The scientific training of graduates from three masters of science degree programs: a ten year follow up (1999-2009)

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Resumen

En México, la formación del científico inicia en el posgrado, específicamente en la Maestría en Ciencias, por lo que es necesario analizar cuántos egresados de este nivel se convierten en científicos. El objetivo de este trabajo fue llevar a cabo un seguimiento durante 10 años (1999-2009) de los egresados de tres programas de Maestría en Ciencias, usando como criterio de la formación como científicos, la publicación de dos o más artículos en revistas internacionales indexadas. Para el análisis, se usaron los datos de 100 estudiantes de tres maestrías en Ciencias que en 1999 cursaban este nivel de estudios en las Facultades de Medicina, Ciencias Biológicas e Ingeniería de la Universidad Autónoma de Nuevo León (UANL).

Palabras clave:

- Científico
- Vocación
- Maestría
- Posgrado
- Ciencia
- México

Abstract

In Mexico, a scientist's career begins in graduate studies, specifically at the Master of Science level, therefore it is necessary to analyze how many of the graduates from this level become scientists. This is a 10 year (1999-2009) follow up study of graduates from three Master of Science programs, using the publication of two or more indexed papers in international journals as the criterion for becoming a scientist. Data were collected from 100 students enrolled in 1999 in 3 Schools (Medicine, Biology and Engineering) at the Universidad Autónoma de Nuevo León.

Key words:

- Scientific career
- Science
- Research
- Master degree
- Postgraduate studies
- Mexico

Introduction

Science is an important element for the economic development of a country (Morales, 1999; Muñoz, 1991). Therefore, if a country is to compete at the international level it must be at the forefront of knowledge (Flores, 1982). Considering this, it can be argued that science is the basis for generating technology (Russell Group, 2010), as such a country lacking in it is forced to buy technological applications produced by other countries, thus generating an indefinite reliance on them (Pérez, 1988). To avoid this situation, it is necessary to have scientists able to produce the knowledge needed to strengthen national technological and economic development with quality and efficiency (Benítez, 1994).

However, to train scientists is far from simple, there is no universal recipe, since it is not known precisely what are the conditions required for the training of scientists (Loria, 1989). It has been suggested that this competence is acquired at the graduate level (masters and doctorate), but formal education is only part of the experiences that students require to be trained as scientists. Some authors have suggested that one way to induce young people to this activity is to expose them, as early as possible, by working in research centers (Fortes and Lomnitz, 1991). Thus, the learner can interact with teachers conducting research, publishing in international journals, value reading scholarly articles and giving lectures at conferences. In this environment, students can adopt the standards and the specific attitudes of the community and therefore develop their scientific vocation. Besides these aspects personal factors have been considered such as curiosity, perseverance, steadfastness, resistance to failure, among others, as important elements for a person to train as a scientist.

According to the sociology and psychology of science studies (Merton, 1977 and Singer, 1971) for the training of scientists it is necessary to take into account two aspects: theoretical, methodological and human. Therefore, it is important that students learn the theories and methods of a field of knowledge, but it is also relevant to know the rules of conduct for scientists, this means having knowledge of the norms, group rules, work style, perseverance, discipline, and scientific attitudes (Anderson, Louis, and Earle, 1994; Benítez, 1988).

Thus, Valdez (1996) proposes a model to study the training of a scientist. According to this model there are four crucial factors: contact with research, interaction with scientists, the conditions under which science is conducted and personal factors.

To promote contact with research a tutoring system has frequently been proposed, which means that interested young people join a working group, that is, a laboratory, department, center or clinic, where they can mimic a skilled person in a given area (Pérez, 1988). In the working group, students interact with both their tutor and other scientists. In this way, students learn the theories and methods of a field of knowledge, to raise and address problems, to propose hypotheses, to develop methods, techniques, to write scientific papers, to communicate with other scientists, and to correct errors (Merton, 1977).

An important element in the interaction proposed by this model are the tutors, who teach their disciples the problems and methods of a specific field of science (Pérez, 1988). However, there are tutors in the research medium that do not have the ideal characteristics and instead of inspiring they discourage students (Garza and Malo, 1988).

