

[I-001 A quantitative historiography of Mexican integration into the international standards of scientific research¹].

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[I-006 Abstract]

[I-006 A study is presented on Mexican science published in mainstream journals during the first half of the 20th century, based on the analysis of the bibliographical elements present in the records from the *Science Citation Index Expanded* from 1900-1950. Organizational structures and patterns of communication, publication and citation were determined which represented the scientific practices of the research community during this period. We found three distinct modes of knowledge production: amateur, institutional and academic which corresponded to different periods in the process of the incorporation of Mexican science into the communication patterns of international science. The production modes were characterized by a variety of indicators: periods and types of research, publication and citation patterns, author production, journals and subject categories, institutional structure, and geographic distribution of production].

Keywords

Mexican Science; Knowledge Production Modes; Quantitative Historiography; Scientific Communication Patterns].

Introduction

The recent availability online of the *Century of Science* initiative within the *Web of Science* presents us with the possibility of developing new perspectives on the growth and evolutionary paths taken by science during the 20th century in countries like Mexico. The wealth of objective research data available can assist historians and sociologists of science and other scholars (Shapin, 1992), to re-examine, reflect on, strengthen or put to the test what has been written about the past in the field of science studies and even in some cases, to correct traditional historical methods (Kragh, 1987). Traditionally, the historical record, as a collection of personal and collective testimonies, has relied heavily on the readings, bibliographical research, and collective memory of the specialist scientific communities, without the added advantage and insight that bibliometric data can provide. Bibliometrics is most often used in the field of library and information science. However, it can be applied to any discipline to learn more about its scholarly content. In the history of science, it is used

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to elucidate the development of scientific disciplines by tracing the historical movements that are revealed in the results obtained by researchers (Okubo, 1997). While scientometrics and bibliometrics focus on the formal reporting of science, historiography, in contrast, tends to explain the formal on the basis of the informal (Edge, 1979).

The historiography of science was originally written by philosophers and by practicing and retired scientists (Christie, 2005) as a way to communicate the virtues of science to the public. In the 1930s, effort was directed towards looking at the ways in which scientific practices were allied with the needs and motivations of their context. By the 1960s with the increasing importance of science and technology to modern life, the emphasis was on problematizing the scientific enterprise, thus making it difficult to reach consensus as to the best way to write its history (Suárez, 2005). The professionalization of the historiography of science during the 20th century, increasingly in the hands of the historians of science and now accepted as a legitimate field of academic study (Christie, 2005), brought with it a greater richness and variety of interpretations and viewpoints (Laudau, 2005) and an increasing demand for specialized documental and other information resources. In 1963, Eugene Garfield, influenced by *Shepard's Citation Index* for legal cases, founded the *Science Citation Index* (SCI). Although bibliometric analysis predates it, SCI and its access to ISI's large datasets increased the popularity of bibliometric research, especially outside the field of information science. The SCI and more recently the *Web of Science* have become the most generally accepted basic source for bibliometric analysis. With the advent of *Century of Science* initiative we can now go back and use bibliometrics on the timeline previous to the creation of the SCI.

The prevailing vision of the history of Mexican science has been written mainly by members of the national scientific community, through personal viewpoints, essays and monographs, some as eyewitness accounts of the period (Beltrán, 1952, 1970, 1989; Gortari, 1963), others as eminent saviors of our scientific past by way of general works (Pérez-Tamayo, 2005; Moreno, 1986), biographies of prominent scientists (Coordinación de la Investigación Científica, 2003; Academia Mexicana de Ciencias, 2003), evolution of disciplines (Pérez-Angón, 2006; García, and Pérez, 2006), as well as institutional histories. The emergence of the first studies by specialists in the sociology and historiography of Mexican science from the 1980s and 1990s, (Trabulse, 1983; Casas, 2003; Saldaña, 1982) introduced new ways of writing about Mexican science, the questions asked were more diverse as were the study objectives, and diagnosis went deeper. Mexican science required a greater wealth of historiographic sources and interpretations (Trabulse, 1996, 2003) to complement the mainly descriptive and externalist approaches (Casas, 2003) and to strengthen conceptual study frameworks by incorporating both endogenous and exogenous factors to the analysis of the local maturing process of the sciences (Saldaña, 1994).

