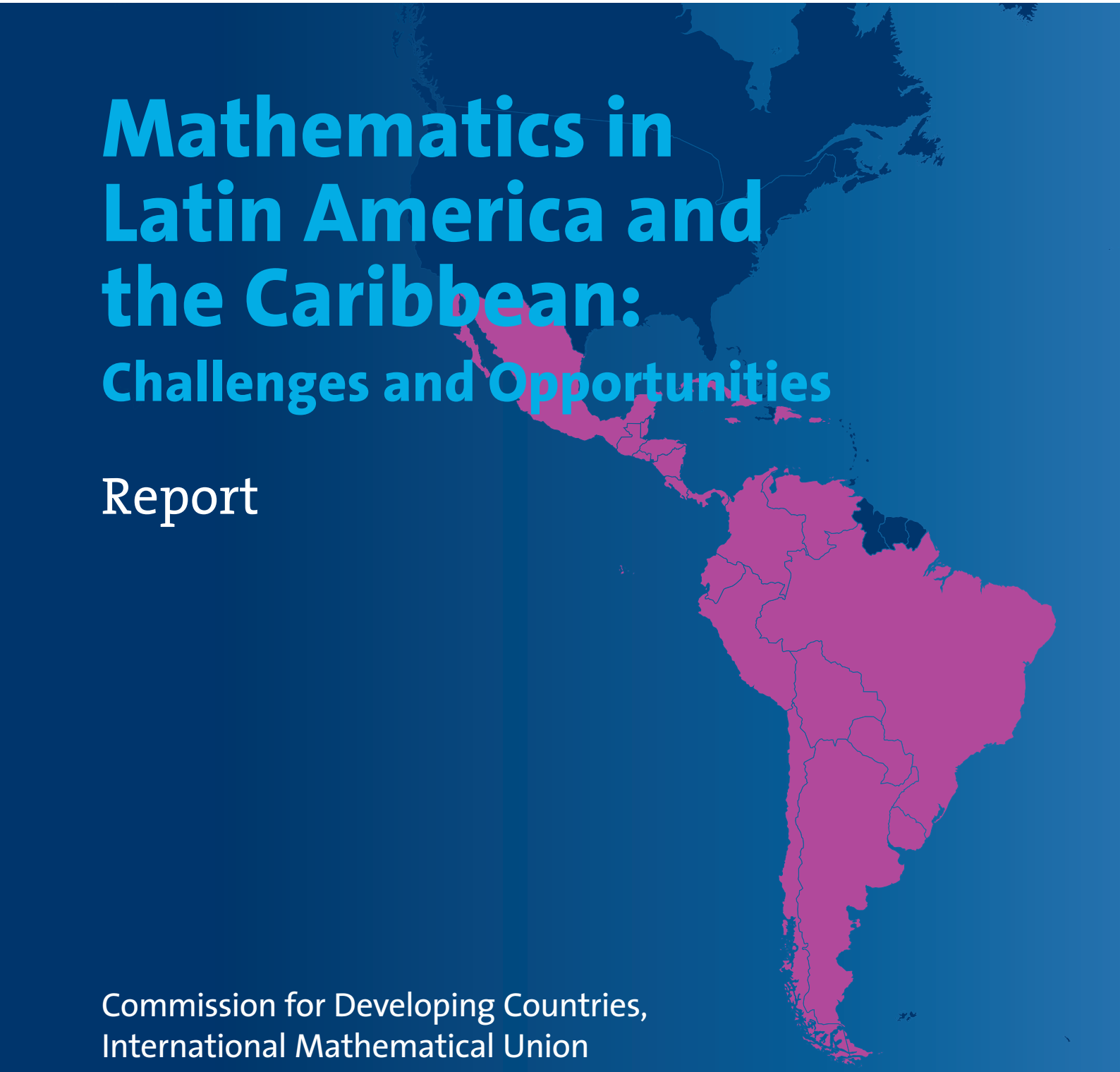
Mathematics in Latin America and the Caribbean:

Challenges and Opportunities

Report



Commission for Developing Countries,
International Mathematical Union

Mathematics in Latin America and the Caribbean: Challenges and Opportunities

Introduction

Many things are common to most countries in Latin American and the Caribbean (LAC): language, culture, even a general approach to life. Some of the cultural similarities may be reflected in convoluted bureaucracies and an irregular distribution of wealth and resources, but others reflect a culture of optimism and hope. There are also many differences in size and scale: huge countries next to tiny ones, not only when we refer to geographical area, or number of inhabitants but also referring to striking financial and educational differences. Some countries' internal differences are as big as differences between countries. These similarities, as well as deep differences, can be found when analyzing the main trends of the development of science in the LAC region. In this report, we identify some common patterns of the development of mathematics in this region while recognizing the differences.

The region suffers from a severe shortage of financial and human resources in many countries, excruciating burdens of governmental incompetence and lack of interest in scientific development. Despite these challenges, there are success stories. The average performance in the Mathematical Olympiads has been improving; there are strong centers of mathematical research; the scientific production shows Latin America as the zone of the planet with highest growth; UMALCA, a regional organization of mathematical societies supports many regional schools every year, and promotes collaboration among mathematicians of the region. In short, there are reasons to be optimistic but the building of a better future requires the concerted action of mathematicians and organizations (regional and global) to develop the full potential of mathematics in this region of the world. The two following examples illustrate both the challenges and the opportunities.

The Mexican Academy of Sciences launched a program, led by university faculty, with the aim of training secondary school teachers in new aspects of mathematics, physics and biology. At the first training weekend the 250 teachers who volunteered to participate in the program were asked: "Who already had an e-mail account?" No more than 10 hands rose. Most of the participants were sitting for the first time in their lives in a university classroom and they were amazed that scientists worried about their training. Educational authorities missed the opportunity to acknowledge the effort of the teachers by including it in the *magister career* program that rewards teachers through salary or teaching duties, citing opposition by the teachers' union. In the end, and against all odds, 240 teachers successfully completed the one-year training program. For the first time in Mexico scientists and teachers joined efforts to benefit education.

Paraguay, a country adjacent to the more developed Argentina and Brazil, had never had until recently a graduate degree program in mathematics. For historical reasons, high-level teaching of mathematics was to be found mainly in the engineering faculties. At the engineering department of the National University of Asunción (UNA), UMALCA organized the first school in mathematics in September 2005. Organized by a group of mathematicians including a postdoctoral associate at IMPA, the mathematics institute in Rio de Janeiro, and by representatives of the Mathematical Paraguayan Olympics (OMAPA) who coordinated the participation of high school students, the response to the UMALCA call was

amazing. Not only did students from several schools participate, school teachers and engineers did also. There were newspaper articles about the event. Today at UNA, there are a master's program in mathematics, and a master's and Ph.D. programs in computer science. The first Ph.D. in the history of Paraguay graduated in 2011. In a few years the number of professional mathematicians in the country has rocketed to 15. In addition, there is a demand for scientific progress in the country. This led to the creation, by law of the Paraguayan Congress, of the National Fund for Excellence in Education and Research.

There are many examples but the essence remains the same: some actions from professional mathematicians are needed to initiate changes in policies and old structures. What to do? Where to do it? This is a matter of discussion and essentially, a matter of maturity and the right mood in the involved communities. In a global world, help from neighbors may speed up and facilitate processes. The similarities of the LAC region, such as language and culture, make influences from countries within the region more suitable.

Our intention in creating this mapping of mathematics in LAC is to identify the most urgent needs within the region and the capacities already in place that may serve to start action. Organizations, such as the International Mathematical Union (IMU), may participate in and even lead some of those actions.

Preface

In August 2010 prior to the International Congress of Mathematicians (ICM) held in Hyderabad, India, new members of the Commission for Developing Countries (CDC) of the IMU were elected. In 2011, the CDC met at the new IMU permanent office at the Weierstrass Institute in Berlin. Part of the discussion centered around the possibility of organizing a meeting of parties interested in the work of the IMU in the developing world. If feasible, the meeting would be held prior to the next ICM in South Korea in August 2014. One *a priori* need was stressed for the meeting: IMU needs to know the most urgent needs in mathematics and mathematics education in emerging nations and the possibilities for mathematical development. Based on this knowledge, some resources may be identified and allocated to strategic programs: volunteer lecturer programs, building of a repository of internet resources (talk library, software, etc.) for mathematical research, support for graduate study in mathematics, or other initiatives. The mapping of needs and strengths would serve as a guide of where and what is feasible to do.

In our view, this was the motivation that led CDC to launch a project to map mathematical development around the world. The project had a forerunner in a 2008 report on African mathematics and mathematics teaching funded by the Templeton Foundation that has proved quite useful in several contexts. Hence 2012 was dedicated to seeking information from a cross-section of developing countries in Asia, Africa and Latin America and the Caribbean.

This document represents the report from the Latin America and Caribbean region. The scope of the report encompasses the state of mathematics in this region including countries in early stages of development and the possibilities to accelerate transition to a level that can sustain mathematical research. To do this work, information available through databases was not enough. There was an obvious need of having direct personal contacts *in situ*.

The author team of this report consists of five mathematicians from different countries in the LAC region. The essential part of the work was done via written surveys with representatives of the mathematical communities in most of the countries considered in the study. In fact the **objectives** set for the work became more ambitious than those considered at the creation of the project:

- to gather information to coordinate future efforts in mathematical development in the region;
- to identify potential activities with the highest impact for improving access to mathematics in under-served populations;
- to create a network of mathematicians to support each other in mathematical development.

We report in these pages the results of our consultations. To establish a conceptual framework for the information-gathering we begin this report with a section entitled **General Context,** presenting the information available on education and scientific production in the LAC region, with an emphasis in mathematical education and training, and research in mathematics. We consider the current state of mathematics at all levels but emphasizing universities in the region, the current state of mathematical research and other trends and general patterns in education and research.

In the second section we review the six regions of our study, finding common trends and giving specific qualitative information on many of the countries of the LAC region. Our report includes:

- Mexico;
- Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama);
- The Caribbean (Cuba, Dominican Republic, Jamaica, Puerto Rico, Trinidad and Tobago, US Virgin Islands);
- North of South America (Colombia, Ecuador, Peru, Venezuela);
- Brazil;
- South of South America (Argentina, Bolivia, Chile, Paraguay, Uruguay).

In the third section of this report, the author team has compiled a list of recommendations of feasible actions to be carried in order to further develop mathematics in the LAC region. This section identifies challenges and opportunities for the region. It is our hope that national organizations, as well as global partners, such as IMU, find the report useful for decisions and actions.

In the appendices we provide contact information on mathematicians in each country, the survey used and the author biographies. We hope this work has already helped to form a network of useful contacts in the LAC region.

Acknowledgements
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General Context

Basic Education and PISA Evaluations

Mathematics and science are primary sources of lifelong learning and progress for our civilization. Although there is a general social awareness of the relevance of mathematics education and mathematics as a support of science and their applications, many countries in the world perform poorly in student assessments in mathematics and in the production of mathematical knowledge or its many applications. The Latin American and Caribbean region is an area of deep concern in this respect. In spite of certain progress in some countries, the region is behind in terms of basic education in mathematics.

