Basic, Applied and Technological Research:: Computer Science and Applied Mathematics at the National Autonomous University of Mexico
Larissa Adler Lomnitz and Laura Cházaro
Social Studies of Science 1999; 29; 113
DOI: 10.1177/030631299029001005

The online version of this article can be found at:
http://sss.sagepub.com/cgi/content/abstract/29/1/113

Published by:
SAGE
http://www.sagepublications.com

Additional services and information for Social Studies of Science can be found at:

Email Alerts: http://sss.sagepub.com/cgi/alerts
Subscriptions: http://sss.sagepub.com/subscriptions
Reprints: http://www.sagepub.com/journalsReprints.nav
Permissions: http://www.sagepub.co.uk/journalsPermissions.nav
ABSTRACT Our purpose in this paper is to offer an historical account of the relationship between basic, applied and technological research, as found in a case study of the Institute of Research in Applied Mathematics and Systems (IIIMAS) at the National Autonomous University of Mexico (UNAM). We found that researchers who have dedicated themselves full-time to the development of technology related to computing science have, in their academic careers, faced a system of evaluation based upon an ideal of basic science: this results in an adverse environment for the development of technological research; and this, in turn, has negative consequences for basic research itself, as the achievements of basic and experimental science cannot be understood nowadays without any active collaboration between technology and theory. The concepts which give rise to the different forms of evaluation at UNAM resulted more from a value-ridden symbolic construction, than from the processes of the actual production of new knowledge.

Basic, Applied and Technological Research:
Computer Science and Applied Mathematics at the National Autonomous University of Mexico

Larissa Adler Lomnitz and Laura Cházaro

Various studies in the history of science have shown the relevance of technological and applied dimensions in the production of basic knowledge.\(^1\) Artifacts, instruments and precision equipment are necessary (and therefore essential) in the daily practice of science, as is an understanding of engineering and technological developments – in other words, of applied knowledge.\(^2\) However, despite this, there are elements that differentiate the ‘basic’ from the ‘applied’ aspects of science. Though we currently lack a consensus regarding what these differences are, the distinction between ‘applied’ and ‘basic’ research, as Dorothea Jansen has pointed out,\(^3\) cannot be reduced to one single element or characteristic. A complex network of variables seems to intervene in the differentiation between these two types of research. Their epistemological status, for example, distinguishes them: basic research is defined by a long-term quest for analytical and experimental knowledge, whereas applied research produces knowledge intended to answer immediate questions of a practical and precise nature.\(^4\) Likewise, the interests that each type of research responds to are different. Basic research produces new knowledge, without considering its possible applications, whereas applied research is driven by concrete interests,\(^5\) ranging from the creation of new artifacts to the development of analytical methods.
for controlling engineering processes, the production of software or the
development of mathematical applications for industrial production.  
It has also been pointed out that the differences between basic and applied
research may be reinforced by the institutional environments in which they
are carried out: an industrial laboratory provides an infrastructure that
induces applied research, whereas a university institute, with its limited
resources, induces basic research. Many more such elements could be
cited. Even so, despite all these differentiating variables (epistemological,
or related to the interests or organization of the activity), the fact remains
that scientific research currently requires both ‘basic’ and ‘applied’
knowledge.

This paper deals with a paradoxical situation that has evolved in Latin
American universities. Despite the acclaimed importance of applied and
 technological research for the development of science, university policies
and evaluation systems seem only to benefit basic research. Apparently,
this differential treatment is justified by the different interests and ob-
jectives of the knowledge sought in ‘basic’ versus ‘applied’ or ‘technological’
research. In the context of certain Latin American universities, however,
we argue that these differences result from policies and evaluation stand-
ards that follow a model of basic research: these policies have conditioned
the production of research in accordance with an ideal of pure science that
tends to deny the value of applied and technical research. As Hebe Vessuri
has pointed out, Latin American universities present themselves as havens
with a greater interest in basic research, grounded upon a fragile relation-
ship between academic research and the national production system. Thus,
whatever objective differences may exist between basic and applied re-
search, or between science and technology, we find a sense of obligation,
an ideal that views science as something ‘pure’, and its applications as
‘impure’ routines and techniques.

Our thesis is that the characterization of – and the relationship
between – basic and applied aspects of science are not defined by any
actual differences they may display in practice, but as the outcome of a
specific ideal of science – namely, that of basic research. Historically,
changing definitions of what constitutes ‘applied’ science have stemmed
from that ideal. Applied science has been conceived of as a utilitarian
application of theory to technique and art, referred to as ‘technological
development’, and always in relation to a basic science which, because of
its theoretical outlook, is idealized as being pure. In the context of Mexican
universities, in particular, this leads to a differential status for applied or
technological research, which is evaluated according to the criteria of basic
research – the latter being considered, apparently, as the only valid manner
of conducting scientific research.

The purpose of this paper is to offer a historical account of the
relationships between basic, applied and technological research. Our case
study of the Institute of Research in Applied Mathematics and Systems
(IIMAS) of the National Autonomous University of Mexico (UNAM)
shows how researchers who have dedicated themselves full-time to

Downloaded from http://sss.sagepub.com at CINVESTAV DEL IPN on July 15, 2009
developing technology related to computing research have found their academic careers evaluated by a system based on an ideal of basic science. This has produced an adverse environment for applied and technological research. By open interviews with the Institute’s researchers, we explored the outlook and values that these researchers have expressed in (and about) applied and basic research, while introducing – to the University and to Mexico – the most important mathematical technology of this century: the computer. By examining the Institute’s development, we seek to reconstruct how the University’s ideal of basic science was itself constructed.

The group which developed into the Institute was first established in the 1950s to develop computer technology and research, specifically for its applications to scientific research within the University. Paradoxically, the University was simultaneously reinforcing its tendency to stimulate basic science in every field: norms of evaluation and promotion were being established which clearly benefit basic researchers, neglecting engineers and applied researchers. The latter seem to have lost the struggle to gain a legitimate position as researchers within the Institute, because the product of their skills has not been recognized as valuable for the production of new knowledge. The distinction between basic and applied research is not based upon the actual characteristics of research practice, but rather upon value-laden ideals that underestimate technologists: its application not only diminishes the ability of applied researchers to produce technological development – it also limits the capacities of basic research.

The First Stage: Computer Services at the Electronic Calculus Centre (1958–70)

By the mid-1950s, the first computers (most developed for military purposes) had proven their enormous usefulness for scientific research: they simplified work that required handling large amounts of data and, above all, offered reliable solutions to many complex scientific problems.10 Because of their characteristics and the advantages they offered, many universities quickly encouraged their use;11 among them, UNAM took a relatively early interest.