The present study, therefore, puts a different perspective on the history of Mexican science by analyzing its production and communication patterns during the first half of the 20th century. We are especially interested in mapping the organizational and disciplinary structures that emerged over this period, as well as publication patterns which characterized knowledge production during this time. We also hope to identify aspects that help characterize the process of transition and rupture between knowledge production based on immediatist intentions, centred on specific regional developments and applications (Pérez-Tamayo, 2005) and the new mode of knowledge production that started to gestate within the universities during this phase of development.

Material and Methods

Information sources:

- *Science Citation Index Expanded (SCIE)*, 1900-1950

- Library holdings and fulltext journals

Internet

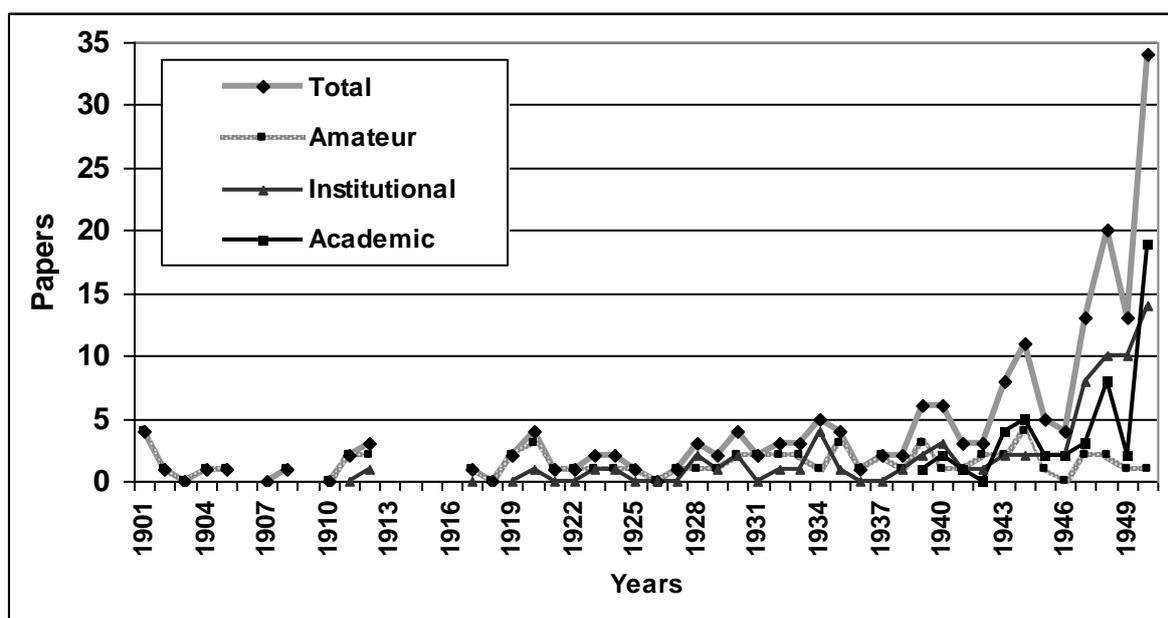
Literature on the history of Mexican science