This model's third factor indicates the importance of a work environment that values research. In this environment, the student meets recognized scientists, as well as having the necessary resources, both human and material, to do science (Benítez, 1994).

Finally, the fourth factor indicates that it is necessary to study the personal motives, goals, priorities, consistency, persistence and discipline, and work styles (Pérez, 1988).

According to this proposal, having a space that covers these factors could ensure the training of a scientist. However, there are cases in which students have the necessary conditions for development but do not complete their training or when they finish they engage in another activities. Benítez-Bribiezca (1994) notes that scientific training is an arduous task, which involves a responsibility toward the scientific community and society, thus he proposes a broader study of the factors involved in the formation of the scientist.

As mentioned above, scientists are important to help a country's economic development, hence the first world countries recognize the need to train scientists, so they have proper conditions for training them. However, underdeveloped countries are not clear about the importance of science or scientific training, so the training of scientists in these countries involves many difficulties (Benítez, 1994, Valdez, 2005).

In Mexico, scientific training begins in graduate studies, specifically in an MSc program, which is considered an induction stage, while students are expected to consolidate their training in the PhD program (Ziman, 1972). Master's and doctoral degrees in science are supported by the National Council for Science and Technology (CONACYT). Students enrolled in master's and doctoral degrees that meet the criteria established by CONACYT's National Program for Quality Postgraduates (PNPC) receive a monthly grant for living expenses.

Nevertheless, Mexico still lacks the right conditions to promote science and scientific training (Cereijido, 1994, Maddox and Gee, 1994). The science budget is very limited, barely 0.37% of gross domestic product (GDP), while in developed countries this figure ranges from 2 to 3% (OECD, 2010). In addition, the real budget exercised in science is much lower, since priority is given to applied projects or technological development (Loyola and Paredes, 2008). Moreover, the country has few scientists, to date there are only 0.9 for every 1,000 workers, while in developed countries this figure is from 5 to 10. Another aspect to be stressed is that Mexico ranks last among the Organization for Economic Cooperation and Development (OECD) member countries, both in terms of the science budget, and the number of scientists (OECD, 2010). It should also be noted that research is centralized in Mexico City, where approximately 50% of resources devoted to science and over 50% of the country's scientists concentrate (CONACYT, 2007). However, it should be clarified that the lack of support for science in Mexico results in poor conditions for the training of scientists, as there are few scientists who can serve as tutors, few working groups where the student can be inserted and work along with several scientists, and there is no adequate infrastructure for students to learn science (Valdez, 2009).

Despite Mexico's problems as a developing country, it is necessary to learn about the process for training scientists to create the human resources that in the future will result in the development of the country (Fortes and Lomnitz, 1991). However, most of the publications addressing this issue consist of reflections and proposals by some scientists drawn from personal experience, other studies analyze the training conditions of science taking the statistical data published by different agencies, such as CONACYT, the Ministry of Public Education (SEP), OECD, etc. as base material.

To deepen this analysis, it is necessary to conduct follow-up studies of graduates from MSc and PhD programs, which would give an indication of how well these are really promoting the training of scientists in Mexico, and for these publications, under the graduates responsibility, in international journals as well as citations to their work, should be added as an indicator of graduates becoming scientists. The fundamental criterion basis for that being two or more papers published in indexed journals, which can be documented through a follow-up period of several years after graduation.

Publishing a single paper should not be considered evidence of the graduate becoming a scientist for it could have been the publication of the master's or doctoral thesis. In fact, some doctoral programs establish as a requirement for graduation the publication in an indexed journal of a student's article. As a result, one paper may only imply compliance with this requirement, but not necessarily mean that the person continued devoting to science. The purpose of this paper is do a 10 year (1999-2009) follow-up of graduates from three Master Of Science programs, using as a criterion of the graduate becoming a scientist, the publication of two or more articles in international indexed journals. Given the precarious conditions of science in Mexico, especially in the interior, it is hypothesized that the training of scientists in our country is very limited, and as so it is expected that few graduates continue to work in science.