In 1958, the Electronic Calculus Centre (CCE) was created at UNAM to introduce the computer to the University. Nevertheless, as Sergio Beltrán (one of UNAM’s leading promoters of computers) has pointed out, the creation of CCE was a product of chance and ingenuity. Beltrán and Dr Nabor Carrillo (at that time UNAM’s Rector) took part in a collaborative project with the University of California at Los Angeles (UCLA) and the Mexican National Institute of Scientific Research (INIC): the Mexican group had to solve some complex simultaneous equations – so complex that it took Beltrán and Carrillo nearly nine months to complete the work. They then sent the results to UCLA: their American counterparts reviewed them in less than three weeks. This quick response surprised the Mexicans: to do these calculations so quickly,
Beltrán pointed out, would require ‘half the United States’ population’. Curiosity led Beltrán to contact the UCLA project’s director, only to be told (bafflingly) that the work had been carried out by the ‘National Electronic Brain’. Beltrán took this answer as a joke in poor taste, and went to UCLA to look into the matter. The ‘American Brain’ was an IBM-650 computer. Once he had seen for himself its enormous possibilities, Beltrán returned to Mexico and convinced the UNAM administration to rent an IBM-650 for the University.\textsuperscript{12}

This led to the creation of CCE, and made UNAM the first Mexican university to acquire a computer.\textsuperscript{13} Among CCE’s most important objectives were, precisely, to encourage the dissemination of, to offer services from, and to teach techniques related to, computer science among the University’s faculty and students.\textsuperscript{14} Demand quickly grew: the Centre broadened its services, offering them to bodies outside the University, such as (among others) Petróleos Mexicanos (the state-owned petroleum company), the Comisión Federal de Electricidad (the state-owned electricity commission), Banco de Crédito Ejidal, the now defunct Secretaría de Recursos Naturales No Renovables (Ministry of Non-Renewable Resources), the Secretaría de Agricultura y Ganadería (Ministry of Agriculture and Livestock), and the Instituto Mexicano del Seguro Social (Social Security Institute). By the late 1960s, CCE had rented a Bendix G-15 computer,\textsuperscript{15} to satisfy the growing demand for services, and to disseminate the possibilities of computers in scientific research: a ‘Mobile Computation Centre’ was created, taking the Bendix G-15 to several Mexican universities – a truly educational and dissemination crusade for computer science.

Training students and professors in computer science was another of the Centre’s important activities. A master’s degree programme was established, sponsored by UNESCO,\textsuperscript{16} and undergraduate students at the Schools of Sciences and Engineering were encouraged to complement their studies with training in computer science, and in similar disciplines, in foreign universities.\textsuperscript{17} Between 1959 and 1963, as part of this interest in training computer specialists, the Centre sponsored five international colloquia: these are still remembered for having brought together important foreign specialists in computer science, ‘superlanguages’ and cybernetics.\textsuperscript{18} The mystique surrounding computer science transformed the lives of many academics and students who joined CCE: they dedicated all their time and energies to their encounter with computers, exploring the possibilities of the new discipline. The result was a feverish work environment, but also one in which academics had the freedom to pursue their concerns beyond merely providing services.

CCE’s organization reflected this environment of broad perspectives and interests: the Centre was not organized in formal departments; rather, groups emerged informally around common interests. From 1960 to 1969, the following groups existed:\textsuperscript{19} (1) mathematical theory of programming (studying formal languages, mathematical models and simulation); (2)
computer science teaching; and (3) computer services (maintaining equipment and developing hardware for UNAM’s branches and schools, and for other universities and institutions). There was also a group of professors and researchers from UNAM and other bodies: although these academics did not formally belong to CCE, their interest had been aroused by the possibility of applying computer science to various disciplines, and so they had approached the Centre. And there were (among others) researchers from the Institute of Biomedical Research, working on biocybernetics and biotechnology; researchers from the Mexican National Polytechnic Institute (IPN) and the National Nuclear Commission, devoted to cybernetics and the theory of automata; anthropologists interested in linguistic research; and statisticians from the School of Economics and the School of Accounting and Administration. Although, at first, most of the research projects developed at CCE required no more than the technical support of computers, they led to other concerns: the study of methods for optimizing the use of computers, mathematical programming and formal languages all broadened the Centre’s interests. For example, interest in designing and building computers led to the *MAYA* digital computer, which was constructed as an experiment; in 1963–64, an analogue computer, named *UNKORNIO*, was built. These experiences transformed CCE’s initial activities, and led to tasks going well beyond service provision. By the late 1960s, a distinction had arisen that would mark the Centre’s future experiences: computer science techniques had been developed in contraposition to basic research.

**Can Basic Research be Technical?**

Officially, CCE was created as an administrative office for computer services: it was therefore not considered to be one of UNAM’s research institutes. Its personnel were hired as administrative employees – that is, they were not subject to the rules then governing academic careers. The exploratory tasks they carried out in research projects within the new discipline were in direct contradiction to the ‘administrative’ nature of the work they had been hired to do – namely, administrative tasks and computer services, excluding any type of research.

This apparent ‘contradiction’ between the status of the Centre’s staff, and their interest in going beyond providing services and training personnel, soon became significant for the University’s researchers and professors: they felt that the activities carried out by CCE staff could not be considered as ‘legitimate research’. In our interviews, this point was repeated: ‘the Beltrán Centre did not do scientific work but handiwork, since the computer was merely an instrument’; CCE was entering fields that ‘did not correspond to’ it; the Centre had ‘unorthodox’ people who did no more than develop computer skills and techniques; consequently, these people could not claim to be researchers. Computer science seemed to many observers to be an occupation that, although possibly revolutionary, was technical in nature, not scientific.
The new computer found a University that predominantly cultivated traditional disciplines: biology, physics, mathematics, geology. The fields of applied mathematics and computer science were emerging and, above all, competing with well-established disciplines. As one interviewee pointed out, there was a certain .

... rigidity regarding the type of mathematics one could do at the University; for example, probability and statistics were considered too applied vis-à-vis topology [and] the dominant mathematics of the period.²²

Despite its technical aspects, the new discipline offered possibilities for developing electronic engineering, mathematics, superlanguages and cybernetics. In the mid-1960s, as one interviewee noted, CCE had become fertile ground for developing the new applied mathematics that until then had not been explored anywhere else in the University. The problem was that CCE’s presence ran counter to the most common definition of scientific research and researchers. One respondent recalls:

With Beltrán, CCE had a services [oriented] nature: that is, it was UNAM’s computer. Basically, what we had were computer operators, and, because of those things that were so strange, [and] which Beltrán had glorified, some operators considered themselves researchers, but this was a completely fictitious [title].