Methodology

The new version of SCIE allows information to be recovered by country name from 1940 to 1945 and from 1973 to the present but not between 1945 and 1972 where records did not include author affiliations. The scientific production of Mexico from 1900-1945 was downloaded from the SCIE using the following search strategy “MEXICO NOT NEW MEXICO”, and from 1945-1950, using the names of authors who featured prominently in different texts on the history of Mexican science and were therefore considered likely to have published in the mainstream literature. We consulted available library, fulltext journals and Internet sources to determine the institutional affiliations of these scientists. By way of the analysis of the common elements of bibliographical records (such as author, title, journals, addresses, numbers of references and citations, document type, categories) and the application of quantitative, desaggregation and word frequency techniques, we were able to identify important differences between the institutional structures, forms of organization and scientific communication patterns present during the period analyzed. This allowed us to identify three knowledge production modes: amateur (Saldaña and Azuela, 1994), institutional and academic, each one with its own mechanisms for incorporating the standards of publication of international science which we were able to characterize with the help of 13 different bibliometric indicators.

Results

We recovered a total of 185 mainstream publications spanning the years from 1900 to 1950. More important than the actual numbers of papers is the fact that Mexican science showed a continuous, albeit small, presence in the international databases during this period of greatest political instability in the history of the country caused by the revolution of 1910.



[I-007 Figure 1. Scientific production modes of Mexican science during the first half of the 20th century].

Figure 1 shows the general distribution of scientific production from 1900 to 1950 according to the three different types of knowledge production and communication. Two distinct periods are apparent, the first covers the long period of reliance (1900-1930) on the customary ways of doing science, based on a single type of scientific practice. This changed during the second period from 1930 to 1950, with the coexistence of three different modes of knowledge production.

One third (62) of papers correspond to the amateur mode which exhibits a static form of production, suggestive of precarious scientific activity related to limited organizational structure and isolated

scientific practices. In contrast to the other two modes the amateur mode is present during the most part of the fifty-year period and represents the most traditional way of doing science in Mexico during this time. The institutional mode is responsible for the largest part of the production, 40% (74) appearing in the intermediary decades as an emergent form of production which is consolidated during the last five years of the period under study. The studies undertaken in the academic environment correspond to 26.5% (49) of the total and are concentrated in the final decade of the period. These represent the first international publications produced by the newly-established research institutes and are mainly physics papers authored by the National Autonomous University of Mexico (UNAM).

Each one of the production modes was sustained by distinct circumstances and organizational structures which replicated clearly differentiated patterns of publication, citation and information usage characterized in Table 1.

[I-007 Table 1. Production modes and publication and citation patterns].

Characteristics	Mode 1	Mode2	Mode3
Denomination	Individual or Amateur	Institutional	Academic
Period	Occurs throughout the period but mainly from 1900-1940	Begins towards the end of the 1910s.	Begins towards the end of the 1930s.
Type of research	Isolated, local, utilitarian	Continuity in the production: topics, authors and institutions.	Scientific practice: institutional, professional and independent
Publication patterns	Sole author: 93 % Co-authorship: 7 %	Sole author: 38 % Co-authorship: -Two authors: 24 % -More than two: 38 %	Sole author: 73 % Co-authorship: -Two authors: 15 % -More than two: 12 %
Reference and citation patterns	Av. no. references: 2 Av. no. citations: 0.16	Av. no. references: 11 Av. no. citations: 13	Av. no. references: 6 Av. no. citations: 6
Document type	-Articles -Technical Reports -Descriptions -Reports	-Articles -Meeting Abstracts -Reviews -Notes -Letters	-Meeting abstracts -Articles -Letters -Notes -Editorial Material
Language	-English -French	-English -French -German	-English -French -Spanish -German
Authors	-Medina, M -Ordóñez, E -Sánchez, PC -Matuda, E -Herrera, AL -Urueña, JG -Gallo, J	-Giral, F -Varela, G -Costero, I -Mazzotti, L -Rosenblueth, A -Mooser, H -Hudson, NP -Gómez, F -Romo, J -Rosenkranz, G -Chavez, I -Castañeda, MR	-Vallarta, MS -Guerra, F -Baños, A -Moshinsky, M -De Oyarzabal, J -Barajas, A -Graef, C