Latin American and Caribbean countries are very different in some aspects, while at the same time, very similar in others. The area is comprised of countries with only three main spoken languages —Spanish, Portuguese, and English, so most people in the region are able to communicate with most others in this region of the world. Thus, linguistic homogeneity is a regional strength. However, population and per capita gross domestic product (GDP) separate the region's countries into very different groups. Some countries, like Brazil and Mexico, have large populations (195 million and 111 million inhabitants, respectively), while Saint Kitts and Nevis has quite a small population (52,000 inhabitants). On the other hand, the region's per capita purchasing power parity (PPP) ranges from 1,587 USD in Nicaragua and 2,247 USD in Honduras, to 14,993 USD in Chile and 16,699 USD in Trinidad and Tobago (Table 1). And this is even more dramatic when compared to countries like Canada, whose per capita PPP reaches 50,345 USD. Among the similarities, literacy for the 15-24 year age group, which is estimated at nearly 90%, is similar in most LAC countries, while there are great differences in literacy levels of older people.

Most LAC countries provide education for almost all their young people. Regrettably, education quality is too often poor. In Latin America and the Caribbean, many children are not being taught at the level they will need to live their lives and work productively.

There are countries in the LAC region such as Argentina, Chile, Uruguay and Cuba, among others, with a good level of primary and secondary education compared to others such as the Dominican Republic, Paraguay and Bolivia. A characteristic which is common to several countries of the LAC region is the significant difference between educational opportunities in large cities and those in rural areas; also in many cases the quality of education depends strongly on the purchasing power of families; expensive private education frequently offers a better training. In addition there are significant differences in terms of the academic preparation required for a teacher in schools of different countries in the LAC region. However, in basically all countries of the LAC region there is deep concern about the deterioration in the training of teachers for elementary, middle and high school. This insufficient preparation of teachers has contributed over the years to a systematic deterioration in the academic quality of the students.

	Total population (thousands)	Annual population growth (%)	Life expect at birth	Poverty (% at pop. with less than 2 USD/day)	GDP (per capita ppp in USD)
Antigua & Barbuda	-	1.0	75	-	12 480
Argentina	40 666	0.9	76	1.9	10 942
Barbados	257	0.2	77	-	13 453
Bolivia	10 031	1.6	67	24.9	2 374
Belize	313	3.4	76	-	4 059
Venezuela	29 044	1.5	74	-	10 810
Brazil	195 423	0.9	73	10.8	12 594
Chile	17 135	0.9	79	2.7	14 394
Colombia	46 300	1.4	74	15.8	7 104
Costa Rica	4 640	1.4	79	6.0	8 647
Cuba	11 204	0.0	79	-	5 397
Dominican Republic	10 056	1.3	73	9.9	5 530
Ecuador	13 775	1.4	76	10.6	4 496
El Salvador	6 194	0.6	72	16.9	3 702
Guatemala	14 377	2.5	71	-	3 178
Guyana	761	0.2	70	-	3 408
Haiti	-	1.3	62	-	726
Honduras	7 616	2.0	73	29.8	2 247
Jamaica	2 730	0.3	73	-	5 330
Mexico	110 645	1.2	77	5.2	10 047
Nicaragua	5 822	1.4	74	-	1 587
Panama	3 508	1.5	76	13.8	7 498
Paraguay	6 460	1.7	72	13.2	3 629
Peru	29 496	1.1	74	12.7	6 018
Saint Kitts and Nevis	52	1.2	71	-	13 144
Suriname	524	0.9	71	-	8 292
Trinidad and Tobago	1 344	0.4	70	-	16 699
Uruguay	3 372	0.4	76	1.2	13 866
Canada	34 483	1.0	81	-	50 345

Table 1. Socio-economic figures for the LAC region[1]

Evidence of the poor elementary education in the region can be found in the results of international evaluations like the Trends in the International Mathematics and Science Study (TIMSS), or the regular evaluations of the Program for International Student Assessment (PISA) conducted by the Organization for Economic Co-operation and Development (OECD). Both programs provide reliable and timely data on mathematics and science achievement in many countries. The PISA program evaluates reading and mathematical abilities. Not surprisingly, in many countries, low mathematics results correlate with low language results. Below are the reading and mathematics results for some countries found in the OECD's 2006 PISA database.

[1] Sources: Population: http://www.onuhabitat.org/ (UN); Population Growth, Life Expectancy, Poverty Rate and GDP: http:/datos.bancomundial.org/ (World Bank).

Selected countries	Reading	Mathematics
Korea	556 (maximum)	547
Finland	547	548 (maximum)
United Kingdom	495	495
Slovenia	494	504
Spain	461	480
Chile	442	411
Uruguay	413	427
Mexico	410	406
Brazil	393	370
Colombia	385	370
Argentina	374	381
Kyrgyzstan	285 (minimum)	311 (minimum)

Table 2. 2006 PISA scores for countries in the LAC region along with a few other countries for comparison. Note that few of the countries in LAC take the exam.

Perhaps the fundamental problem is not the low scores, but their meaning. We shall emphasize that, according to the PISA results, mathematics is the best academic indicator of the student overall accomplishment. According to the PISA Board more than 50% of the Latin American students at the age of 15 are not able to solve simple problems which need two or more logical steps for their solution. On the other hand, the best social indicator of a student success is the level of preparation of the student's mother. Long-term solutions require a better mathematical literacy of the population of our countries and actions are urgently needed. An identification of the most critical problems in the region points to the need of better training for the mathematics teachers.

In spite of those poor general results, we can find in the region examples of significant efforts that have proved successful in improving mathematics teaching and results, and which involved professional mathematicians. The International Council for Science (ICSU)-LAC Scientific Planning Group on Mathematics Education has compiled and made available information from several countries.

Mathematical Olympiads in the LAC Region

In several countries of the LAC region, the Mathematical Olympiads have been a very effective vehicle to promote mathematics and to identify highly talented students. Some countries in the region such as Brazil, Colombia and Cuba have participated for over 30 years in the *International Mathematics Olympiad* (IMO). In 1985, under a Colombian initiative, the *Iberoamerican Mathematical Olympiad* was established, and it has been held continuously since then. This Olympiad involves the participation of 22 countries of the LAC region, as well as Spain and Portugal. This prompted the creation of Mathematical Olympiad programs in different countries. Some years later, other regional competitions as the *Olimpiada Matemática del Cono Sur* and the *Olimpiada Matemática de Centroamérica y el Caribe* were created. Argentina has twice hosted the IMO, Mexico and Colombia once.

The National Mathematical Olympiad in Brazil is an event of an impressive magnitude; 18 million of young people are involved, which constitutes 10% of the country's population. Peru has recently experienced a dramatic advance, with excellent participation in international competitions partly due to mandatory participation of public school students. Mexico, Colombia, Brazil and Argentina are countries of the region that have shown consistency in their performance in the International Mathematical Olympiad.

The Tertiary Educational System

Each country of the region presents its own characteristics. Differences among educational systems consist in their sizes, the age distribution of the students, relations with the government, funding and budgeting along with the participation of each country´s private institutions. However, it is possible to find some common tendencies regarding their development, which makes it possible to understand predictable limitations to their growth (Brunner 2008).

From 1950 to 1975, the student population in the LAC region increased by a factor of almost 13, reaching almost 3.5 million students. In the last 50 years, the number of institutions has increased as has the diversity in size, with student populations as big as 200 thousand students and others with less than one thousand. In the Latin American region, the number of tertiary level institutions has multiplied reaching over 11 thousand, 4 thousand of them being private and public universities. Within this anarchic growth, a strong tendency is an increasing presence of tertiary private institutions that do not rely on public funding and have about 47% of the total student population of Latin American institutions (Garcia Padilla 2006). Their participation rate is of more than one half of the students enrolled in Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Paraguay and the Dominican Republic.

Because of the historical evolution of the tertiary educational systems and the public policies of the Latin American countries, the principal state universities have a strong relative predominance in each country, for instance: University of Buenos Aires in Argentina, University of San Marcos in Peru, the University of Chile, the Central University of Venezuela, the Republic University in Uruguay, the National University of Colombia, the University of Puerto Rico, the National Autonomous University of Mexico and the University of San Paulo in Brazil –which, at the top of the state subsystem, have accumulated through their history the benefits of public allowances, the prestige of being bearers of a national culture and the institution of the most acknowledged professionals. On the other hand, state universities used to have chronic problems in management and, according to particular and temporary national conditions, might also be confronted with political problems and pressures related to credibility as institutions of higher education.

Regarding personnel dedicated to scientific research activity, it is scarce and concentrated in the national and state universities. Together, the region contribution to the total of Scopus citable publications in 2011 was of 3.60%, less than Italy. Within this percentage, Brazil produces almost half of it (Scimago). On the other hand, only ten Latin American universities are included among the 500 of the 2012 *Academic Ranking of World Universities* (ARWU); six of them are in Brazil, two in Chile, one in

Argentina and one in Mexico. Three of these institutions are ranked between 101 and 200; one between 201 and 300 and another three between 301 and 400. The other three are ranked between 401 and 500.

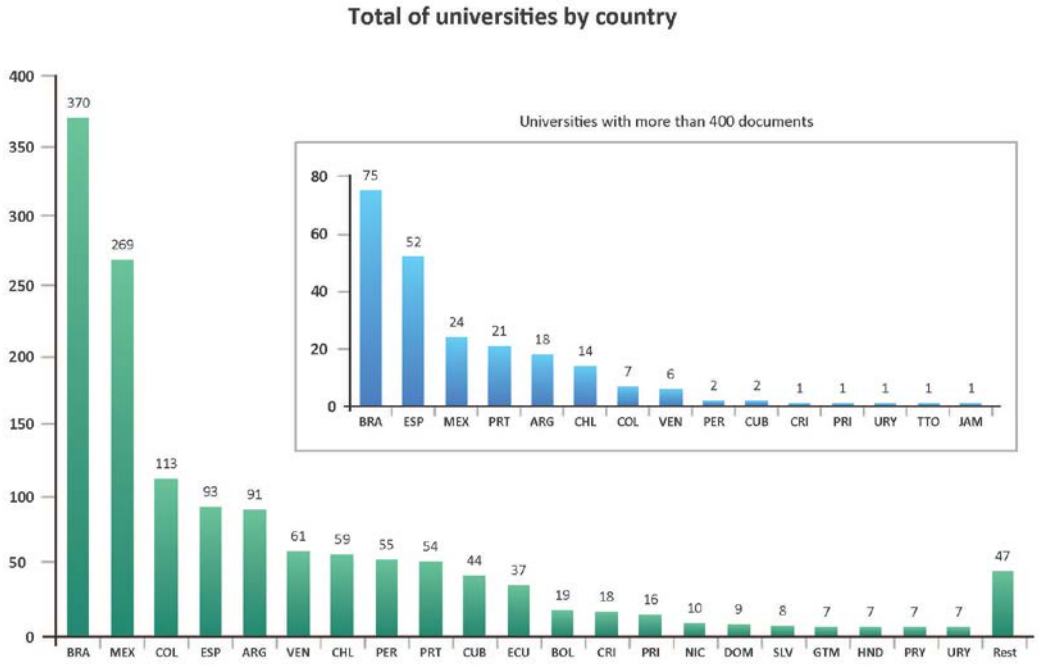

Figure 1. Number and research output of universities in LAC (Spain and Portugal were included for comparison). Source: 2012 Scimago Institutional Rankings.

In Search for a Science and Technology Normative System

From the decade of the 1950's, some of the region's countries established institutions devoted to the creation of public policies, planning for and promoting science and technology. In the following ten years those institutions received plenty of support, but some of their actions were contradictory and were interrupted; others showed continuity, in general because the socio-political circumstances allowed it, and they were designed following organizational trends and general concepts popularized by UNESCO and the Organization of American States (OAS).