The debate raised by these opinions led to the view that computer science and related disciplines involved technical work – with no distinctions – that did not fit into the definition of research given by established academics. When computer-related tasks emerged, they faced a double obstacle: they had to gain an institutional, legitimate space within scientific research; and they also had to acquire the status of a science. This implies disciplinary and even philosophical questioning: ‘Can the development of services and technology be considered a scientific activity?’; ‘What disciplinary characteristics define services and technology vis-à-vis other research activities?’

The following stage in the Centre’s experience constituted a first attempt at tackling these problems. As we shall see below, institutional resolutions were taken that, while they did open new spaces for applied research, were still always formulated according to the ideal standards of basic science: this held back the academic careers of the technicians who were introducing the computer into the University.²³

The Second Stage: CIMASS (1970–73): Research versus Services

In 1970, UNAM decided to put the Centre in charge of the University’s administrative computer services; these were carried out at the Unit of Data Systematization, in the Rectoría (administration building).²⁴ With these new activities, the Centre’s status changed: it was integrated into the group of ‘Institutes and Centres of the Field of Sciences,’²⁵ and renamed
the ‘Centre for Research in Applied Mathematics, Systems and Services’ (CIMASS).

This change had been in the pipeline for some time. In 1967, when Sergio Beltrán resigned as Director of the Centre and was succeeded by Dr Renato Iturriaga, the group was important enough to continue to evade the issue of whether computer science was a technique (or a mere craft derived from engineering), or could be called ‘research’. The responses were paradoxical: to eliminate the tension implied by the notion of research as a process divorced or removed from the production of techniques and tools, it was decided that the Centre would be transformed into a body for carrying out scientific research. But, to do this, it was necessary to eliminate the supposed technical nature of computer science: the new Centre’s production would have to approximate the prevalent ideal – ‘pure’ scientific research, removed from practice, application and service.

Once it had become a research unit, the Centre changed the classification of its staff: the erstwhile administrators now became academicians. According to the recently enacted Academic Personnel By-Laws (Estatuto del Personal Académico, or EPA), the term ‘academic’ included professors, researchers, academic technicians and research assistants. The CIMASS administration (headed by the last CCE Director, Dr Iturriaga), inspired to some extent by the EPA’s guidelines, set out to recruit academics with different profiles from those of the Centre’s former employees. CIMASS sought people with doctorates, feeling that the Centre would then become more oriented toward scientific research – or, at least, that it would complement the work of its already established technicians and engineers. Indeed, most of the CCE staff were engineers somewhat removed from UNAM’s traditional research: they were considered ‘outsiders’ in traditional science; their affiliation to the University did not appear sufficient for them to be deemed ‘researchers’. However, computer science was a young discipline and there were few people in Mexico with doctorates in that field. Newly arriving academics with foreign doctorates were not specialists in computer science: most were mathematicians or statisticians; a few were physicists interested in applying computer science to their fields. In the end, this academic spirit, rooted in the EPA and in an insistence on making the study of computers a scientific activity, led CCE to hire researchers whose training and aspirations were different from those of the Centre’s original members.

CIMASS’s organization reflected this situation: it had an ‘Under-directorate of Research’ and an ‘Under-directorate of General Services’. The first was responsible for two areas: Technological Research (including biocybernetics, statistics, computer science and mathematics); and Computer Services and Electronics. The latter group dealt mainly with services for researchers and students, and also with teleprocessing (electronics and software), and the development of basic printed-circuit technology. The Underdirectorate of Research also established a new electronics laboratory, initially to solve practical problems with the B-6700 computers the Centre had purchased. However, it was soon decided that the technical staff
should not be obliged to do maintenance work on the computers, but rather that they should concentrate on exploring, developing and building equipment to meet the need for teleprocessing;\textsuperscript{29} that is to say, the electronics laboratory was integrated into the research area. Moreover, the Underdirectorate of General Services was responsible for UNAM’s administrative computer tasks: scholastic services, accounting and payrolls. This organization saw computer science as a part both of research (as a tool and technique for numerical analysis, and for mathematics in general) and of a technical activity, applied to the administrative services that the Centre offered.

The newly created CIMASS thus resignified the terms \textit{technical} and \textit{applied work}: there were still computer technicians, providing services and, at times, introducing technological development, but they were now accompanied by applied researchers, whose imperative was to make the study of computers a part of science; for the latter, computers were merely tools for solving the problems of (that is, they found an application in) traditional scientific areas. As Felipe Bracho points out,\textsuperscript{30} in that perspective of applied research, ‘computing’ began to be confused with ‘computers’. Computing became a \textit{scientific tool}. The figure of the \textit{technician} became more complex: there were technicians in charge of providing user services, and overseeing the upkeep and operation of computer equipment; but some were devoted to designing and constructing equipment, searching for applications for microprocessors in problems related to real-time controlling, switching, data acquisition and transmission, and computer-based design. The latter were technicians taking part in applied research: but not all of these \textit{applied} elements had the same importance. In normal circumstances, the services department and the electronics laboratory were CIMASS’s central areas: rather than shrinking, they grew larger and became more important. To meet demands for new academic and administrative computer services, CIMASS had to recruit more engineers and technicians, whose background did not correspond with the ideal of encouraging \textit{scientific research}.

As Dorothea Jansen points out, one of the most important distinctions between basic and applied researchers is the manner in which their work is organized.\textsuperscript{31} Indeed, differences between those who favoured research and those who were specialized in technical work stem from each group’s work methods. Technicians who provided services, staffed the electronics laboratory and developed computing techniques, worked to external demands – either for service projects, or to the requirements of ‘researchers’. Most technical work was absorbed by service projects, which required the development of software and knowledge of computer architectures. One of the largest service projects was provided for INFONAVIT (the National Institute for the Promotion of Worker Housing): even today this is one of the best-remembered projects, as it required an enormous amount of work. In the rhetoric of CIMASS staff, services had value insofar as they generated revenue, thereby offsetting the high costs of equipment and maintenance. The technicians gained power: they could decide, with some
degree of freedom, how to use their funds to obtain more and higher-quality equipment, or to hire students (called 'chickens') as support personnel.\textsuperscript{32} But the skills and resources they acquired were not appreciated by the new members of CIMASS, who felt that the usefulness or prestige of an academic activity did not stem from the management of resources and machines, but from the theoretical research that could stem from computing. Unlike the partisans of research, who held doctorates (usually from abroad), the technicians had been trained in user services, through daily experience, and applying their own resources and knowledge. They met the demands of others (both in services and in research), but the product of their work was not printed in journals: it was delivered to a client who set deadlines and required practical results. One interviewee noted that the activities technicians carried out in large service projects were . . .