Method

Data and analysis

We conducted a follow-up of 100 students (34 women and 66 men) who in 1999 were enrolled in a Master of Science in three faculties at the Universidad Autónoma de Nuevo León (UANL), at the age of 26.12±4.09 (mean ± standard deviation, range = 21-41). 31 from the Faculty of Medicine (Medicine) (16 men, 15 women), 33 from the Faculty of Biological Sciences (Biology) (20 men, 13 women) and 36 from the Faculty of Mechanical and Electrical Engineering (Engineering) (30 men, 6 women). The follow-up included the total number of students enrolled in the Master of Science in the Faculties mentioned. In 1999 all of these programs were registered in the PNPC, so the students mentioned were receiving a monthly stipend from CONACYT so they could be devoted full time to the Master Of Science program. It is pertinent to add that these programs are still enrolled in the PNPC.

The following databases were used:

1. Google Scholar (GS) and Science Citation Index Expanded (Institute for Scientific Information). These databases were searched for indexed publications by the graduates of the programs. Only publications that were indexed in Journal Citation Reports were included.
2. Journal Citation Reports (JCR) 2006 and 2008. These databases were consulted for the Impact Factor of the journal where the articles were published. The impact factor was sought in the JCR-2008, but some journals were not found in the database for that year, so we resorted to JCR-2006. The impact factor is a measure of the importance of a scientific publication. It basically consists of the average citations per article in the journal, calculated after obtaining the articles, dating for 2 years.
3. UANL's Electronic Catalogue. Through this base data were obtained on the graduates masters theses and those who continued their PhD at UANL.
4. Current list of researchers in the National System of Researchers (SNI) in 2009.

Procedure

The students' publications were searched from February 2008 to March 2009 in the Google Scholar database and Science Citation Index Expanded (Institute for Scientific Information), the search was conducted from the following combinations of students names:

1. Name, last name and mother's maiden name.
2. Last name and mother's maiden name.
3. Name and last name.
4. Last name and first name.

5. First name initial and last name.
6. Last name and first name initial.

In order to ensure that publications found in the databases belonged to students, the following criteria were taken into consideration:

1. Articles that matched the student's name were selected. If in the databases during the search only the initials of the participants appeared, these were collated with other information such as the student's full name (for example if the complete name was Juan Carlos López Pérez, the initials should be in the following order, JC López Pérez, Juan C. López Pérez, López Pérez JC, López Pérez Juan C., JC López, JC López, J. López, López J, etc.), the name of the university from which the author graduated, his or her place of birth, the place where the author completed his or her degree, the author's e-mail, if his or her masters thesis advisor or masters classmates were among the coauthors.
2. Only papers published in indexed journals were selected and book chapters, conference abstracts, theses, patents, articles in refereed journals or general interest magazines were excluded.
3. Then, through performing a search using Google Scholar the number of citations that each of the articles published had was obtained. Only external quotations were included, meaning those that did not include any of the authors of the particular article.
4. Subsequently, the number of authors was obtained as well as the position of the graduate in the list of co-authors in each of the published articles.
5. We obtained the number of graduates belonging to SNI, through the 2009 list of researchers.
6. Information about graduates' masters theses, and those who continued their PhD studies at the UANL, was obtained through the institution's electronic catalog.

Results

It was found that 78 students were awarded masters degrees. 28 in Medicine, 22 in Engineering and 28 in Biology. 16 students obtained a doctoral degree at the UANL. 8 in Medicine, 5 in Engineering and 3 in Biology. In 2009, 11 were enrolled in the SNI, 9 with candidate level and 2 with level I, 7 from Medicine, 2 from Biology and Engineering each. There were significant differences in the age of the students from each school ($F=9.65$, $df=2$, $p<0.001$), according to a post-hoc analysis medicine and biology students were older than those from Engineering (Medicine 28.10±4.25, Biology 26.48±4.32, Engineering 24.08±2.63). There were significant differences in gender according to school (Chi square=8.10, $p<0.02$), in Medicine there was no difference between men (n=16) and women (n=15), but in biology and engineering were more men than women (Biology 20 men, 13 women; Engineering 30 men, 6 women) (Table 1).