The Latin American experience in using scientific and technological policies as a development instrument has not been fully successful, regardless of some academic achievements. The space left by the industrial sector demand was occupied by the scientific community, playing a policy role in the design of science and technology that exceeded by far the role played by the scientific community in developed countries.

In recent years, science and technology policies in the LAC region are evolving from a governmental policy to a public one. For that reason, different tensions have built upon legal, institutional and organizational matters inside the science and technology system. Within this period, changes in the norms have constituted important but insufficient advances. That is why the system frequently works in an unarticulated way and with little coherence and focus. Besides, as a public policy, it is unclear which

is the issue it is trying to cope with; is it about promoting the scientific research or about solving national problems through fostering innovation?

Debate between these positions has not yet finished and, in general, is not the central issue of the national agendas. Nevertheless, a gradual consciousness about the risks of the current political and economic order, and the necessity to answer the *challenge of knowledge* is rising. This challenge implies the need for attention to education, scientific research and technological modernization, with the understanding that science and technology is not only a matter of scientists and technologists, but of the whole society.

Comparing the population of Latin America with its productivity shows obvious weaknesses. While the internal gross product of the United States is 4 times that of Latin America, its expenditure in research and development is 20 times bigger. In other words, the Latin American productivity in science and technology is larger than one would expect from the investment made. A detailed analysis of Latin American countries shows dissimilar situations. Only Brazil and Venezuela state that their 2008 expenditure in research and development was over 1.0% of their national gross product, putting them far ahead of the rest of the countries in the region, but far behind the United States (2.84%) and Canada (1.86%). In the mid-range, between 0.5% and 1.0% were Chile, Uruguay and Argentina. The rest of the countries did not reach the threshold of 0.5%, see Figure 2.

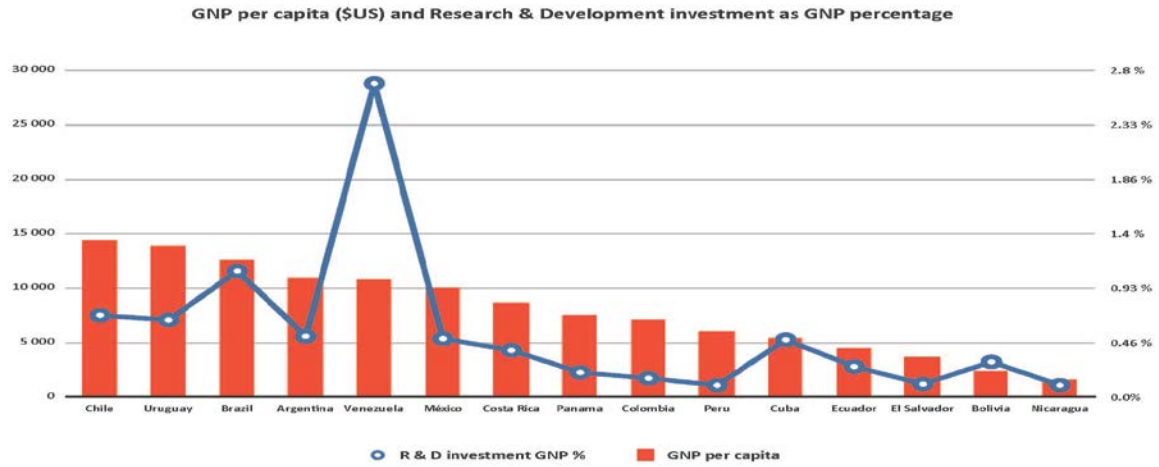

Figure 2. Gross national product (GNP) and research & development investment as GNP percentage for selected countries in the LAC region.[2]

[2] Source: http://datos.bancomundial.org/indicador/GB.XPD.RSDV.GD.ZS (World Bank). It appears that Venezuela counts technological purchases which did not involve internal research as R&D investment which may explain the high number being reported.

Research in the LAC Region

Within the 147 most scientifically productive countries, covering a ten-year plus eight-month period (January 2000–August 31, 2010), the Iberoamerican countries included among the top twenty were Spain (rank 9) and Brazil (rank 15). Within the same period, Mexico was ranked 28, Portugal ranked 34 and Argentina ranked 35. This is an interesting improvement compared to a similar survey made between 1967 and 1973. The latter had Argentina (ranked 27), Spain (ranked 29), Brazil (ranked 32), and Mexico (ranked 34) as the most productive nations of the Iberoamerican and Caribbean region (De Solla Price,1986: pp. 192–193). Nevertheless, the scientific productivity of most of Latin American countries, between the late 1970s and the late 1980s, remained almost constant. From the mid-nineties, most of the nations of the region began increasing their productivity again. Note the political and economic changes reflected in figure 3. For example, the jump in the productivity in Argentina in 1986 can be explained by political changes starting at the end of 1983 in that country.

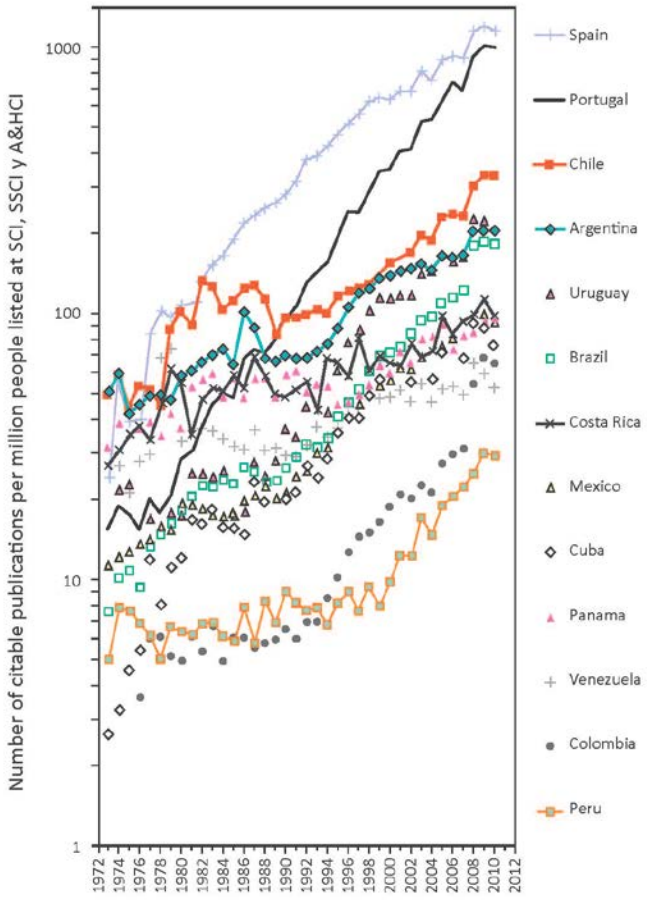

Figure 3. Number of citable publications per million people for the Iberoamerican countries with the largest number of publications.

Temporal evolution of total number of publications in the three databases (SCI, SSCI and A&HCI) per million inhabitants for each of 12 Iberoamerican countries responsible for the 98% of the total number of articles published between 1973 and 2010 within the region. The population data for each year at each country were obtained from the UN Statistics Division (http://unstats.un.org/).

It is interesting to observe the difference between the total number of publications and the exponential growth constant. Portugal has the highest growth constant of our sample. Within a period of 38 years, Portugal increased its publications by a factor of 76; its publications per million people by a factor of 64 and its publications per GDP in 2005 USD by a factor of 34. In 1973 Portugal had the 7th position within the ranking of publications in the Iberoamerican region (close to Peru) in the number of published articles of the region, while in 2010, it moved to 3rd, shared with Mexico which has 10 times Portugal's population (Figure 4).

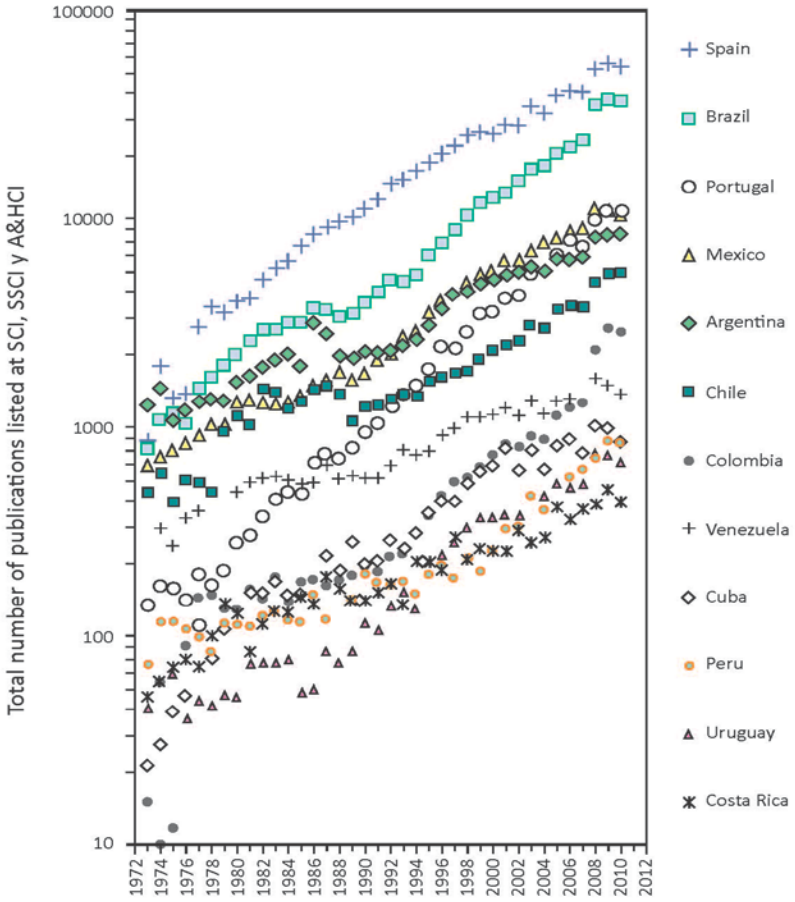

Figure 4. Number of citable publications for the Iberoamerican countries with the largest number of publications.

An interesting case is Colombia, which has the second highest growth constants if we consider only the data after 1993. This is consistent with several science and technology organizational reforms generated in 1990, such as the creation of the National Science and Technology System and the inclusion of COLCIENCIAS as part of the National Department of Planning. Spain ranks third in growth rate. On the other hand, Venezuela, Guatemala and Jamaica have the lowest growth rates. In these last cases, the number of citable publications per million people has increased less than a factor of 2 over 38 years. These bibliometric measurements belong to the S&T output indicators set (i.e. OECD Frascati Manual), and their study represents, in many ways, the performance of the national production of knowledge as a consequence of their R&D activities.

Mathematical Research: Published Articles

We include below a table comparing the production of mathematical documents published in the years 1996-2011. The table indicates the number of citations and the average number of citations per document.