... to develop systems [software], without aiming for all of this to be published. Yes, the idea was to develop software, since we were all taught that the work here was to develop software and that [our work] was finished when the software was operating. There was not the cultural need to publish.

Another respondent, recalling the same period, said:

[W]ith Renato we were much more oriented to the interest in learning and communicating with people. Perhaps we lacked methodology, in terms of clear objectives on what was being done, but it had good results! I do not remember at that time having heard of anyone who was concerned with publishing. Moreover, I don't remember anyone having published anything in that period. We had to document the programs that were written; then we would give a conference; and, on some occasions, we would assume an approach to convince people that this was what was important.

In contrast, the group of researchers (most of them devoted to applied mathematics as research on operations, statistics and numerical analyses) had different work habits. In principle, their research projects were unrelated to services and, in general, to technological development: nevertheless, conceptualizing and carrying out these projects depended on 'technical' work. Their most salient characteristic, according to the researchers themselves, was that they had been trained to do research, to interact with international scientific networks and to publish in prestigious journals. In their vision, the University was not obliged to solve technical problems, since industry and the market, rather than the researchers themselves, were the beneficiaries of such work.\textsuperscript{33}

However, these distinctions could become blurred. Due to institutional factors, the applied researchers were often obliged to collaborate in service projects: because these projects entailed so much time and labour, all staff had to participate; then the differences between applied and technical research could be seen:

I believe that [purposes of the Centre] became distorted a bit because it took too much responsibility for providing support for INFONAVIT . . .
we were all involved in one of those projects. We took care of the payroll and, although it was a very large and interesting computer system, it did not really represent research, per se, but rather, it put into practice a technique that was [already] known.\textsuperscript{34} (our emphasis)

Researchers' resistance to participating in service projects gradually institutionalized the differences between the two forms of work. Research advocates were interested in the growth of applied mathematics, such as statistics and numerical analysis: from their perspective, service projects merely caused them to neglect their research:

I can mention, for example, a colleague who was not a programmer, but [who] had to write some programs for that package and naturally he was annoyed.

However, these two different forms of work overlapped with a difference in values. There was no doubt that the technicians organized their work in laboratories, with machines, and handled external requests, whereas the researchers focused on the production of theoretical papers: yet their differences went beyond the mere manner in which their work was organized, and often became a difference in values.\textsuperscript{35} For the 'applied' researchers, it was not sufficient that CIMASS had a group devoted to research: the fact that computing still existed as an activity linked to services distorted the nature of the word 'applied'. If the autonomous technical activities of research were to disappear, then applied mathematics (including computing) could be considered part of the corpus of the sciences. Eventually a consensus emerged on the possibility of making the 'applied' a part of 'research' – that is, removing it from the sphere of 'services', from the handling of software and machines. The old balance based on the strength of services and on disciplinary heterogeneity yielded to the power of research.

The corollary to this differentiation and competition among different visions of 'the applied' (as a service, as a technique, but also as research) was the transformation that the group, once again, underwent. In 1973, the CIMASS Director proposed that the University authorities separate the Centre's research area from services: computer services (both academic and administrative) would then be relocated in a new unit, the 'Centre of Computer Services' (CSC), and the research area become the 'Centre of Research in Applied Mathematics and Systems' (CIMAS). Hence, CIMASS lost the 'S' for Services, and was put in charge of the scientific development of applied mathematics, including computer science. One respondent recalls that 'when Iturriaga's period as Director ended, another stage began for the Centre. It truly became a research centre'.

The Third Stage: CIMAS and IIMAS: The Definition of Basic Research and Applied Research versus Technical Research

The new CIMAS only lasted a relatively short time: a mere three years. In 1976, it became an Institute, and was given its present name, the 'Institute
of Research in Applied Mathematics and Systems’ (IIMAS). Once computer services had been eliminated, a way was found to allow the Institute to become a legitimate space for applied research.

CIMAS was formed with 43 academics (nine academic technicians, two research assistants, and the rest researchers), and was divided into work groups: computing; the electronics laboratory; statistics (which in turn was subdivided into probability theories and operations research); functional analysis; differential equations; and numerical analysis. In 1976, once it had become an Institute, its academic organization was divided into Departments: Numerical Analysis; Mathematics and Mechanics; Probability; Statistics and Operations Research; and Computer Sciences and Digital Systems Design (which had once been the electronics laboratory). There were also two special groups: Anthropology and Taxonomy, and Continuous Media Mechanics; the first would become the Department of Mathematics Modeling for Social Sciences, and the second was later integrated into the Departments of Numerical Analysis, Mathematics, and Mechanics.

CIMAS brought with it a total reorganization. Although it had been agreed that it would work jointly with CSC, this commitment was soon broken: ‘in practice ... the centres evolved entirely independently’. CIMAS now depended on terminals directly controlled by CSC, causing ...

... the CIMAS computing work group to be separated from its fundamental work tool: the computer. ... The services group lost the interaction of studies and qualified personnel in the informatics area and, along with that, the academic support that had at other times made the development of systems easier.

Also contributing to the transformation of the old work methods was the fact that most of the academics who provided services stayed at the research centre; institutions can be divided; individuals cannot. In interview, a member of the Centre active at that time said that ‘the policy of cancelling the commitments that had been acquired with the computer system for users’ (such as the arrangements with INFONAVIT) transformed the group of technicians and engineers who stayed at the CIMAS themselves into computer users. Clearly, computing and electronics, but also applied mathematics, were assimilated into the model whose ideal was the criteria of basic research: now computers could only be a tool for inquiring about (and applying the solutions of) pure research problems.