Preferred journals	-Trans Am Geophys Union -Trans Am Inst Mining Metall Eng -J Ind Eng Chem -Am Midland Nat	-Am Heart J -J Infect Dis -P Soc Exp Biol Med -J Cell Comp Physiol -Arch Biochem -Compt Rend Sci Soc Biol -J Am Med Assoc -J Am Chem Soc -Am J Hyg -J Exp Med	-Phys Rev -J Pharmacol Exp Ther -Am J Roentgenol Rad Ther -Arch Int Med
Categories	-Geochemistry & Geophysics -Engineering, Civil -Metallurgy & Metallurgical Engineering -Medicine, General & Internal -Ecology -Biodiversity Conservation -Chemistry, Applied	-Medicine, General & Internal -Medicine, Research & Experimental -Cardiac & Cardiovascular Systems -Infectious Diseases -Biochemistry & Molecular Biology -Immunology -Biology -Pathology -Chemistry, Multidisciplinary	-Physics, Multidisciplinary -Pharmacology & Pharmacy -Multidisciplinary Sciences -Medicine, General & Internal -Psychiatry
Institutional structure	-Mining companies -Directorate of Geographic and Climatic Studies -Head office of Geography, Meteorology and Hydrology -Oil companies -Mutada Herbarium Esquincla	-National Institute of Cardiology -Institute of Health and Tropical -Laboratories of Hormon -General Hospital -Institute of Hygiene - Syntex Research Laboratories -Hospital Laboratory America -Pediatrics Hospital	-UNAM -UAL -AUP -IPN
Geographic (distribution by state)	-Mexico City: 53 % -Hidalgo: 7 % -Chiapas: 5 % -Coahuila: 5 % -Sonora: 5 % -Otros: 25 %	-Mexico City: 97 % -Yucatán 3 %	-Mexico City: 96% -Puebla 2% -Nuevo León 2%
Word frequency	Mexico, Geodetic, Mexican, Mining, Mine, Methods, Pachuca, , Cyanide, Ore, Geology, Gravity-Station, Fresnillo, Oil, Plasmogenesis	Typhus, Mexican, Heart, Steroids, Experimental, Guinea pigs, Mexico, Synthesis, Treatment, Rheumatic, Oils, Pigs, Turtle, Patients, Brucellosis	Cosmic, Radiation, Gravitation, Fields, Energy, Magnetic, Spectrum, Rays, Birkhoffs, Particles

The amateur or individual mode is associated with poor, non-professional scientific practice, principally the result of the individual effort of the authors, accomplished locally in isolation from peers and with immediate utilitarian objectives in mind. Within the subject areas related mainly to the mining, oil, railway and health industrial sectors, a variety of different research topics were undertaken which showed little continuity and connection between authors. With the notable exception of A. Medina, the most productive researcher during this period, who published original results on the characteristics and progress of geodetic work in Mexico in the decade of the 30s, the majority of the authors published only one paper and the few who published three papers wrote about different subjects each time. Such is the case of E. Ordóñez who published on the Mexican railway system, the mines from the Pachuca district and oil in the south of the State of Tamaulipas. Another example is P.C. Sánchez who wrote about heartquakes, the history of geodesy in Mexico and about volcanoes.

This production mode replicates the publication patterns of a sole author which have no references and no citations. The papers are typically reports, classification studies, descriptions, technical research reports, implementations of solutions, clinical methods and studies, written in English by researchers such as engineers and physicians, affiliated mainly to foreign companies from the mining, oil, and railway sectors and to a lesser extent, from national institutes in the fields of geography, geology and private hospitals. The specialized journals used are in the subject categories of engineering: geochemistry, geophysics, civil, chemical, mining, and general, internal and clinical medicine, which are no longer covered by the SCI. An interesting feature of this mode of production is that, unlike the institutional and academic modes, research is much less centralized within the federal district of Mexico City.