Position	Country	Documents	Citations	Citations per doc.
1	United States	226,914	2,380,547	10.5
2	China	101,042	462,185	4.57
3	Germany	79,857	635,231	7.95
8	Canada	42,093	321,656	7.64
9	Spain	41,960	274,370	6.54
15	Netherlands	19,150	157,790	8.24
16	**Brazil**	18,897	112,371	5.95
17	Taiwan	18,803	127,144	6.76
25	Greece	10,045	61,402	6.11
26	Iran	9,418	38,753	4.11
27	**Mexico**	8,902	47,065	5.29
28	Portugal	8,786	52,961	6.03
36	Norway	5,975	41,772	6.99
37	**Argentina**	5,162	38,503	7.46
38	Ireland	5,035	28,147	5.59
39	New Zealand	4,372	29,577	6.77
40	**Chile**	4,306	26,903	6.25
41	South Africa	4,077	22,365	5.49
42	Egypt	3,469	18,334	5.29
57	Lithuania	1,536	5,364	3.49
58	**Venezuela**	1,415	7,557	5.34
59	**Colombia**	1,358	7,564	5.57
60	Jordan	1,074	4,488	4.18
66	Estonia	725	3,877	5.35
67	**Cuba**	633	2,141	3.38
68	Uzbekistan	578	1,908	3.3
72	Lebanon	517	1,749	3.38
73	**Uruguay**	517	3,435	6.64
77	**Puerto Rico**	408	3,085	7.56
78	Iceland	398	2,277	5.72
92	**Peru**	114	685	6.01
96	**Costa Rica**	103	665	6.46
110	**Jamaica**	56	360	6.43

113	**Barbados**	49	175	3.57
116	**Guadeloupe**	46	197	4.28
119	**Trinidad and Tobago**	44	60	1.36
132	**El Salvador**	22	122	5.55
135	**Martinique**	19	101	5.32
136	**Paraguay**	18	39	2.17
138	**Bolivia**	17	129	7.59
140	**Panama**	14	37	2.64
149	**Guatemala**	7	34	4.86
152	**Dominican Republic**	6	11	1.83
154	**French Guiana**	6	20	3.33
166	**Honduras**	3	9	3
169	**Bahamas**	2	9	4.5
171	**Dominica**	2	0	0
177	**Belize**	1	1	1
183	**Saint Kitts and Nevis**	1	2	2
184	**Nicaragua**	1	39	39

Table 3. Total number of documents in mathematics in countries of the world 1996-2011. Retrieved from: http://www.scimagojr.com.

The growth of the mathematical production in the LAC region can be seen in table 4. The data shows that the production has doubled in the lapse of 8 years. According to the Scimago data basis, there is no other region of the world with this growth.

	Documents	Citations[3]	Citations per Doc.
1999	1.501	8.260	5,50
2000	1.565	8.437	5,39
2001	1.765	10.331	5,85
2002	1.963	10.753	5,48
2003	2.273	9.093	4,00
2004	2.672	7.673	2,87
2005	2.597	3.661	1,41
2006	3.073	1.630	0,53
2007	3.219	316	0,10

Table 4. Total number of documents in mathematics produced in the LAC region each year of 1999 to 2007.

[3]The decreasing number of citations in more recent years is a reflection of the time delay between the publication date and when the papers get cited.

Organizations

In 1990, UNESCO initiated, once again, a system of Latin American regional scientific networks using the model of the biology network (RELAB). Financial support for the networks was slim and soon they either disappeared or went their own way.

After a couple of years, the mathematics network created by UNESCO (RELAMA) became UMALCA, Unión Matemática de América Latina y el Caribe (Latin America and the Caribbean Mathematical Union). UMALCA is a network formed by the mathematical societies of the following countries of the region: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, Mexico, Paraguay, Peru, Uruguay and Venezuela. The member societies provide financial support for the activities of UMALCA.

Probably the most successful program at UMALCA is the series of schools running under the acronym of EMALCA. The objective of the schools is to put young people in contact with relevant topics of current interest and to inspire some of them to continue in higher education. From the beginning of the EMALCA program in 2000, CIMPA, a UNESCO center of type 2 based in France, has supported the program. Without a doubt, the joint action of UMALCA and CIMPA has contributed significantly to the mathematical development of the region in the last years. Each year between four and seven CIMPA Research Schools take place in Latin America.

EMALCA schools have served as a model to similar activities in Africa and East-Asia. Starting with two schools a year, the number of EMALCA schools, and those with CIMPA support, has rapidly increased. As an example, there have been ten EMALCA schools in 2013, five of those receiving financial assistance from CIMPA.

Maps of Mathematical Research Activity in Latin America

The complexity of the state of mathematical research in the LAC region cannot be captured by a single number. Our intent with the following maps is to capture rough indicators of the untapped mathematical potential in terms of human capital (mathematical publications per capita, Figure 5) and financial capital (mathematical publications per GNP, Figure 6). The maps presented in this section are based on the data from Table 5.

There is a big difference between publications per capita between Canada and the United States and the LAC region. Within the LAC region there is large variability with a few countries having significantly higher productivity.

Country	Publications 1996-2011 /Population (Millions of Inhabitants, 2010)	Publications 1996-2011 /GNP (Millions of USD, 2011)
Canada	1.22E+03	2.42E-02
United States	7.28E+02	1.51E-02

Chile	2.51E+02	1.73E-02
Barbados	1.91E+02	1.33E-02
Uruguay	1.53E+02	1.11E-02
Argentina	1.27E+02	1.16E-02
Puerto Rico	1.02E+02	4.24E-03
Brazil	9.67E+01	7.63E-03
Mexico	8.05E+01	7.72E-03
Cuba	5.65E+01	1.04E-02
Venezuela	4.87E+01	4.47E-03
Martinique	4.68E+01	3.11E-03
Trinidad and Tobago	3.27E+01	1.96E-03
Dominica	2.99E+01	4.13E-03
Colombia	2.93E+01	4.07E-03
Costa Rica	2.22E+01	2.52E-03
Jamaica	2.05E+01	3.88E-03
Saint Kitts y Nevis	1.92E+01	1.43E-03
Cayman Islands	1.75E+01	9.99E-04
Ecuador	9.29E+00	1.94E-03
Virgin Islands	9.17E+00	5.00E-04
Bahamas	5.78E+00	2.57E-04
Panama	3.99E+00	5.23E-04
Peru	3.86E+00	6.44E-04
El Salvador	3.55E+00	9.54E-04
Belize	3.19E+00	6.91E-04
Paraguay	2.79E+00	7.55E-04
Bolivia	1.69E+00	7.10E-04
Dominican Republic	5.97E-01	1.08E-04
Guatemala	4.87E-01	1.49E-04
Honduras	3.94E-01	1.72E-04
Nicaragua	1.72E-01	1.07E-04
Bermuda	0	0
Granada	0	0
Guyana	0	0
Haiti	0	0
Saint Lucia	0	0
Santo Tomé y Principe	0	0
Suriname	0	0

Table 5. Number of mathematical publications per capita and per GNP for countries in the LAC region plus the USA and Canada. Computed using the sources from tables 1 and 3 and ordered based on publications per capita.

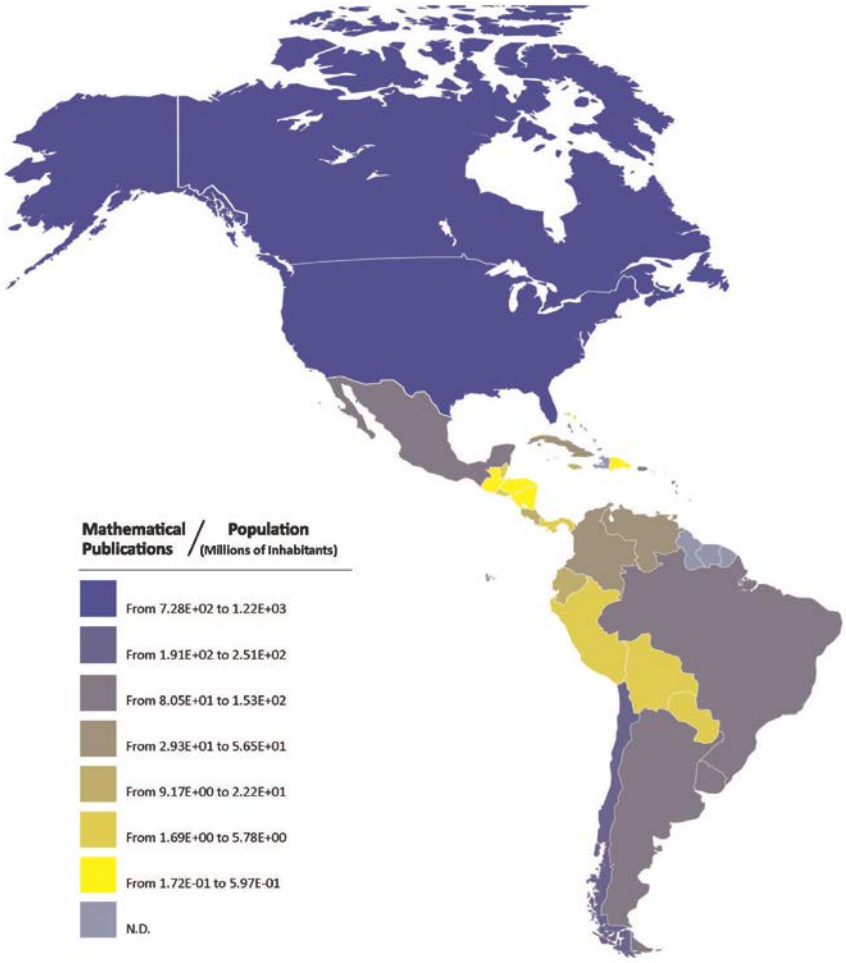

Figure 5. Map describing the per capita publications in the LAC region.

Under the assumption that mathematical talent is uniformly distributed, Figure 5 visually displays the efficiency in converting that talent into new mathematically knowledge as reflected by publications. We see a large variability in the efficiency across the LAC region. In the extremes, the number of publications per capita of Chile is approximately 1450 times larger than that of Nicaragua. If we consider a country in the top 25% (Venezuela) it is approximately 123 times more efficient than a country in the top 75% (Honduras). A critical factor which leads to such a discrepancy in scientific output is whether a country has reached a development level where it can sustain a PhD program in mathematics.

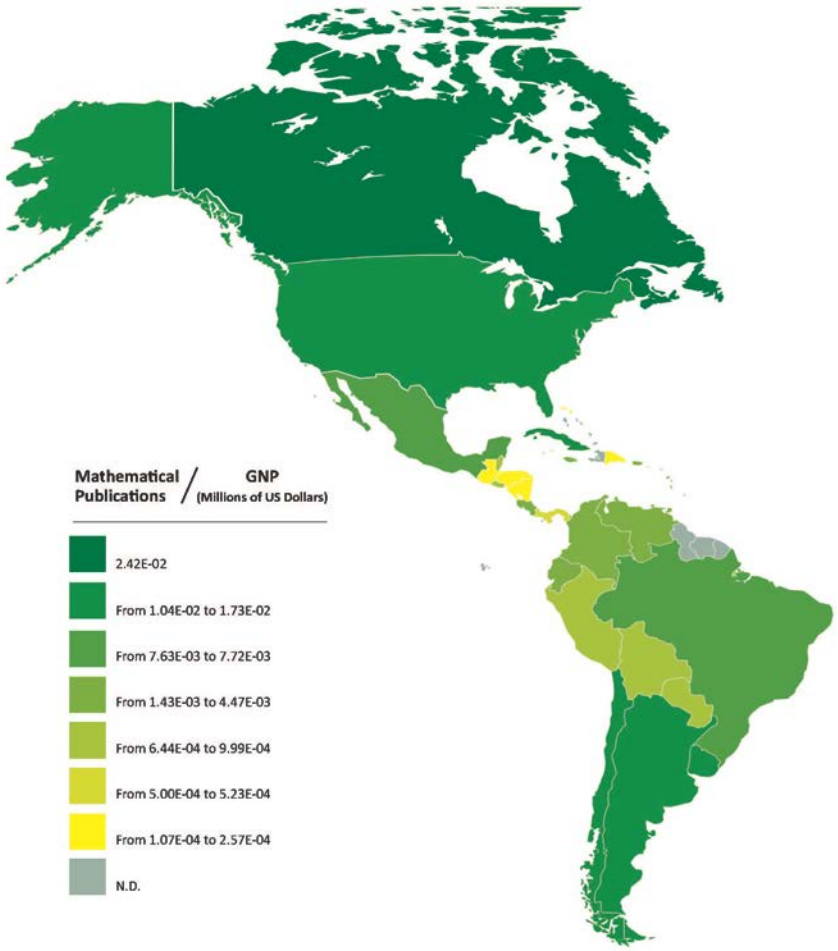

Figure 6. Map describing the mathematical research productivity per GNP in the LAC Region.