The Introduction of the Theoretical Applied and the Technological Applied

The question, then, was: ‘How could one develop computing (and, in general, applied research) within a branch of the University that no longer possessed a computer as its central tool?’ In other words, what did it mean to do research in applied mathematics when its fundamental tool was not directly reachable?
At the same time, this development of mathematics as applied mathematics was also a slow process of differentiation not only from the traditional mathematics cultivated at UNAM, but also from the technological disciplines within which the new Institute’s members worked. In the early 1970s, as one respondent pointed out, ‘what we understood by [the term] applied mathematics was something quite broad: there were no set plans regarding research topics nor research threads’; nevertheless, it was by then clear that the work carried out by applied mathematicians was very different from that conducted at IIMAS.40 As one respondent put it:

When it was created, [IIMAS] cultivated traditional fields. It was [most interested in] fixed mathematics: algebra and topology. By contrast, at CIMAS developments were made in the direction of analysis and differentials. This is no longer done, but, at the time, [these fields] were important, although they were considered second-class fields in comparison with conventional mathematics. Hence, applied mathematics were distinct, and they continue to be so, although [the field has] a common language with pure mathematics.

Nevertheless, the changes that led to the creation of CIMAS consolidated a space for research in applied mathematics. There was already a consensus that applied mathematics (and, in general, all applied research) was not opposed to scientific knowledge: it could be part of that world if it was ‘applied’ to problems of traditional sciences. The applied could exist as a ‘basic’ paradigm as long as its purpose was not to provide services. What, then, was the relationship between applied mathematics and the work of computational and engineering technologies? At CIMAS, two options emerged for applied researchers: some decided to carry out theoretical applied (basic) mathematics; others preferred to conduct technological or practical mathematics:

Many things can be called applied mathematics. To begin with, [non-applied] mathematics is the only scientific discipline of the hard sciences that studies itself, that creates its own objects of study and knows them with a special language, and, therefore, we can say that it is not related to ‘reality’. What, then, is applied mathematics? [It is the mathematics] that does study phenomena of reality, such as physical, chemical and biological ones. However, within applied mathematics there are, at least, two types of developments: those which you do not know when, nor with what they will be applied. . . . I would call [these] ‘theoretical applied mathematics’. Normally [these focus] on basic sciences, the rules of the game of which – types of products, production times – are similar to those of basic sciences. [Secondly], there is mathematics applied to industrial and technological processes with rules and work methods different from those of theoretical applied mathematics.

That is, the applied now reproduces the old distinction between basic and applied: applied-research projects involved in theoretical problems of basic sciences are perceived as different from those applied to develop technological innovations. Technical applied research is practical; this is the research closest to computing and electronics.
Once again, perception of these differences is embedded in distinct forms of work organization. Between 1975 and the early 1980s, *practical* applied researchers set in motion a series of applied academic projects that effectively constituted their ‘work model’. They defined them as . . .

. . . complex projects in recently developed areas, with an orientation complementary to the activities of basic and applied research. These are not original works; nevertheless, results have been obtained in the technological aspect. . . . They are motivated by more or less concrete problems from the immediate reality. . . . They are developed without resorting to foreign experts, which, although it means that it will take longer for them to be conducted, at the same time allows for greater creativity and . . . occasionally generates extraordinary resources.  

Of these projects, the following were the most important: the ECO Project (in computer networking), to bring together a group of researchers to develop infrastructure that would implement computer networks within UNAM and throughout the country; REDLAC (carried out with IPN researchers), to establish computer networks in Latin America; RAMSES (Automatic Micro-Meteorological and Echo-Probing Network), to develop mathematical models of atmospheric microcirculation and pollutant dissemination; the Remote Perception (RP) Project, to research applications of teledetection; and RESMAC (Mexican Seismological Continental Opening Network), to design and construct a network of seismometric stations interconnected through a central computer, for registering and transmitting information in real time on seismic events throughout Mexico. Since these projects were all motivated by *practical* problems, they were not intended to offer services; nor was it their final mission to construct devices or to develop software – these were merely means for conducting the projects. Organized by researchers who acted as project leaders, they advanced with engineers and technicians carrying out support work, developing software, designing or adapting instruments. Although most of these applied-research projects absorbed a great deal of technical work, this was subordinated to their research aims.

This new work structure redefined the limits of ‘the applied’. *Technical work* was no longer anything except the specific activity for supporting research (applied/basic) that was defined as a function of research itself. However, as in the preceding stage at CIMAS, in which machine operators and programmers were distinguished from would-be researchers, *practical applied researchers* were distinguished from *theoretical applied researchers*. The former worked on projects intended to solve problems from pure sciences, but they could end up providing practical solutions and, at times, meeting specific market demands; developing these projects required teamwork and large numbers of technicians and researchers. By contrast, theoretical applied researchers were organized on a model of ‘solitary’ work, so that they could publish, and solve disciplinary problems at a theoretical level. Applied ‘technological’ research only appeared in those Departments characterized as carrying out technical tasks: except for RAMSES (led by researchers from Numerical Analysis), these projects were directed by the
Electronics and Computing Departments. The Departments of Statistics and Operations Research, Numerical Analysis, and the group for Mathematics and Mechanics, kept their distance from such sponsored research, working instead on academic projects which were, to them, the expression of basic research:

There were theoreticians and applied [researchers]. The former did not have sponsored projects and the latter typically did. . . . We, applied [researchers] said, 'it's all right to publish but we need the machine to work, to not have mistakes, to make its calculations, to perform its data transfers correctly. And we want it to work by such and such a date. . . .' They were progressing on the theories, and we were advancing in practice. What they were thinking, we were doing. They did not have the knack, the experience [to know] what works and what doesn't. And we, in turn, did not have time to be thinking abstractly.

Another theoretical applied researcher said that in his Department . . .

. . . there are no leaders; we work very anarchically or very democratically; we are all equals. Everyone functions individually, as he best sees fit. Yes, there are projects, but they have arisen over time, and collaboration is the same way: it emerges spontaneously; as you identify common interests, you begin to associate with those people and to try to make progress on certain issues. . . . However, we certainly don’t function on the basis of large projects.

In 1982, the Computing Department split into two groups: one was called the ‘Department of Computer Sciences’; the other the ‘Department of Computer Systems’. Although this separation was not officially recognized, it reflects the conventional contrast between ‘the applied’ and ‘the basic’. Although all members of the Computing Department were interested in research, some saw it through a theoretical perspective, and others as an activity that should be oriented toward technological development:

And we said, we are going to have an applied [Computing] Department and we'll call it Computer Systems. . . . Then, when the resources had to be divided, everyone wanted to have an equal share. But when we had to work and get projects done, it wasn’t the same any more. Some [people] were very busy, doing their special research projects, and they didn’t help. Then we said, 'here a few people grind the mole sauce [and cook] the stew, but everyone eats!' Hence it would be interesting to draw a well-defined line: on one side those who don’t work, and on the other those who [are involved in] sponsored projects. Those who were in the group of [persons] who did not generate resources, who did not have projects, were putting out interesting research, from a theoretical standpoint.