Mode 2 of production corresponds to scientific practice which shares the characteristics and circumstance of local and external development of modes 1 and 3 throughout the period analyzed. Nonetheless, it also presents important differences with respect to communication, publication and citation patterns as shown in Table 1. This mode is replicated in the institutions of geology, geography, medicine, public health and hygiene, astronomy and biology, created by the state under varying names beginning in the 19th century and is manifest in the international, mainstream literature in a more marked and continuous way in the decade of the 1930s by the attention given to the topic of typhus as a particular local, public health problem by different specialists with M.D. degrees. Doctors, such as G. Varela, M.R. Castañeda, H. Mooser, J. Sozaya, and N.P. Hudson, affiliated to institutions of public health and hygiene, such as the Institute of Hygiene, the Institute of Health and Tropical Diseases and the General Hospital which created a laboratory specialized in typhus research, as well private laboratories and hospitals. This environment created as a result of typhus research, produced the first instances of national and international scientific collaboration with respect to a local problem, in addition to the first Mexican papers to receive more than 10 or 20 citations.

Mode 2 emerged under different local social and political circumstances and with changes in the authors and in their professional profiles with respect to mode 1. In the decade of the 40s, new specialists joined the researchers studying typhus; among them were exiles from the Spanish Civil War and Mexican researchers who had trained abroad. For instance, I. Chávez, B. Sepúlveda, A. Rosenblueth, I. Costero, F. Giral, J. Romo, G. Haro, and F. Gómez, among others, attached to the Institutes of Cardiology, Pediatrics and institutions from the chemical and pharmaceutical industry, created new openings in the relationship with international science which translated into the consolidation of new patterns of scientific production and communication. These were associated with the adoption of scientific practices involving co-authorship with peers, in both national and international scenarios, diversification of languages and research methods, the presentation of papers in international meetings which were reviewed in mainstream journals, as well as the publication of short communications in the form of notes and letters.

In Mode 2 efforts are directed along different paths towards insertion of Mexican science into the international standards of publication and citation, manifested in accordance with Table 1, by an increasing average number of references cited in the papers accompanied by a rise in the impact of local studies through citations given by peers in the international scientific community. The average of

13 citations achieved per paper, is competitive with the present-day average numbers of citations for Mexican science. These characteristics are associated with changes in the objectives set by scientific practices, above and beyond utilitarian considerations of the results, as shown by basic research of a theoretical and experimental nature which has guaranteed the continuity of the new topics studied and has allowed access to different journals with the highest impact factors in their respective areas. Such is the case of the *American Heart Journal*, *Ecology*, *Proceedings of the Society for Experimental Biology and Medicine*, and the *Journal of Cellular and Comparative Physiology* where the first studies were published which received more than 50 citations and the *Journal of the American Chemical Society* with the highest average number of citations, 79 citations per paper and the paper with the highest number of citations, 154, for the period analyzed. Mode 2 was developed in a centralized manner in the federal district of Mexico City.

Mode 3 corresponds to professional research carried out within institutions and linked to academic topics and interests. This implies a greater freedom in the choice of research topics and greater independence from considerations related to the solution of local problems, than with respect to modes 1 and 2. Its origins lie in the incorporation of the Institutes of Geology, and of Biology, of the National School of Medicine, the National Astronomical Observatory, among others, to the National Autonomous University of Mexico (UNAM) in the period from 1930-1950. It initiated its development in a strongly centralized way, 90% concentrated in this institution, particularly in the Institute of Physics and within the federal district of Mexico City.

This academic mode is the least present and appears only at the end of the period analyzed. The production mode and communication patterns identified in Table 1, correspond principally to the physical sciences and, in particular to the area of Cosmic Rays, the theoretical research topic with most influence among physicists at that time. These scientists started disseminating their first studies internationally through their contributions to the *Proceedings of the American Physical Society*, principally in the meeting celebrated in 1947 in Houston, Texas and in 1950 in Mexico City. This communication channel guaranteed the publication of papers in *Physical Reviews*, the main international journal in the field, in the form of meeting abstracts. This document type represents 50% of all contributions made under mode 3 and are generally written by a sole author, references are not included and they are rarely cited. These conditions were a fundamental influence on the overall characteristics of the academic mode, identified in Table 1, which refer to publication patterns exemplified by individual authorship, low average numbers of references and citations per paper and 70% of the production centralized in the journal *Physical Reviews*.