Table 1
Overview

School	N	Age	Gender	
		Average (s)	F	M
Medicine	31	28.10 (4.25)	15	16
Biology	33	26.48 (4.32)	13	20
Engineering	36	24.08 (2.63)	6	30
Total	100	26.12 (4.09)	34	66

N=participant number, s=Standard deviation, F=Female, M=Male.

It was found that 65 students did not publish any papers and 35 students published at least one article in indexed journals, 14 of them published only one article and 21 published two or more papers. This allowed us to classify students into three groups: P-0 Group (without publications), P-1 Group (one publication) and P-2 Group (with two or more publications). Table 2 presents the results of each of these three groups.

Group P-0 (not published) (n=65), 12 were from Medicine, 23 and 30, from Biology and Engineering.

Group P-1, in which, 6 were from Medicine, 4 from Biology and Engineering each, obtained a mean of 0.35±0.74 citations per article, 0.5±0.83 for Medicine, 0.5±1 for Biology and 0 for Engineering. They published on average with 5±2.25 collaborators, Medicine with 6.16±2.56, those in Biology with 5±1.41 and in Engineering with 3.25±1.5. As co-authors they occupied an average position of 2±1.24, for Medicine 2±1.26, in Biology 2.75±1.5 and in Engineering 1.25±0.5.

Group P-2, in which 21 students published two or more papers, 13 were from medicine (42% of the School) 6 from Biology (18% of the School) and 2 from Engineering (6% of the School). Published an average of 4.95±3.23 papers, 4.31±2.66 for Medicine, 6.33±4.59 for Biology and 5.00±1.41 for Engineering. These students obtained an average of 4.51±5.22 citations per paper, 3.79±5.55 for Medicine, 6.49±5.16 for Biology and 3.25±3.18 for Engineering. The number of citations from this group was higher than those obtained by the students who only published one paper ($U=43.5$, $p<0.001$). Their works appeared in journals with an average impact factor of 2.28±1.08. The students in this group published in journals with a higher impact factor in comparison to students who had only one article published ($U=74$, $p<0.02$). The 21 students on average published with 6.90±3.74 collaborators, for Medicine with 6.54±3.67, for biology with 8.58±4.01 and for Engineering with 4.25±2.47. They occupied an average position of 2.67±2.18 as coauthors, 3.04±2.43 for Medicine, 2.25±1.89 for Biology and 1.50±0.71 for Engineering.

There were no differences found between the two groups that had published (P-1 and P-2), in terms of gender, the average number of co-authors, or the position they occupied among them.

Table 2
Results of the groups according to the number of articles published

Group	Variable	Medicine	Biology	Engine	Total	U	p
		Average (s)	Average (s)	Average (s)	Average (s)		
P0 (No Publications) N= 65							
P1 (One Publication) N=14	Citations per article	0.5 (0.83)	0.5 (1)	0	0.35 (0.74)		
	Impact Factor	1.65 (0.73)	1.46 (1.35)	1.03 (0.44)	1.42 (0.86)		
	Co-authors	6.16 (2.56)	5 (1.41)	3.25 (1.5)	5 (2.25)		
	Position among co-authors	2 (1.26)	2.75 (1.5)	1.25 (0.5)	2 (1.24)		
P2 (Two or more Publications) N=21	Papers Published	4.31 (2.66)	6.33 (4.59)	5.00 (1.41)	4.95 (3.23)		
	Citations per article	3.79 (5.55)	6.49 (5.16)	3.25 (3.18)	4.51 (5.23)	43.50	0.001
	Impact Factor	2.48 (1.3)	2.11 (0.49)	1.53 (0.31)	2.28 (1.08)	74.00	0.02
	Co-authors	6.54 (3.67)	8.58 (4)	4.25 (2.47)	6.9 (3.74)	93.00	NS
	Position among co-authors	3.04 (2.43)	2.25 (1.89)	1.5 (0.71)	2.67 (2.18)	128.00	NS

s=standard deviation, U=Mann-Whitney U test, comparisons between groups P1 and P2, NS=Not Significant.