Eventually, accumulated experiences (from the introduction of the first computer to the definition of applied research, as theory and technique) discredited the model of pure scientific research that had dominated the group well into the 1970s. In its place, a new model was instituted: scientific research would now be mapped on to a spectrum from applied to basic research; at one end, there is a search for knowledge offering practical
responses to major problems of science, dealt with technically; and on the other, a type of knowledge that tackles theoretical problems, removed from the impurity of practical matters. But in this new model, as in its predecessor, there were imbalances, since preference was given to theoretical activities. Since the 1980s, the group of applied technicians has shrunk, and those Departments conducting theoretical research have prevailed. According to a survey we conducted, 23 academics left the Institute between 1982 and 1989, a period of economic crisis commonly known at the University as the ‘lost decade’: in just three years (1982–85), the ‘technical’ Computing and Electronics Departments lost eight staff (roughly one third of the 23).

This imbalance in favour of theoretical applied research can possibly be explained by the Mexican economic crisis of the 1980s, the clearest manifestation of which was the deterioration of the purchasing power of academics and, in general, of the University. In this period, the job market outside the University offered better salary options for computer and electronics researchers, but basic applied mathematicians had few comparable opportunities. But there is a second possible explanation, of at least equal importance: University policies for scientific and technological development – and, particularly, the system of academic work evaluations, which have been based on standards of academic success inspired by basic research. According to University policies, outstanding research is identified with work methods and types of products that are close to the norms of basic research: compared with that ideal, applied research (and especially technological applied research) apparently has no place. And although the University authorities have increasingly recognized and stressed the importance of applied research to UNAM, they have not acknowledged the different (but also confusing) manifestations of ‘the applied’ – technological research, technological development, or theoretical research – since the balance of evaluative criteria increasingly encourages presenting findings in journals, thus leaving no room for the products of technological research. We believe that this situation, allied with economic pressures, can explain why most applied investigators and technicians at UNAM do not presently fit the University’s ideal model of scientific researchers. Few practical applied researchers remain. Since the 1980s, the attraction exerted by market salaries on IIMAS researchers with clear technological interests seems to have brought to an end a period in which ‘the applied’ also implied technological work and innovation. In the end, many went into the job market and stopped doing academic research.

The questions that need to be asked are: ‘How can we create a space within the University for the work of those who have stayed and those who will come, that might transform the energies currently dissipated in the present difficult situation (and in the strong competition both inside the Institute and in the University at large) into productive cooperation between “basic” and “applied”?; and ‘To what extent do the researchers themselves (both basic and applied) share the ideal of basic science that has so enhanced the differences in their work organization as to make them
appear irreconcilable in the University environment? In any case, it is highly likely that the value differences between what is ‘pure’ and what is ‘applied’ will persist, while the University’s policies continue to confirm perceptions of the ‘technical applied’, and of ‘technological work’, as ‘mere trade’: routine, mechanical skill that simply does not accord with the definition of what successful researchers do, or should be.

Final Thoughts

In our UNAM case study, we found a segmentation between three types of academics: the *theoretical applied*, the *applied* and the *technicians*. The objectives of ‘theoretical applied researchers’ are closest to the ideal of *basic science research*; although ‘applied researchers’ use the same methods as theoretical applied researchers, they choose to work on topics applicable to solving practical problems; while the technician’s rôle is to produce technical devices necessary for solving scientific problems, and to design experiments that support research projects. The products of technicians’ work are different from those of basic or applied researchers: rather than writing papers, technicians produce technology. All these forms of applied research production are essential to basic research, not only in offering instrumental services, but also in stimulating and resolving theoretical problems in applied mathematics. And yet, as IIMAS became institutionalized, UNAM’s evaluation policies drove those applied researchers whose work is linked to technical aspects to lose interest – not only in the electronic engineering laboratory, but in the entire ‘outside world’, as it is represented within the University. While beginning to acknowledge the importance of applied and technological research, UNAM still evaluates its results by ‘basic research’ ideals, values and standards: the scientific authorities have decided that ‘the absence of formal publications in the academic work of a researcher is unacceptable’. These policies lead to stagnation in the academic careers of researchers devoted to developing applied and technological innovations: many have had to leave the University and look elsewhere for satisfying, well-paid work. This situation can make sense of the enormous gap that exists, in Third World countries, between university research and those countries’ desperate need for industrial renovation.

In 1990, the External Computer Science Committee, which evaluates IIMAS’ master’s degree programme in computing, underscored this problem, pointing out that at UNAM, when research is evaluated (and, therefore, encouraged), no distinction is made between basic and applied aspects: ‘What distinguishes computer science from all other academic disciplines is that it had both strong mathematical foundations (computer science finds its deepest roots in recursive function theory and automaton theory – fields pioneered by mathematicians in the 1940s) and engineering applications’. Indeed, computer science (like many other applied disciplines) has both technological and basic aspects, both of which are necessary for its development. UNAM has not resisted the temptation to overemphasize the (basic) mathematical aspect, which is fundamental for
the discipline: but the Committee warned that, if the technological aspect was not attended to, 'computer science at UNAM will become a sterile field, as only theoreticians survive academically. They, in turn, will suffer in the long term; in computer science most important theoretical problems are derived from practical, technological challenges'.

Underestimating the technological aspects of applied sciences, such as computer science, has negative consequences – not only for applied mathematics, which offers practical solutions to scientific problems, but also for basic research itself. The achievements of basic and experimental science cannot be understood without considering the participation of technological work. For example, CERN is an enormous research project, posing and tackling deep theoretical problem in physics, but it could only be carried out through close collaboration between scientists, engineers and technicians: the 1984 Nobel Prize in Physics was shared by the Italian physicist Carlo Rubbia and the Dutch engineer Simon Van Der Meer. This award recognized that technical activities dealing with engineering artifacts and products are not only necessary for so-called pure sciences, but that they can achieve the same status and earn the same merit.

Traditional university research increasingly requires high-level technological support if it is to respond to cutting-edge theoretical and technological problems. But the career development of technical applied researchers runs up against university opinions and policies that do not afford them the same recognition, nor offer them the same material and symbolic incentives, as those granted to researchers in theoretical applied sciences. In the Institute we studied, those working in applied fields with technological characteristics faced situations which reflect the continual dominance of the traditional vision of science: in our sample, the technological and engineering support required by basic research work has been reduced to a minimum. Clearly, this problem has no single solution: rather, it represents an invitation to university scientific policy-makers, and to science studies scholars, to rediscover the complex dimensions and characteristics of university research, of scientific knowledge, and of applied and technological activities.