Figure 6 illustrates a different sort of efficiency than Figure 5. Figure 6 informs how much of the financial resources of the countries invested in science and technology impact mathematical research. Here we see smaller discrepancies than what we see in terms of population. The largest ratio (between Chile and Nicaragua or the Dominican Republic) is approximately 160. The difference is still dramatic but less so than when considering efficiency based on population.

These gross numerical representations of the mathematical research situation coupled with the geographic information from the maps provide a useful view of mathematical research in the LAC region but for a complete picture we present the following regional reports.

Regional Reports

1. Mexico.

Mathematics in Mexico has a long history going back to pre-hispanic times. Modern research in mathematics started with the foundation of the Institute of Mathematics of the National University and the Mexican Mathematical Society in 1942 and 1943, respectively. This was the outcome of amazing work done by among others Sotero Prieto, Alfonso Nápoles Gándara and Alberto Barajas.

In 1945, Solomon Lefschetz came to Mexico for the first time, when he was a Professor at Princeton. Until his death in 1972, he visited the country frequently and for extended periods of time. He was an important force in the creation of the foundations of Mexican mathematics. Along his students, Emilio Luis, Humberto Cárdenas, José Adem, Samuel Gitler, Santiago López de Medrano, Francisco Gonzalez Acuña and Alberto Verjovsky, Lefschetz launched seminars, teaching and research areas in mathematics in our country.

The influence of Lefschetz was particularly strong on the development of algebraic topology and differential equations. In 1957, Mexico organized the International Symposium on Algebraic Topology whose proceedings contain seminal papers by Thom, Serre, Milnor, Chern, Adem, Bott, Hurwitz, Hirzebruch, Cartan and many others. At the beginning of the 1960's, the Mexican Mathematical Society launched the Bulletin which, under the leadership of José Adem, was consolidated as an important mathematical journal. Of course, there were other important personalities that left their mark in Mexican mathematics. We mention Victor Neumann-Lara (combinatorics), Roberto Vazquez (algebraic topology) and Jorge Ize (PDEs), who have already passed away, and many others who are active mathematicians. Currently Mexico has several well established research centers. Each one of these has consolidated lines of research, top level research groups with world-class mathematicians and graduate programs training hundreds of master students and dozens of doctoral students every year.

The National University hosts several centers and schools: the Institute of Mathematics, the Institute of Applied Mathematics and Systems and the Department of Mathematics of the Faculty of Sciences, at the central campus, and centers at Cuernavaca, Morelia, Querétaro and Oaxaca. These centers gather more than 250 mathematicians working in many different research topics.

The Institute at UNAM is the mother institution in Mexico, from which all other major research centers in mathematics have sprung. It has strong research groups in various areas of mathematics, most notably in algebra, combinatorics and discrete geometry, PDEs and topology. The Institute of Applied Mathematics and Systems has a strong tradition in PDEs, mathematical physics, probability and statistics and applied mathematics. The Center of Mathematical Sciences in Morelia has recently become an independent research center. Its main research areas are algebra, analysis, mathematical physics, topology and number theory.

The Department of Mathematics of CINVESTAV (acronym for Centro de Investigaciones y Estudios Avanzados) was founded by José Adem in 1961 and has always had a strong tradition in algebraic

topology, today led by Samuel Gitler. Other important research areas are probability, control theory and algebra.

CIMAT, an acronym for Centro de Investigación en Matemáticas, is located in the city of Guanajuato, 400 km to the Northwest of Mexico City. This center was founded in the early 1980s and has become one of the strongest centers of mathematics in Latin America. The main research areas are dynamical systems, differential geometry, probability theory, statistics and scientific computation. It has more than a hundred mathematicians and engineers dedicated to research, graduate programs and work related to industry. More than 200 students in the master's and doctoral programs come from many cities around the country and several other countries, mainly from Central and South America.

Besides those listed above, there are solid groups in several state universities around the country, though most of them are formed by small groups. Some places: Sonora, Durango, Aguascalientes and San Luis Potosí at the central north and north of the country; Puebla and Veracruz at the center of the country and Oaxaca, Tabasco and Yucatán at the south.

Some Mexican mathematicians have been awarded international distinctions for their individual research achievements, such as the TWAS prize, the Ramanujan Prize, the Humboldt Prize, the Ferran Sunyer i Balaguer Prize, and the Steklov Institute best research paper. There are Mexican mathematicians participating in the direction of some of the important world organizations such as the International Mathematical Union, the Bernoulli Society and UMALCA.

Mexican institutions have a well reputed tradition in the organization of international meetings. We just mention the recent joint meetings of the Mexican Math Society with its counterparts in the United States, Canada and Spain, and the organization of the Bernoulli Society meeting in 2000 and the UMALCA meeting in 2004. The Mathematical Congress of the Americas in August 2013 took place in Guanajuato at CIMAT.

The level of mathematical research in Mexico has not permeated to the more basic educational levels, probably due to the still small numbers of professional mathematicians. A member of the ODCE, Mexico participates in the PISA evaluations since the early 90's of last century, getting systematically the last position among the member countries. More significantly, more than 60% of the fifteen year old students are not able to solve problems requiring two steps of mathematical calculations. Training of mathematical educators, both in basic and secondary levels, is identified as the main cause of these delays. In the last years, several institutions are trying, independently of the government, to influence the training of school teachers and the early education of youngsters.

Since 1986, Mexico has participated in the International Mathematical Olympiads with teams trained by researchers belonging to the Mathematical Society and the Mexican Academy of Sciences. In the first national steps, several thousand students aged 12 to 18 are assessed to form state and national teams. Internationally, those teams are performing better, passing from the last quarter of countries, to the first 30%, systematically earning several prizes.

2. Central America

Central America has large sections of the population living in poverty and access to solid education is limited. High teaching loads and low wages for teachers at all levels make a teaching career a difficult choice. The prevalence of corruption and bureaucratic procedures create a difficult environment for bringing about change. Despite all of these challenges, mathematicians working in this region are creating opportunities for their students with very limited resources but a lot of optimism and energy.

Central America is in a critical time in its mathematical development. There are various national and regional activities that will improve mathematics education at all levels. Several countries are beginning masters' programs in mathematics (applied, educational, statistics and pure) and there is a project to create a regional doctorate by Central American University Higher Council (CSUCA) with support from Abdus Salam International Centre for Theoretical Physics (ICTP). Several countries are also creating mathematical societies to coordinate efforts and create links with international organizations like UMALCA and the IMU. Central America is making a transition from mathematics teaching at the undergraduate to master's level, which brings along with it an interest in research. In this region there are more than 40 million people without local access to a PhD program. Currently, a small number of students mostly associated with the Mathematical Olympiads have been able to attend programs at major research institutes (CIMAT, IMPA, CINVESTAV) but most of the mathematical talent is not developed. The support for national efforts to have masters programs and the regional effort to have a PhD could be a critical aid in the development of the substantial mathematical talent of the region. Having a regional PhD program will also strengthen local master's programs.

A common interest in the region is to connect mathematics to the socio-economic problems the countries face. This results in a significant interest in developing mathematical and statistical programs which have direct application to problems in the local industry and government. Such involvement of mathematics in everyday problems would make the value of mathematics evident.

There is a big difference in access to mathematical resources depending on geographical location (cities or rural areas) and with respect to socio-economic status. The Mathematical Olympiad and the Math Kangaroo have been effective in promoting mathematics and identifying talented students even in poor or isolated areas. In most countries, these programs have a large potential for providing access but are often underfunded which results in very limited training and support for the students who participate. There have been a few extremely talented students who have obtained medals at the IMO with these limited resources which highlights the potential mathematical talent that exists.

The number of students per teacher in elementary or secondary school is about 40 students. The teacher education ranges from three years in a normal school to a college degree in mathematics. The limited preparation of secondary school teachers and the large number of students per teacher are some of the reasons for the low level of mathematics in the region.

University professors typically have master's degrees at leading universities but usually have undergraduate degrees in rural colleges. There are professors with doctorates in some major universities but many countries having only one or two faculty members with doctorates in mathematics. In part, because of this, research in the region is very limited. The country with the highest number of publications is Costa Rica. Other countries are close to having conditions that support research. The teaching load in most universities is so high that it prevents research even from faculty with doctorates.

All of the countries in the region expressed interest in having volunteers from the IMU teaching mathematics at the master's level. Two of these countries (El Salvador and Honduras) have already had volunteers. The mathematicians of the region also would like to have more access to mathematical talks, articles, and information about conferences and scholarships through online repositories.

Belize

Belize is different from the rest of the Central American countries in that English is the primary language. Primary school attendance is mandatory and accessible. All pre-university education is affordable. However, at many primary schools, teachers are inadequately prepared to teach mathematics. At the secondary level, there are similar challenges with teacher preparation, especially at private schools. Another major challenge faced at the primary and secondary levels is a major lack of teaching/technological resources.

Most students take the regionally recognized Caribbean Secondary Education Council's (CSEC) mathematics examinations. Students with high scores (in multiple subjects) in the CSEC exams are offered tuition scholarships to any tertiary level institution in Belize. Some students also participate in the Mathematical Olympiads which has inspired students to develop a greater interest in mathematics at the secondary level.

The mathematics program at the University of Belize, established in 2000, emphasizes the training of teachers in mathematics and the use of technology in the classroom. The university is recognizing the need for diversification within the math program, steering away from solely pure math to having applied math options for students. Currently, there are no master's degrees in mathematics offered in Belize. The Mathematics Department would like to design and implement a master's degree in mathematics involving both online and face to face teaching modes. Support from international organizations such as the IMU, for example through the volunteer lecturer program could play a major role in the creation of the master's program.

Costa Rica

Due to governmental policies which have differed from neighboring countries, such as not having an army, Costa Rica is in a better economic situation than the rest of the countries in the region. The political situation has also been more stable than the rest of the Central American countries which has led to a more democratic and peaceful recent past. Costa Rica still faces many of the same challenges of the other countries in the region but these differences have helped to create an environment where there is a regionally strong mathematical community.

At the pre-university level, like many of the countries in this study, there was concern over the level of mathematical content knowledge of the teachers. There is an organization, ASOMED, which focuses on mathematics education and organizes activities to improve the situation. Costa Rica has a consortium of universities with governmental funds to support the Mathematical Olympiads program. Over the last few years, this support has resulted in a consistently high performance.

Costa Rica has the highest mathematical research level in the region. During 2006-2011 there were 44 publications archived by MathSciNet with affiliations in Costa Rica. From 1996-2011, Costa Rica also had 103 articles archived by SCOPUS. Costa Rica has master's degrees in pure and applied mathematics and mathematical pedagogy. In the Department of Mathematics at the University of Costa Rica most professors have doctorates. In the engineering programs or other universities in the country, most of the professors have undergraduate degrees. Costa Rica hosted EMALCAs in 2005 and 2012.