Discussion

This study found that 21 of the 100 Master of Science students published two or more articles in international journals. According to the criteria used in this work, we can say that only these 21 students were trained as scientists. Consistent with this criterion, students that published only one paper had fewer citations. In contrast, the 21 students who published several papers obtained a higher average of citations and published in journals with a higher impact factor. The analysis only included external quotations, so the increase in the average number of citations is not due to self-references, this suggests that students with two or more papers published are more involved in scientific circles.

This study leaves more questions than answers. To begin, the main result is that only 21% of Masters students become scientists, is this figure high or low? We do not know what is the scientist training rate in other countries. However, efficiency is very low if we consider that the masters programs are registered in the PNPC, this implies that they have curricula designed to promote the training of scientists, PhD teachers, SNI faculty members, on top of the fact that students benefited from a scholarship enabling them to pursue their studies full time. What went wrong? Why do these conditions fail to train a greater number of scientists? The problem is even more serious when we note that there is great variability in the results for each school. Medicine trained 13 scientists (42% of students) Biology 6 (18%) and Engineering 2 (6%). Although medicine has the highest scientist output, the figure is still low, but it is even worse in Biology and Engineering. What factors promote more students becoming scientists in medicine, less in biology and only a few in Engineering?

One of the limitation of this study is that it is a small sample including only 100 students from 3 MSc programs. However, it includes the whole generation that was studying at this level during that time and corresponds to the number of students who usually enroll in these programs at the UANL.

As a form of reflection, we can raise some issues that may be involved with the problem of training scientists in Mexico. First, scientific education is not being promoted in a clear and systematic way at any educational level. Proof of this is the low performance in reading, math and science that is observed in the OECD test results (Guichard, 2005; Hopkins, Ahtaridou, Matthews, Posner, and Toledo, 2007). Undergraduate students lack basic knowledge about science, they see it as tedious, removed from reality, without concrete applications in real life. Students often confuse science with methodology courses, research design and philosophy of science, subjects they tend to look at as boring and useless, which contributes to further distorting their notions about science. Very few students have actively collaborated in a research project under the direct tutelage of a scientist. This situation would happen –occasionally– when students had to conduct a degree thesis, however, recently UANL removed the theses as a graduation option, which significantly increased the number of graduates who obtain degrees (completion rate) but cancelled this avenue of student interaction with science. In summary, the undergraduate degree does not promote scientific training either, but emphasizes technical training.

Due to these conditions, very few students enter graduate studies with the goal of becoming scientists. Some enter with the idea of being trained for a better job in the professional field. Others, with the idea that degrees will give them access to higher salary jobs in professional environments. Others complete their degree and are unable to find a job, so they enroll in graduate programs to generate an income (from the scholarship) that would allow them to get by for a few years. Some programs invite students with the highest undergraduate grade point average, which only attracts students trained to meet requirements, rather than students with a vocation for science. On the other hand, there is no real continuity between the masters and doctoral programs, so perhaps better results could be achieved through 5 year doctoral programs, aimed toward science training from the start.

Another problem in training are the conditions in which science takes place in Mexico, the budget for science is very low and there are few scientists who can serve as mentors for graduate students. Scientists working in Mexico have little time for science and to advise their students, as they have to pursue other activities. They are also responsible for seeking, and constantly managing, the funding for research projects, and mostly serve as teachers in various universities in the country for which they are paid low wages. To get extra income, they often resort to the various types of support available, but this in turn leads to an increase in activities other than research, filling out applications, updating their resumes, reporting, evaluating projects and graduate academic programs. On the one hand, they apply to be sni members and when getting this support they almost double their basic salary. They also apply for "program incentives for the performance of teaching staff for the strengthening of academic bodies", getting this incentive may triple their basic salary. However, to get this extra income the teachers have to apply for two different announcements of selection: obtaining a certificate as a "Distinguished Professor with Desirable Profile" and form part of an "Academic body" (Carmona and Reyes, 2009). This means filling out more applications and other requirements, such as: participating in the tutoring program (academic orientation) for undergraduate students, develop curricula, assess graduate programs and participate in administrative activities at the university.