Notes

The authors wish to thank all the people who, in interviews and daily conversations, allowed us to become familiar with the history of the IIMAS; without their participation we could not have written this paper.


5. The classic definition, from the OECD’s Frascati Manual, differentiates basic and applied research according to the different interests they pursue.

Research and Development (R&D) is a term covering three activities: Basic Research, Applied Research and Experimental Development. . . . Basic Research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena as observable facts, without any particular application or use in view. Applied Research is also original investigation in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.


. . . all those scientific, technological, organizational, financial and commercial steps which actually, or are intended to, lead to the implementation of technologically new or improved products or processes. Some may be innovative in their own right; others are not novel but necessary for implementation.


12. The IBM-650 computer had a dynamic bulb memory (magnetic drum) and a card reader and card punch. It had its own language, called BIQUINARIO, in addition to an assembler called SOAP (Symbolic Optimizer and Assembly Program), and a pseudo-compiler (macroassembler medium) called RUNCIBLE, as well as a BELL interpreter. See: Manuel Soriano and Christian Lemaitre, ‘La era digital’, *Ciencia y Desarrollo*, Vol. 60 (México City: CONACYT, 1985), 133–40, at 136.

13. Shortly thereafter, in 1961, the National Polytechnic Institute created the National Calculus Centre (CeNaC), with an IBM-709 computer. Despite the dynamism these two centres gave to academic computing nationwide, in 1972 there were only 18 computers for 156 Mexican universities and institutes of higher education: see Raymundo Segovia, Sidhu Gursharan and Cristina Loyo, ‘Redes de computadoras’, *Ciencia y Desarrollo*, Vol. 26 (1979), 10–19, at 16. Obviously, if we compare these numbers with the experience of countries such as the USA, the differences are remarkable: according to the well-known *Rasser Report* (1966), the USA in 1957 had 40 computer centres; by 1964, 400 were reported: Aspray & Williams, op. cit. note 11, 64.

14. The University researchers and students closest to the Centre were, among others, those at the Institute of Physics, at the School of Engineering, and at the School of Sciences.

15. The G-15 ‘was semi-transistorized, with a drum memory and [it had] the feature of short and long lines, having a total 2200 locations called words, each one with a capacity of nine hexadecimal characters; in addition, it had a magnetic tape, a reader and a paper punch, a typewriter [that] served as a console for entering and receiving instructions, [which] could be used for data, as well’: Soriano & Lemaitre, op. cit. note 12, 135.

16. From very early on, although outside any formal organization, there were initiatives to teach computing at the University. Among those most remembered, due to the extraordinary professor who taught them, were the doctoral and undergraduate courses offered by Dr Alejandro Medina Plascencia to mathematics and physics students at the School of Sciences; Medina included in his courses topics related to computing, such as control theory, linear programming, automaton theory and artificial intelligence, among others. See: Christian Lemaitre, ‘La computación en la UNAM en el periodo de 1968–1980: Una interpretación’, in *Memoria: Pasado, presente y futuro de la computación: 30 aniversario de la computación en México* (México City: UNAM, 1988), 358–69, at 361. Subsequent to the master’s degree programme that had been promoted by Beltrán, in 1970 another was created in computer sciences, based at CIMAS (and later, at IIMAS), within the programme of the Academic Unit of Professional Cycles and the Postgraduate Programme of the College of Sciences and Humanities, at UNAM, which continues to operate to this day.

17. Although we do not have precise data on the number of Mexican students who have studied computer science abroad, it is important to point out that many engineering and mathematics students joined the Centre and received support to pursue doctorates or specialized degrees abroad, in disciplines related to computer science.

18. Among the most important specialists who came into contact with the members of the Centre were: Alan Perlis; John Weber Carr III; Abe Chernes, a specialist in operations research; Dr Leon Cooper, an expert in computer science applied to administration; and Harold McIntouch. See: *Gaceta UNAM*, Vol. VI (24 August 1959), 3.


20. Sergio Beltrán and Manny Lemann, among others, participated in designing it; Lemann temporarily joined CCE, after having participated in the Fourth Colloquium on electronic computers, held in 1962.

21. From its creation until 1970, the Centre only had appointments for administrative personnel; indeed, according to statistics provided by the University itself, its members were not counted as academics (either professors or researchers), but rather were considered within the UNAM’s Area of Sciences, as administrative personnel. From 1965–67, only administrative appointments were made: ‘professionals, specialists,
administrators and workers’, with ‘specialized staff’ as the largest group. ‘Specialized staff’ covered those persons who conducted ‘specialized technical activity, such as laboratory workers, statistics graphers, filing clerks, card punchers, bookkeepers’. See: UNAM, Estadísticas del Personal Académico (México City: UNAM, 1967), 3.

22. As noted by Raymundo Bautista, it was not until the 1970s that the institutionalized development of CIMASS in applied mathematics and statistics (see below) could be considered to have begun: ‘Applied mathematics, understood as the study of medium-scale phenomena, approachable through continuous models, began independently with the work of Ismael Herrera … in the 1970s’: R. Bautista, ‘Treinta años de investigación matemática en la UNAM’, Ciencia: Revista de la academia de la investigación científica, Vol. 45 (México City, 1994), 231–39, at 232.

23. Of all Mexican higher education centres, UNAM is the public university employing the greatest number of researchers. According to the 1991 OECD Review, of a total 27,105 scientists, engineers, technicians and supporting personnel working in Mexican public universities, 21.63% were in UNAM. In the same year, 10.28% of the 57,016 Mexicans dedicated to I&D activities worked in UNAM. See: OECD, Reviews of National Science and Technology Policy: México (unpublished report, OECD, Mexico City, 1993), 21. And if we take into account that, in 1994, it was estimated that there were nine scientists and engineers for every ten thousand working Mexicans, the basic and applied research taking place in UNAM is of crucial importance. See: CONACYT, Estadísticas Básicas: Resultados de la actualización del Inventario de investigación y recursos dedicados a las actividades científicas y tecnológicas (México City: CONACYT, 1994), 115.

24. As far back as 1961, at the offices of the University administration building, a Data Systemization Unit had been installed, where peripheral equipment was used exclusively for processing administrative information pertaining to the University: the payroll and scholastic data. These processes had until then been handled outside the Centre, ‘due to the secrecy of university administrative information’: Soriano & Lemaître, op. cit. note 12, 136.