El Salvador

The pre-university level of mathematics education is typical of the region with large number of students and low content knowledge by teachers. Strengthening the mathematical competency of teachers and students at this level is one of the goals in the country.

El Salvador has a program for talented youth which identifies and supports students before they arrive at the university. This program serves as a model for supporting students in mathematics and the sciences. It also has a publication which includes mathematical articles produced regionally. In El Salvador there have also been recent developments in the creation of laws for scientific and technological development. The vice-minister of science and technology has identified the regional PhD in mathematics as one of the projects to support.

In the School of Mathematics at the University of El Salvador, 6% (2 of 33) professors have a doctorate, 56% (17 of 33) have a master's degree and 38% have an undergraduate degree. El Salvador is creating masters' degrees with international support. Spain has been supportive in the creation of masters' degrees in statistics and in the teaching of mathematics. There is still a need to strengthen these programs. Two IMU volunteer lecturers from the VLP have recently taught courses. El Salvador hosted an EMALCA in 2011.

Honduras

The educational situation for Honduras before the university resembles that of many of the countries in the region. Teacher training is viewed as one of the primary needs.

Honduras regularly sends students to the regional and International Mathematical Olympiad (IMO) and some students have won medals. The recruitment and training of students is done by faculty from the National Pedagogic University (UPN). Some students who participated in the IMO have obtained scholarships for study at major research centers in Latin America (CIMAT, IMPA).

In the School of Mathematics at the Autonomous University of Honduras (UNAH), 4% of the professors have a doctorate, 20% have a master's degree and 76% have university degrees. In the last five years there have been no international publications but there have been four publications in national journals. The Honduran Mathematical Society (SOMATH) is being created. There is a master's degree in mathematics education at the UPN. A master's degree in mathematics and statistics at the UNAH are currently being proposed. Two IMU volunteers from the VLP have recently taught courses. Honduras hosted an EMALCA in 2013.

Guatemala

The typical number of students in a grade school or secondary mathematics classroom is between forty and fifty. At the grade school level, the great majority of the students do not have a college education. They mostly attend normal schools. At the high school level, teachers often are students at the university in their final years in mathematically related fields. There is an organization of mathematics teachers (APROMATE) which supports activities for teaching mathematics at the pre-university level. There is also an annual congress on mathematics education hosted by the University of San Carlos.

The Mathematical Olympiads in Guatemala are coordinated by mathematicians at the University of San Carlos and the University of the Valley of Guatemala (UVG). The participation from Guatemala in the Olympiads varies from year to year. Several students who have participated in the Olympiads have gone to study abroad.

The typical level for university professors is a bachelor's degree since there are no graduate programs in mathematics in Guatemala. This creates a large variability in the preparation in mathematics. At the university level there is no incentive to conduct research. At this point, there is little to no research activity. Guatemala hosted an EMALCA in 2009.

Nicaragua

At the primary and secondary level there are about 60 students per classroom and there are a large fraction of teachers without formal training. The Nicaraguan Mathematical Society focuses on high school level mathematics.

Mathematical Olympiads are sponsored by a local bank (Banco Uno) which promotes a talent academy which trains the students. Nicaragua has had a good participation at the Central American level. The university has scholarships for talented students with financial need.

There are four professors with doctorates in mathematics in Nicaragua. Mathematical areas where faculty members specialize include algebra, analysis and statistics. Most professors have a bachelor's degree. There is no master's degree but Nicaragua is the host site for the regional doctorate being planned by the CSUCA. Nicaragua hosted an EMALCA in 2007.

Panama

Most elementary and secondary schools have 40 students per classroom. At the grade school level, teachers lack mathematical training. At the high school level, teachers are now getting university degrees. A major current emphasis is an undergraduate degree for teaching mathematics at the grade school level. This is an area of perceived potential support from the international community.

The Mathematical Olympiads in Panama have been successful identifying talented students. Those who do well, receive scholarships to study the career of their choice.

The professors at the University of Panama (UP) and the Autonomous University of Chiriqui (UNACHI) typically have a master's degree. There are masters' degrees in pure mathematics, applied mathematics and mathematics education supported by Germany and France during the 1990s. There is no longer support for those masters' degrees. There is a master in pure mathematics at UNACHI during weekends. The University of Panama has similar master's degree in mathematics education. The Panamanian Mathematical Society and Panamanian College of Mathematics are currently consolidating. Panama hosted an EMALCA in 2013.

3. Caribbean

The political situation, the different languages and the geographic location are some of the aspects that make that the Caribbean countries have significant differences in their mathematical development. Although there is great interest in establishing academic collaborations between countries of the region, these same issues have contributed so that this collaboration is not necessarily carried out.

Puerto Rico and the United States Virgin Islands (USVI), because of their political status, have a close relationship with the U.S. and share many of the characteristics of the U.S. educational system both at the pre-university and university levels. However the mathematical relationship between these two countries is not so close despite of their geographical proximity. Cuba has more relations with universities in Brazil, especially with the IMPA. Dominican Republic has some academic exchanges with the U.S., Mexico and Brazil, such as conference participation, student scholarships and grants.

The Dominican Republic receives significant support from Europe, but sometimes in programs that are not consistent. Puerto Rico has very little to do with Europe at the pre-university level, but there are several European professors in the universities of the island. There are currently a large number of Cubans doing master's and doctoral studies especially in France and Spain.

Another important factor that could help the mathematical integration of the countries of the region and in general to their mathematical development is the existence of teacher organizations or mathematical societies. In Cuba there is the Cuban Mathematical Society but in the Dominican Republic, Jamaica and USVI no such organization exists. In Puerto Rico they have existed in the past, but not currently.

A common feature in the region is that there is not necessarily a connection of mathematics to everyday life, nor is an intention to link culture with mathematics. There is interest in obtaining strategies to apply mathematics to everyday life and to present educational materials in new ways adapted to the student population of the time. It is very rare to find math-related news in the media, except sometimes when they comment about the low achievement of students in government tests.

There is much interest in all countries of the region to obtain free educational resources and to have resource sharing programs among countries, but there is also concern that these resources are tailored to different countries. In the region there are many differences in the educational idiosyncrasies.

Mathematical Olympiads have been a valuable resource to identify and support talented students in mathematics. Cuba has been involved for decades in the IMO, but in recent years its participation has not been consistent. Trinidad and Tobago has also been involved for over a decade in the IMO. Puerto Rico has successfully been integrated into the IMO movement in the last decade and has a Mathematical Olympiad program that reaches all students of the Island. Jamaica has recently begun a national Olympiad program and started participating in international mathematical olympiads since 2010. Dominican Republic has also participated in international olympiads but has not created a consistent national program. In general, the region has a long way to go in terms of Mathematical Olympiads. This

situation may reflect that governments and the public sector in the region invest little in talented students and they are more concerned with low-performing students.

All countries of the region are very interested in the volunteer lecturer program of the IMU. However in Cuba, there might be restrictions from the Ministry of Education.

Cuba

In the Caribbean region, Cuba is a country with a strong mathematical tradition. There are research centers in different areas of mathematics publishing both in regional magazines and in internationally recognized journals. A total of 90 indexed publications were made between 2010 and 2012. Several conferences in mathematics and math education are held in the country. Currently there are a significant number of Cubans doing masters' and doctoral studies especially in France and Spain. The most common level for a math university professor is the master's level. It is one of the few countries in the region that has a mathematical society and some mathematical research centers.

Cuba has an acceptable academic level in mathematics education in primary and secondary schools. They prepare their teachers well. There is an average of 25 students in each classroom. The rural areas of Cuba have more serious problems in their schools, in part because of the difficulty of recruiting qualified teachers.

Cuba has had a tradition of having special programs to identify and support talented students in mathematics, indeed in the Caribbean region Cuba is the first country that participated in the IMO. In recent years, participation in international mathematical olympiads has been sporadic.

Jamaica

In Jamaica research in applied mathematics is done, especially in physics and mathematics stochastic differential equations. These investigations are carried out mainly by a small group of professors of the University of the West Indies, Mona Campus. There is some academic collaboration with the campus of the University of the West Indies in Barbados and Trinidad and Tobago. However there are neither mathematical societies nor mathematical research centers.

Jamaica does not have a strong development in education at primary or secondary level and there is a deep concern about the preparation of teachers and students' results on standardized tests. This problem occurs most significantly in rural areas. Communication networks between mathematicians and educators are almost nonexistent. The average number of students in a school classroom is 42. In Jamaica elementary teachers need a Diploma in Education (equivalent to two years of university education). For the intermediate level and above a bachelor's degree is required.

In 2010 for the first time in Jamaica a program for identification and support of gifted students in mathematics was started, also a Jamaican group of students participated for the first time in international regional mathematical Olympiads.

Puerto Rico

In Puerto Rico mathematical research is led by the University of Puerto Rico which is the state university. There are two Ph.D. programs at the University of Puerto Rico, one in mathematics at the Rio Piedras campus and another one in Computing and Information Sciences and Engineering at the Mayaguez campus. There are also master's degree programs in mathematics, statistics and computer science with many years of experience and tradition. From all these graduate programs professors regularly publish in recognized journals.

In addition to Puerto Rican students, dozens of students from other countries, mainly from Colombia, Peru and some Central American countries, graduate each year from these masters and Ph.D. programs. Computational Mathematics is an area where significant resources have been invested, as well as biological mathematics and some areas of pure mathematics. There are research centers in different areas of mathematics.

The lowest requirement to be a professor in some private universities is a master's degree. In the public university, a Ph.D. is required. Professors have access to different U.S. programs that allow them to obtain funds for research and mathematics education projects. There is no Puerto Rican mathematical society, but several professors are members of the American Mathematical Society and some other U.S. math societies. Similarly math students from different universities have access to summer programs or to exchange programs in the U.S.

Although the government invests much of its budget in public education, Puerto Rico does not have a strong development in education at the primary or secondary level. There is great concern about the preparation of teachers and students results in standardized tests. To teach at public schools a BS is required, but in the case of primary school, the Bachelor of Science (BS) in mathematics is not a requirement. In Puerto Rico, professional development programs for teachers of mathematics are carried out regularly, especially with funding from the U.S. government. In Puerto Rico there are schools of all academic qualities both in rural and urban cities and class sizes could vary from 10 students to 40 students.

For over a decade there has been a program to select and support talented students in mathematics. Puerto Rico has consistently participated in the international mathematical olympiads during the last years. Most talented students participating in the international mathematical olympiads, and those who reach the final stages of the local competition, finish studying in U.S. universities, several of them in careers in related to mathematics, other sciences or engineering. There are very few specialized schools for talented students and support for these students on the island is limited.

Dominican Republic

In the Dominican Republic there are professors who work in mathematical research at their own universities, but there are neither math research centers nor consistent collaboration between local

universities. Only a couple of national or international conferences are held each year in the country. In general, most of the professors who do research in mathematics do it as part of their graduate studies, but research is not an institutional tradition. Most university professors have an undergraduate level of education, but during the last few years, progress has been made towards a master's requirement.

The Dominican Republic has large gaps in their education at the primary or secondary levels. There is an average of 42 students per class in schools. Teachers must have a BS, but there are several cases of teachers who have not acquired this level and they teach anyway. Schools in rural areas of Dominican Republic have more serious problems, in part because of the difficulty of recruiting qualified teachers. There are European programs supporting education, but often in programs that are not consistent.

The Dominican Republic has programs to identify and support talented students, but these programs are not necessarily consistent or they sometimes don't possess sufficient mathematical rigor. Participation in international mathematical olympiads is not consistent even though in the past, the Dominican Republic has hosted the Iberoamerican Mathematical Olympiad.