Mexico has very few scientists, which are indispensable to develop the science required to promote economic development. It is therefore extremely important to train scientists. This paper examines how many scientists are trained from when they start to pursue a masters degree in science, according to the current conditions of the university and the country. The result is poor: graduate studies in Mexico are training few scientists. This type of feedback can be useful to create better conditions for training scientists. Often results are evaluated in Mexico through correlating the number of graduates, the number of doctors who are working in the universities and the number of sni members. This evaluation strategy is insufficient, this study shows that follow up studies are needed, so that it can be determined how many graduate students are becoming scientists with a clear criteria based on their production in the field of science. This type of analysis can be useful for evaluating the results of a graduate program in terms of its real efficiency in the training of scientists.

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References

Anderson, M. S., Louis, K. S., y Earle, J. (1994). Disciplinary and departmental effects on observations of faculty and graduate student misconduct. *Journal of Higher Education, 65* (1), 331-350.

Benítez, B. L. (1988). El fraude en la ciencia, en *Ciencia y Desarrollo, 14* (79), 51-58.

Benítez, B. L. (1994). La formación del científico: espejismos y realidades, en *Ciencia, 45*, 35-41.

Carmona, R., y Reyes, B. H. (2009). La cultura de lo aparente: las evaluaciones al mundo académico, en *Ciencia, 60* (3), 54-58.

Cereijido, M. (1994). *Ciencia sin seso, locura doble*. México, Siglo xxi.

Consejo Nacional de Ciencia y Tecnología (2007). *Indicadores de actividades científicas y tecnológicas*. México, CONACYT.

Flores, E. (1982). El desarrollo de la ciencia y la tecnología en la actualidad, en *Ciencia y Desarrollo, 8*, 107-111.

Fortes, J., y Lomnitz, L. (1991). *La formación del científico en México*. México, Siglo xxi.

Garza, G., y Malo, S. (1988). La formación académica de los investigadores, en *Ciencia y Desarrollo, 14* (82), 93-102.

Guichard, S. (2005). *The Education Challenge in Mexico: Delivering Good Quality Education to All*. Paris, OECD publishing.

Hopkins, D., Ahtaridou, E., Matthews, P., Posner, C., y Toledo, F. D. (2007). *An Analysis of the Mexican School System in Light of the PISA 2006*. Paris, OECD Publishing.

Loría, D. E. G. (1989). La investigación, instrumento fundamental del desarrollo integral, en *Ciencia y Desarrollo, 15* (87), 81-87.

Maddox, J., y Gee, H. (1994). Science in Mexico: Mexico's bid to join the world. *Nature Medicine, 368*, 789-804.

Merton, R. K. (1977). *La sociología de la ciencia. Vol 2*. Madrid, Alianza Editorial.

Morales, Z. M. A. (1999). Gestión pública de la ciencia y la tecnología, en *Ciencia y Desarrollo, 146*, 41-45.

Muñoz, E. L. E. (1991). Reflexiones sobre la investigación científica en México, en *Revista de Gastroenterología de México, 56* (1), 43-46.

OECD (2010). *OECD Factbook 2010: Economic, Environmental and Social Statistics*. Paris, OECD Publishing.

Pérez, R. (1988). La formación del científico en el área biomédica, en *Ciencia, 39*, 77-84.

Russell Group (2010). The economic impact of research conducted in Russell Group universities. *Issue 1*. Londres, Russell Group Papers.

Singer, B. F. (1971). Toward a psychology of science. *American Psychologist, 26,* 1010-1015.

Valdez, P. (1996). Factores que intervienen en la formación del científico, en *Ciencia, 47*, 25-38.

Valdez, P. (2005). La enseñanza de la ciencia en México, en *Ingenierías, 8* (26), 3-5.

Valdez, P. (2009). Problemas en la formación del científico en México, en *Ingenierías, 12* (43), 12-18.

Ziman, J. (1972). *El conocimiento público*. México, Fondo de Cultura Económica.