25. The area of scientific research at UNAM was formally constituted in 1945, with the creation of the Technical Council on Scientific Research (CTIC): there was then an organization to coordinate the University’s research institutes, of which there were nine at that time. In 1970, the Area of Sciences, now known as the ‘Subsystem of Scientific Research’ (SIC), had 12 institutes.

26. In that same year, 1970, the EP4 was approved, by which the expression ‘academic personnel’ was for the first time included in the University’s legislation to refer to the four categories under which University personnel conducting activities related to teaching and research are hired: professors (preferably those who teach at the facultades, or schools); researchers (those who work at research centres and institutes); academic technicians; and research assistants (who perform support work for researchers and professors). With the EP4’s by-laws, which were modified in 1974 and 1975 (the latter version is still in force), it became possible to make definitive appointments for professors, researchers and academic technicians, in addition to appointing those belonging to the first two categories as career university personnel. On this topic, see: Susana García-Salord, Los académicos itinerantes de laberintos y escaleras: Estudio socioantropológico de un grupo de las clases a medias (unpublished PhD thesis, Facultad de Filosofía y Letras, UNAM, 1996).

27. It appears that this situation was not confined to Mexico. In the 1940s, the project to create the first digital electronic computer, the ENIAC (Electronic Numerical Integrator and Calculator) of John Paul Eckert and John Maclaug, was received with a certain indifference by established scientists interested in the development of practical computing methods. For this case, see, for example: Nancy Stern, ‘The BINAC: A Case Study in the History of Technology’, Annals of the History of Computing, Vol. 1 (1979), 9–20. The history of Howard Aiken, another pioneer of computing, reveals a similar situation. According to Cohen (op. cit. note 10, 120–22):
Aiken] was a real outsider and upstart, only a graduate student in a field of science, physics, far removed from any concern with inventing new machines for numerical calculation. He related that he had been told by the permanent tenured members of the Physics Department at Harvard that they had no interest in his proposed machine and would not give it any support, and he maintained that Harvard’s President Conant had even told him that he would have no future at Harvard if he continued work on computing machines rather than doing more traditional work in electron physics.

32. These were undergraduate students interested in computing and electronics who were paid for their work on the Centre’s service projects. Indeed, many of them would eventually become researchers at the Centre.
34. Another researcher, whose background was not in computer science, recalls:

At one time I would go to the Computer Centre of INFONAVIT; at night, because some people from CIMASS, [who were] under contract, were in charge of the payroll of that Institute. Then, one day before INFONAVIT [made its] payments, there was urgent work: the programs didn’t run and I was chosen to go supervise. I didn’t know [anything] about payrolls, nor about COBOL (which was what programmed all of that), but they would send me to solve problems of INFONAVIT’s payroll. It’s funny. I remember that one of my colleagues said, ‘How has a statistician like you been made responsible for seeing that INFONAVIT’s payroll be finished on time?’

On this subject, see also Forsythe, op. cit. note 4, 456–59.
35. It is important to stress that perceptions of this differentiation between theoretical and instrumental work can only be explained by complex variables, both sociological and cultural (‘values’): no doubt psychological factors also play a part. Thus Harry Rothman (op. cit. note 6, 85) points out that . . .

... the asymmetry between the theoretician and experimentalists in science is rather bizarre when one considers their mutual interdependence. It is that experimentalists are less pure, proletarian rather than aristocratic, more likely to be tainted by the dirty world of production. No doubt there are many complex sociological and psychological factors at work.

36. At UNAM, the change in the Centre’s status to an Institute was made when it was felt that there was a group that guaranteed continuity in the disciplines in which work was conducted, as well as faculty with a certain degree of maturity, and that the Centre had acquired sufficient equipment and facilities to allow for its academic evolution. These, among other criteria, were discussed with the Technical Council of Scientific Research, with the Internal Council of the Centre (that would become an Institute), and with the University Council (the University’s highest authority). See: Coordinación de la Investigación Científica, La investigación científica de la UNAM, 1929–1979, Vol. V (México City: UNAM, Tome I, 1987).
37. Bracho, op. cit. note 30, 27.
38. Ibid.
39. The number of academics grew from 42 in 1974 (32 researchers, 10 assistants and technicians), to 46 in 1975; in 1976, the number fell to 43. See: UNAM, "Estadísticas del Personal Académico" (México City: UNAM, 1975–77), 231.
40. Bautista, op. cit. note 22, 233.
42. Segovia, Gusharan & Loyo, op. cit. note 13, 18.
44. Garza, op. cit. note 41, 120; Gil Mendieta, op. cit. note 29, 13.
46. On this issue, Ronald Kline has already shown how American engineers originally constructed and defined their professional field in subordination to so-called basic science, hoping to eliminate the prejudiced association of engineering with art, and associate this applied field with ‘science’: Kline, op. cit. note 9, 220–21.
49. Ibid.
50. This is but one example among many Nobel Prizes given to scientists whose contributions have been experimental and applied scientific inventions. Another case in point is scientists in the field of genetic engineering and molecular biology linked to the Human Genome Project (HGP). In 1980, Fred Sanger and Walter Gilbert received the Nobel Prize for Chemistry for their contribution to base sequencing in nucleic acid. In 1993, Kary Mullis received the Nobel Prize for inventing the polymerase chain reaction (PCR) technique for DNA amplification. No doubt this recognition given to applied researchers confirms that their work is as valuable as that which provides more theoretical results. See Rothman, op. cit. note 6, 85.

Larissa Adler Lomnitz is a Professor of Anthropology, specializing in social networks, and working at the Institute of Applied Mathematics, UNAM. She is the author (with Jacqueline Fortes) of Becoming a Scientist in Mexico: The Challenge of Creating a Scientific Community in an Underdeveloped Country (Penn State University Press, 1994), and of several articles on the scientific community in Mexico.

Address: Instituto de Investigaciones en Matemáticas Aplicados y en Sistemas (IIMAS), Universidad Nacional Autónoma de México (UNAM), Apdo. Postal 20–726 Admon No. 20, Delegacion de Alvaro Obregon, México City 01000 D.F., México; fax: +52 5 5500047; email: larissa@unam.mx

Laura Cházaro was a Research Fellow at the Institute of Applied Mathematics, UNAM. She is now finishing her PhD dissertation on the history of medical statistical thinking in 19th-century Mexico, and has published several articles on this subject. She teaches at El Colegio de Michoacán.

Address: El Colegio de Michoacán, Martinez de Navarrete 505, Fracc. Las Fuentes, C.P. 59690, Zamora, Michoacán, México; fax: +52 351 55307; email: chazaro@colmich.cmicmich.udg.mx