United States Virgin Islands (USVI)

There are no math research centers in the USVI, but research in applied mathematics is carried out mainly by professors at the University of the Virgin Islands. They don't organize math conferences regularly, but due to the political relationship with the United States, teachers and university professors sometimes participate in academic activities there. Most university professors have PhD degrees.

USVI does not have a strong development in education at primary or secondary level and has similar problems to other countries in the region such as insufficient preparation of teachers in mathematics. A typical school classroom has 30 students. USVI has difficulty in recruiting highly qualified teachers in some of the islands belonging to their territory. USVI receives U.S. funding for education and particularly for professional development programs for teachers.

USVI has little experience working with gifted students in mathematics and the mathematical olympiads. In 2010 they participated in their only regional international mathematical olympiad held in Puerto Rico.

4. South America (North)

In general in the northern part of South America, the quality of mathematics education in elementary school and in secondary school is quite deficient, and there is a marked difference in the quality of mathematical education between the main cities and the countryside.

In most of these Latin American countries the role of mathematics in local culture is practically nonexistent. There are few opportunities of good jobs for young talented mathematicians. In general, salaries are very low and conditions for research are not adequate. In most universities there is little encouragement for professors to pursue research activities, and those who do it receive little or no recognition for this. In general, libraries are not well equipped. There is very little contact between the academic and industrial sectors of society.

All mathematicians consulted expressed interest in establishing programs of visiting professors who could teach graduate level short courses of at least three weeks.

Colombia

Several universities have reached a remarkable development of their mathematical activity, both in quantity and quality. In Bogota, notably, Universidad de Los Andes and Universidad Nacional de Colombia; in Medellin, Universidad Nacional and Universidad de Antioquia. In other cities such as Cali and Barranquilla, mathematics departments are beginning to develop graduate programs and research. As it should be expected, in some other cities there are universities where mathematical research is rather poor. In these regions it is convenient to establish support programs and activities to contribute to increase the level of mathematics. One possible program could be based on short courses and schools such as the mathematics schools (EMALCAs) of the Unión Matemática de América Latina y el Caribe (UMALCA).

The most important universities mentioned above offer favorable conditions for mathematical research. This is confirmed by the fact that Universidad de los Andes produced 53 indexed publications in the period 2010-2012; and Universidad Nacional de Colombia – Bogota: produced 69 indexed publications in the same period 2010-2012. Ten or fifteen years ago Colombia was behind Venezuela in mathematical research, measured in number of articles published in internationally recognized journals, nowadays the situation is changing. The more active research groups in Colombia work on the areas of mathematical logic (in particular model theory and its applications), differential geometry, differential equations, and optimization.

The Mathematical Olympiads in Colombia are organized by the private sector, mainly by a private university. Through this activity it has been possible to detect talented young students who afterwards have had successful careers as mathematicians.

The Sociedad Matemática Colombiana was founded more than forty years ago. Its main publication, Revista Colombiana de Matemáticas has been published since 1967, and is included in the

main indices of mathematical publications. The Sociedad Matemática Colombiana organizes a mathematical congress every other year with very high participation of research mathematicians and mathematical educators.

Peru

The Peruvian Mathematical Society was created in 1957. It was devoted mainly to improve the level of university mathematics teachers and also of the secondary school teachers. Later it promoted the cooperation with mathematicians from other countries. Peru hosted a Latin American School (IV ELAM) in 1978. The National Mathematical Colloquium was organized several times later on.

In Peru, the contact and cooperation with neighboring countries has occurred mainly with Brazil. A good number of Peruvian mathematicians have obtained their degrees in Brazil. Presently the best students go to the US to pursue their graduate studies.

The most notable initiative to develop mathematics in Peru has been the creation of the Instituto de Matemática y Ciencias Afines (IMCA), created in 1997, together with a policy of sending students abroad for their mathematical education. The IMCA has hosted a series of mathematics schools of very good quality with participation of Peruvian students and students from other Latin American countries. It also published textbooks and monographs.

Good strategies to help the development of mathematics in Peru would be to support IMCA's programs and to provide opportunities to study and good jobs to those talented students detected through the mathematics olympiads.

Ecuador

The Ecuadorian Society of Mathematics (Sociedad Ecuatoriana de Matemáticas, SEDEM) gives the following information about mathematics in this country. The "Escuela Politécnica Nacional" (EPN) was created in Quito in 1869, date that can be considered as the official start of the college-level mathematical activity in Ecuador. For over a century, mathematics at university level in Ecuador was studied as part of other courses, mainly engineering. Currently, in addition to the EPN, three universities in Ecuador offer undergraduate programs in mathematics: the "Escuela Politécnica del Litoral" in Guayaquil, the "Universidad San Francisco de Quito" and "Central University of Ecuador", in Quito. The "Ecuadorian Society of Mathematics" (SEDEM) was founded in 1967 with the purpose of supporting the development of mathematics in Ecuador. Originally, its main objective was to improve the quality of teaching of mathematics at all levels, but this objective has been extended to include activities to improve the general conditions for the progress of mathematics in the country, regarding both education and research.

In recent years, several young mathematicians have completed their doctoral studies in Europe and North America and are now back in Ecuador, where they hold positions at different universities. In many

cases, they have established or reactivated collaboration programs with academic institutions and research centers abroad.

A prominent project is the PhD Program in Applied Mathematics (PDMA), executed by EPN with support from the Technical University of Berlin (TUB) and the German Academic Exchange Service (DAAD). As part of this program, and for the first time in history, Ecuadorians have completed their doctorates in mathematics within Ecuador, based on research topics proposed in conjunction with professors from European universities.

Venezuela

The development of mathematical research in Venezuela is relatively recent. With very few exceptions, such as the mathematician Francisco Jose Duarte (6 January 1883 - 01 October 1972), one can say that the research activity began at the end of the 1960s. Presently, there are several universities with mathematics departments offering undergraduate and graduate degree programs. In general, these departments have been offering high quality studies at the undergraduate level.

During the 1970's and 1980's an ambitious national scholarship program permitted to a considerable number of Venezuelan students to travel abroad to pursue doctoral studies in prestigious universities of North America, Europe and some of the more developed Latin American countries such as Brazil and Mexico. Most of them became, at their return to the country, part of the faculty of the graduate programs in mathematics, which began in Caracas at the Central University of Venezuela, the Venezuelan Institute for Scientific Research (IVIC), and Universidad Simón Bolívar; and in Mérida at Universidad de Los Andes in 1976. Graduate programs in mathematics were established later on in other cities (Barquisimeto, Cumana and Valencia).

From then on, research groups in various areas of mathematics began to form. The presence of Mischa Cotlar in Caracas since the early 70's had a major impact on the creation of a research group in mathematical analysis, mainly devoted to topics of harmonic analysis and operator theory. A good scientific level was also reached in the area of probability and statistics, as well as in dynamical systems; in these cases with important influence of mathematicians from Argentina and Uruguay who had settled in Venezuela. Other areas that have reached a good level of activity translating into publishing articles in journals of international circulation and the formation of new researchers are numerical analysis and optimization, partial differential equations, set theory, mathematical logic, and number theory.

Most of these groups formed around people who had obtained doctoral degrees outside Venezuela, mainly in the U.S. and Europe, through scholarship programs mentioned above. IMPA's influence in the training of researchers in dynamical systems is notable; several mathematicians who have led the group's activity got their training at this institute in Rio de Janeiro. The development of algebra, geometry and topology is somewhat lower. In each of these areas, research seminars are held. In most of the cases they are inter-institutional. The presence in Venezuela of several mathematicians from Argentina and Uruguay was important in the establishment of some of these research groups.

In terms of publications reviewed by MathSciNet, IVIC had 3 indexed publications, Universidad de los Andes (Merida) had 32 indexed publications and the Central University of Venezuela had 24 indexed publications from 2010-2012.

Mathematics education in primary and secondary education is, in general, very poor. Sometimes, students finish their high school without having had some mathematics subjects due to lack of teachers. Besides this shortage of teachers, the level of training of teachers is usually very low. Initiatives have been implemented to help improve this situation such as programs developed by the Center for the Advancement of Science Teaching (CENAMEC) some decades ago, or Venezuelan School of Mathematics Teaching which has been organized yearly for about fifteen tears, but the magnitude of the problem is such that these initiatives have not been enough to have a noticeable effect nationwide.

The Asociación Matemática Venezolana was created in 1989, and since then it has sponsored the Jornadas Venezolanas de Matemáticas, which is the yearly Venezuelan meeting of mathematicians, with a participation of some 150 mathematicians; the Venezuelan School of Mathematics (EVM); and publishes the Boletín de la AMV since 1994.

Since 1988, the Venezuelan School of Mathematics (EVM) has been held annually (see evm.ivic.gob.ve). In a way this was the inspiration for the successful program of EMALCAs, and indeed since 2000 the EVM is linked to this school program). These schools have been an important support for graduate programs, encouraging the exchange and cooperation between the various universities at the graduate level. A series of over one hundred textbooks has been produced for these schools.

In recent years there has been a significant migration of Venezuelan mathematicians to other countries in North America, Europe, and Latin America. This migration along with the difficulty to replace retiring professors has created a shortage of professors with advanced training in the various departments of mathematics in the country. The causes have been mainly low salaries and poor conditions for pursuing research.

About ten years ago, the Ministry of Education decided not to continue supporting the Mathematical Olympiads program. However, the group of teachers who organized this activity created a private organization that has managed to continue with the Olympiads with the support of private companies, some universities and the Academy of Sciences.

5. Brazil

Some characteristics of this country make it necessary to distinguish it from the rest of Latin America. The degree of development of mathematical research in some institutes and universities in Brazil is remarkable, according to the number of publications, number of doctorates granted and other indicators. Brazil has played an important role as a training center of mathematicians from neighboring countries such as Peru, Venezuela and Paraguay.

Mathematical research has a long tradition in Brazil. Graduate programs in mathematics started in the University of Sao Paulo and the University of Brazil in Rio de Janeiro in the 1930´s. Some of the most prominent figures of Brazilian mathematics were trained as students of these programs. For example, Mauricio Peixoto and Leopoldo Nachbin, who were the first Brazilian mathematicians to give invited addresses in the International Congress of Mathematicians, in 1964 and 1972 respectively, were part of the generation of mathematicians that came out of the graduate program of the University of Brazil in Rio.

An important fact in the development of Brazilian mathematics is the creation of the Instituto de Matemática Pura e Aplicada (IMPA) in 1952. This was the first research center established by the Brazilian National Research Council, presently the Brazilian Council for Development of Science and Technology. IMPA has since aimed at promoting high level scientific research in mathematics and applications, training new researchers and promoting the improvement of mathematical teaching at all levels. In the late 1960s, IMPA started recalling Brazilian mathematicians working or studying in distinguished institutions abroad. In 1970 it established regular master's and doctoral programs, concurrent with the extended growth in its research and researcher-training activities. In 1971, IMPA became the first mathematics center to hold a mandate from the Federal Board of Education enabling it to grant master's and doctoral degrees. More than 200 doctoral degrees and over 500 master's degrees have been granted by IMPA since its inception.

Among other research areas, IMPA has become an international presence in algebraic and differential geometry, probability and statistics, operations research and mathematical economics, functional analysis, dynamical systems and differential topology, partial differential equations, fluid dynamics and computer graphics.