Discussion

The variables identified in our bibliometric analysis: author, document type, institutional affiliation, geographic location, number of references, number of citations, categories and title words, allowed us, through the application of desegregation techniques quantification and analysis of word frequency, to follow the development of Mexican science during the first half of the 20th century. We established a process of incorporation of the local community into the global scenario by adopting the international standard of publication in mainstream journals. This process evolved accompanying and documenting the construction of new ways for knowledge production that occurred and complemented each other throughout this period. In each of these stages favorable conditions were created for a closer relationship with international scientific culture.

The presence under local conditions of new scientific practices during the period analyzed, were observed using bibliometric methods involving the tracking and quantification of common biographical elements (authors, journals, topics, institutions, references, citations) for the identification of changes occurring in institutional structures, forms of organization and patterns of scientific communication. These biographical elements advise us of evolutionary pathways and other testimonial elements sufficient for the characterization of the development of Mexican science during this period, tracing its journey through three distinct stages for the generation and publication of knowledge in the international environment.

Using the institutional affiliations of authors in the SCI, it was possible to recover the scientific production written by external authors working in foreign companies based in Mexico, corresponding principally to mode 1 where research is carried out locally in mining companies as well as in the transport and health sectors. The bibliographic data associated with this production such as authors, titles, journals and topics, are difficult to document using historiographic methods and for this reason, are not found in the historical works which cover this period.

The general patterns of publication and citation of Mexican science today are defined by the practices of mode 2 scientific research, associated with problems of public health and hygiene, principally as a result of the line of research developed on the study of typhoid disease, by a main group of four scientists: H. Mooser, G.Varela, M.R. Castañeda and N.P. Hudson. Their work generated a body of literature with certain characteristics. Firstly, it represented the first topic in Mexican science whose study continued over a number of years, the 10 years from 1928 to 1938, in which several authors were involved, four principal ones and 15 co-authors. Secondly, 18 papers were published which were the first to cite an average of 10 references and with an average impact of 11 citations each. The papers were published in high impact journals which are still today covered by the SCI: *Journal of Experimental Medicine*, *Journal of Infectious Diseases*, *Proceedings of the Society for Experimental Biology and Medicine*, *American Journal of Tropical Medicine*. The publication and citation patterns of the scientific literature on typhoid disease are the clearest indication of the division of Mexican science during the 20th century, in terms of changes in communication patterns between the amateur and the professional modes. It is also the first example of the internationalization of a local topic which attains wide impact, carried out by Mexican researchers affiliated to institutions in the area of public health and using resources of these home institutions.

The evolutionary information collected in the present study indicate that the least productive state of Mexican science is associated with scientific practices adopted during times of greatest social and political instability, within a single production mode, carried out principally in amateur form, isolated from the influence of other scientific practices and aligned with utilitarian objectives, and representing the form which experiences the most difficulty in coinciding with the standards of international scientific publication. The phase of greatest growth, as the end of the period analyzed, is the result of changes in local conditions, and the convergence and complement of the institutional and academic modes, primarily.

Disciplines and professions exist which are linked with one mode of production, such is the case of physics, which arose with academic practice. Others such as health employ the three modes in its different areas of clinical research, public health and hygiene, internal, experimental and theoretical medicine.

We consider that the quantitative historiographic approach used in the present study made possible by the online availability of mainstream production records from the beginning of the last century, has proved a valuable adjunct in the description of the development of Mexican science from 1900-1950 and particularly for the identification of the mechanisms that were instrumental to the integration of Mexico into international scientific community standards during that period.

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