- [2] Shapter, J.G., Hale, P., Maddox, L.M., Ford, M.J., Waclawik, E.R., *Journal of Materials Education*, Vol. 26, 2004, pp. 191-200.
- [3] *Nanoposts.com; Government Policy and Initiatives in Nanotechnology Worldwide*, 2007.
- [4] *Parque de Investigación e Innovación Tecnológica, PIIT, Monterrey, México, Incubadora de Nanotecnología*, [Oline] <http://www.piit.com.mx/>.
- [5] *Europea Nanotecnología, Acuerdo de Cooperación Científica y Tecnológica entre la Comunidad Europea y los Estados Unidos Mexicanos, FP7-NMP-2010-EU-Mexico "Adding value to mining at the nanostructure level"*, Programa de Cooperación Internacional: Bilateral, Convocatoria México- Unión, 2004.
- [6] *Diagnóstico y Perspectiva de la Nanotecnología en México*, CIMAV-FUNTEC-SE, 2008.
- [7] *Informe General del Estado de la Ciencia y la Tecnología*, CONACYT, 2006.
- [8] Castrillón, L.V., Nueva Licenciatura en Ingeniería en Nanotecnología, *Mundo Nano*, Cartas, Vol. 1, No.1, 2008.
- [9] Espinoza, J.A., Presenta ITT su nueva carrera de Ingeniería, El Sol de Tijuana, 26 Agosto del 2008.
- [10] *Licenciatura en Nanotecnología e Ingeniería Molecular*, UDLA-Puebla, 2009.
- [11] Una Nueva Universidad en Michoacán, Ingeniería en Nanotecnología, Sayula, Michoacán, [on línea]. <http://www.uci negam.edu.mx/>
- [12] González Hernández, J., Nanotechnology in Mexico, *ICAM*, 2009.

- [13] Solorzano, J., Laboratorio de Nanotecnología de la UAM, único en su tipo en América Latina, *Revista Casa Abierta al Tiempo*, Vol. I, No. 2, 2007.
- [14] *Instituto de Investigaciones en Materiales, Posgrados*, UNAM, [on line] <http://www.iim.unam.mx/>.
- [15] *Instituto Potosino de Investigación Científica y tecnológica, Posgrados en Nanotecnología*, IPICYT, [on line] <http://www.ipicyt.edu.mx/>.
- [16] *Centro de Investigación en Materiales Avanzados (CIMAV), Posgrado en Nanotecnología, Campus Chihuahua, Monterrey y Cd. Juárez*, [on line] <http://www.cimav.edu.mx/>.
- [17] Centro de Investigación en Química Aplicada, Departamento de Materiales Avanzados y Laboratorio de Microscopía, Saltillo, Coahuila, México. , [on line] <http://www.ciqua.mx/>.
- [18] Instituto Nacional de Astrofísica, Óptica y Electrónica, Laboratorio Nacional de Nanoelectrónica, Tonantzintla, Puebla, <http://www.inaoep.mx/>.
- [19] Programa de Doctorado en Nanociencia y Nanotecnología, Centro de Investigación y Estudios Avanzados, [on line] <http://cori.cinvestav.mx/Nano>
- [20] Instituto Mexicano del Petróleo (IMP), Postrado en Nanotecnología y Laboratorio de Ultra Alta Resolución, [on line] <http://www.imp.mx/>.
- [21] Universität Erlangen-Nürnberg, Nanotechnologie, Deutschland, [on line] <http://www.uni-erlangen.de/>
- [22] University of Toronto, Centre for Advanced Nanotechnology at the University of Toronto, Toronto, Canada, <http://www.utoronto.ca>
- [23] University of Cambridge, Nanoscience Centre, UK, <http://www.cam.ac.uk/>.
- [24] University of Sussex, UK, <http://www.sussex.ac.uk/>.
- [25] University of Oxford, UK, <http://www.ox.ac.uk/>.
- [26] Rice University, International Council on Nanotechnology, UK, <http://www.rice.edu/>
- [27] Servicio de Información Comunitario sobre Investigación y Desarrollo (ES) Comunidad Europea, <http://cordis.europa.eu/>
- [28] Parque de Investigación e Innovación Tecnológica (PIIT), Monterrey, Nuevo León, México, www.piit.com.mx/.
- [29] Tyrrell, J., Training for Nanotech: e-learning, Nanotechweb.org, IOP, Technology update [online]. <http://nanotechweb.org/cws/article/tech/30396>.
- [30] *Major Academic Pathway (MAP), B.S. in Nanoscale Science Semester-by-Semester*, The College of Nanoscale Science and Engineering of the University at Albany, Albany, 2009. [online] http://cnse.albany.edu/academic_programs/undergraduate/MAP.html.
- [31] Nanotechnology Undergraduate Education (NUE) in Engineering, Program Solicitation NSF 09-533, National Science Foundation, 2009. [on line] <http://www.nsf.gov/pubs/2009/nsf09533/nsf09533.html>
- [32] México, relegado; Brasil es el gigante de América Latina: Stiglitz, Nov 25th , 2009. [on line] <http://www.publimetro.com.mx/noticias/mexico-relegado-brasil-es-el-gigante-de-america-latina-stiglitz/pikv!PThSec3@pRfLbGflrBOQnQ/>
- [33] Palacios, J., Desarrollo Económico y Nanotecnología. Análisis y Perspectivas para la Economía Mexicana, *Razón y Palabra*, No. 68, 2009.
- [34] Barrañón, A., A power law for Mexican nanotechnology research groups size, *Proceedings of the 1st WSEAS international conference on Nanotechnology, World Scientific and Engineering Academy and Society (WSEAS)*, 2009, pp. 17-20.
- [35] *Programa de Mejoramiento del Profesorado. Un primer análisis de su operación el impactos en el proceso de fortalecimiento académico de las universidades públicas*, Secretaría de Educación Pública, 2006.
- [36] Diagnóstico y Prospectiva de la Nanotecnología en México, [online] <http://www.nanored.org.mx/documentos/Diagnostico%20y%20Prospectiva%20Nanotecnologia%20en%20Mexico.pdf>
- [37] Programa de la Red de Movilidad Nacional, ANUIES, 2009. [online] http://www.anui.es.mx/r_academicas/red_de_movilidad.php
- [38] Verano de la Investigación Científica, AMC, 2009.[online] <http://www.amc.unam.mx/modules.php?name=Content&pa=showpage&pid=4>.