A fundamental factor in the consolidation of IMPA was the construction of its own headquarters in Horto Florestal, Jardim Botânico, inaugurated in July 1981, when an International Symposium of Dynamical Systems was held. IMPA has been acknowledged as being a Post-Doctoral Center of Excellence on an international level by the Third World Academy of Sciences (TWAS). It is the permanent headquarters of the Brazilian Mathematical Society, founded in 1969, and of the International Mathematical Union for the period 1990-1998. Its faculty members have earned numerous international prizes, such as the Bernardo Houssay Interamerican Prize for Science, the Third World Academy of Sciences Prize, the Ramanujan Prize and the Anísio Teixeira Prize.

Amongst other centers where mathematical research has reached a high degree of development and excellence are the institutes of mathematics of the University of Campinas and of University of Sao Paulo, and some large universities such as the Federal University of Rio de Janeiro (UFRJ). According to information obtained from MathSciNet, in the period 2010-2012 IMPA has produced 232 indexed articles, USP 172, and UFRJ 157 publications.

There are several other universities where research and teaching have a very good level, and the number of mathematics departments with active research groups that have reached important international visibility has grown considerably in the past few decades. Nevertheless, there are also some regions of the country where mathematics is less developed and research almost does not exist. Presently, the number of Brazilian mathematicians obtaining doctoral degrees is not sufficient to cover the needs of universities of the whole country.

Another landmark in the development of mathematics in Brazil was the organization in 1957 of the first Brazilian Mathematical Colloquium, conceived as a meeting to congregate the whole Brazilian mathematical community. The Colloquium has met every other year ever since and has been a motivating factor in the national production of mathematical books, at both elementary and advanced levels.

During the 1950´s and 1060´s, several federal agencies put through scholarship programs to support talented students to pursue high level scientific training abroad. From these programs a new generation of mathematicians was formed and new graduate programs in mathematics were organized in different institutions.

The Brazilian Mathematical Society (SBM) was founded in 1969 and became the country's adhering organization to the IMU. Presently, the Society has about 2,000 associates, young and senior. It is a nonprofit publishing house for mathematical books and journals, and runs several initiatives of broad interest, such as Klein Project Brazil and the nationwide master's program for secondary school teachers (PROFMAT). There are other mathematical societies such as the Brazilian Society for Applied and Computational Mathematics (SBMAC), the Brazilian Statistics Association (ABE), the Brazilian Society for Mathematical Education (SBEM), and the Brazilian Society for the History of Mathematics (SBHMAT).

The Mathematical Olympiads have proved to be an efficient mechanism to stimulate interest in mathematics and to identify young people with special talents. There are two major mathematical olympiads in Brazil. The Brazilian Mathematical Olympiad, started in 1979, which promotes regional mathematical olympiads as well as participation in international mathematical olympiads, and the more recent Brazilian Mathematical Olympiads for Public Schools, started by IMPA and the federal government in 2005, which has reached the astonishingly high number of close to 20 million participants.

6. South America (South)

Taking into account different kinds of data such as population, mathematical tradition, educational programs, it is natural to organize these countries in two groups: on one side Argentina, Chile, and Uruguay and on the other Paraguay and Bolivia. Argentina, Chile and Uruguay have both a good educational and mathematical level. The situation in Paraguay and Bolivia is considerably different. As a consequence, the mathematical research productivity is lower than in the other three countries.
Two general deficiencies are training of primary and high school teachers (at least in mathematics) and difficult access to education for people living far from big cities. This is considerably more complicated for tertiary education.

Argentina, Chile and Uruguay have a good research level in mathematics and these countries currently have their own institutions to promote research. The case of Paraguay and Bolivia is completely different: there are problems with primary and secondary education and also at universities. There is little mathematical activity. However, the situation is getting better in Paraguay but not in Bolivia.

In Argentina and Chile there are important universities in the big cities, but the situation is worse in areas with less population, in particular in the north and south areas of both countries.

In Uruguay and Paraguay mathematical activity takes place almost completely in Montevideo and Asunción, respectively.

Argentina

Modern history of mathematics in Argentina starts in 1917 with the arrival of Julio Rey Pastor from Spain. He managed to create the conditions necessary for mathematical research. The subsequent work of Luis Santaló, Alberto González Domínguez, Mischa Cotlar, Beppo Levi and Jose Babini among others, settled the foundation for the development of mathematics in the country.

In 1954, there was an attempt in Mendoza to establish a center gathering the most important mathematicians of that time: the Institute of Mathematics of National University of Cuyo, but the abrupt end of Perón's second period as president put an end to this initiative in 1956.

In 1958, the creation of CONICET (acronym for National Council for Scientific and Technological Research) gave important support to scientific research in Argentina, but in 1966 another dictatorship stopped the development of the country and in particular of its scientific system. After a short break in 1973, the situation became worse in 1976 and it was only in 1983 with the return to democracy that a possibility of a normal development reappeared. Unfortunately, successive economic crises made mathematicians' work -as part of the whole country- more and more difficult and a lot of them emigrated. It was only in 2003 that the situation became more stable, and in particular, science started having a better social image and receiving much more consideration from governments, and consequently increasing budgets that are still far from what is needed. It is amazing to notice how these situations reflect almost directly in the figures 3 and 4 of this report.

Public universities have no fees and private ones have almost no mathematical studies. There are some public scholarships for students in scientific areas whose families have low incomes but the amount of these scholarships is low (they mainly cover transportation, materials and daily food at the university). The Mathematical Olympiads -only method in the country of detection for students with special skills in this area- have been important to increase the number of students attending universities.

Future secondary school teachers study either at specialized institutes or at the university. This last option, which is in fact better, is more recent than the other one and rather unknown or not so accepted. Public education (primary and secondary) has had a good level for many years but it suffered from dictatorships and the political ideas of the '90s -at that moment schools depending on the Ministry of Education passed to a local public control with less economic resources. As these problems increased, the number of private schools consequently increased too. The situation currently is that the quality varies in both public and private schools.

Since 2003, education is being awarded more resources but unfortunately the damaged caused before is far from being reverted. The role of traditional universities such as University of Buenos Aires, National University of Córdoba, National South University (Bahía Blanca), National University of Rosario, which have one or more secondary schools attached to them is really important. All these public schools are excellent and they determine the desirable academic level for secondary education in Argentina. The existence of rigorous exams to be accepted in these schools restricts in some way the access mostly to students coming from families of middle or upper classes, and in particular to children whose parents have university education.

As for mathematical research, it covers a wide variety of areas -including harmonic analysis, PDEs, algebra, differential geometry, statistics, probability, number theory- and results in numerous publications, many of which have been published in the most prestigious journals. The number of undergraduate students in mathematics remains unchanged in some universities and increases in others. This is in part motivated by the existence of numerous scholarships for doctorates. Although salaries are lower than in Chile, Brazil and Mexico, the social value of the task of scientific researcher has greatly improved in recent years. Graduates in mathematics find jobs adequate to their training. Most of them remain in the scientific system.

Concerning indexed mathematical publications in the period 2010-2012, MathScinet data gives that mathematicians with affiliation Universidad de Buenos Aires published 189 indexed articles, while those from Universidad Nacional de Córdoba published 80 indexed articles and those from Universidad Nacional del Sur (Bahia Blanca) published 43. The total number of publications from Argentina indexed by Mathscinet in 2010-2012 is 958.

Chile

The modern development of mathematics in Chile starts with the arrival of the German mathematician C. Grandjot in 1930. In the 50's the dean of the University of Chile, Juan Gómez Millas, decided to create the Centro de Investigaciones Matemáticas, with the collaboration of other Geman mathematicians: K. Legrady, A. Zaddach and G. Stahl. The State Technical University (USACH today) launched at the same time a postgraduate program directed by J. Michelow. Universities of Santiago, Concepción, Chile and Pontifical University of Chile have also been at the origin of studies in mathematics in the country.

In Chile university education is not free, but universities provide scholarships for students who get good grades in PSU (acronym for "Prueba de Selección Universitaria") exams to be admitted in the universities. The state also provides scholarships for a considerable number of students of scientific careers. However, since private primary and secondary schools have more economical means, their students get better grades in PSU. We can say that access to university education becomes more difficult for low-income sectors in Santiago, where there are more students that apply to universities. Therefore, some low-income students are forced to take out loans whose later repayment is sometimes very difficult, and any interruption -due for example to pregnancy, illness, family problems- implies the loss of the scholarship.

The research budget is proportionally higher than in Argentina and Uruguay. There are mathematical centers of very good level in Chile. Undoubtedly the existence of the Center for Mathematical Modeling (CMM) in Santiago de Chile is extremely important for research in mathematics in Chile, in particular for applied mathematics. This center, which is a research unit of the University of Chile, has had the long-term support of both academic and industrial counterparts. It is a CNRS's Unite Mixte Internationale since 2000. The CMM also carries out projects dedicated to mathematical education; this subject is also taken into account by the universities, although this has not so far resulted in a significant improvement nationwide. Graduates usually have no trouble finding jobs related to their abilities.

The number of researchers in mathematics has doubled in the last ten years and there are research groups in several universities. Meetings, colloquia and schools are held each year. These groups will certainly continue their activity into the future. Concerning indexed mathematical publications in the period 2010-2012, MathSciNet data gives 40 indexed publications for researchers with affiliation Universidad de Santiago, 43 indexed publications for those from Universidad de Chile, 104 indexed publications for researchers with affiliation CMM, 77 indexed publications for those from Pontificia Universidad Católica (PUC- Santiago de Chile), 15 indexed publications for those from Universidad de Valparaiso and from Concepción.

Uruguay

The only public university is Universidad de la República (UdelaR) located in Montevideo. In order to try to help development in other areas of Uruguay, the UdelaR opened in recent years some peripheral centers (Maldonado, Rocha, Salto and others).

It is a country with a very small population (about 3,3 million inhabitants) of which more than a third live in and around Montevideo. Public education in Uruguay has traditionally had a good level, but the country also suffered from the policies of the 90's. In recent years the state has tried to solve some of these problems, but -as in the case of Argentina- the deterioration was such that it takes a long time to recover what has been lost. Moreover, the development of mathematics in Uruguay had an abrupt interruption during the dictatorship. With the return of democracy several Uruguayan mathematicians returned to the country, and this was the starting point of doctoral studies in UdelaR. Brazilian IMPA has an important influence on people working on dynamical systems. Most graduates find teaching jobs without major problems. The Uruguayan mathematical community is very small and it has not yet reached a critical mass. Therefore it depends heavily on individual efforts. In recent years the salaries of researchers improved, as well as budget for research projects. A couple of years ago a LIA (acronym for French "laboratoire international associé") with France has been created. Its core topics are: Algebra and Algebraic Geometry, Probability and Statistics and Dynamical Systems.

Concerning indexed mathematical publications in the period 2010-2012, MathSciNet data gives 35 indexed publications for researchers with affiliation IMERL (Instituto de Matemática y Estadística Prof. Ing. Rafael Laguardia) -UdelaR and 31 indexed publications for those with affiliation CMAT (Centro de Matemática)-UdelaR .

Paraguay

Paraguay, next to more developed Argentina and Brazil, had never had, until recently, a graduate degree program in mathematics. High level teaching of mathematics was supported mainly by the engineering faculty. The first school EMALCA school in mathematics in Paraguay, organized by UMALCA in collaboration with a small group of Paraguayan mathematicians took place in September 2005.

The first Ph.D. in the history of Paraguay graduated in 2011. In a few years the number of professional mathematicians reached 15. There is a demand for scientific progress in the country. This led to the creation, by law of the Paraguayan Congress, of the National Fund for Excellence in Education and Research.

The teacher training is still not very good. The production of graduates is presently very low, so that they find work quickly. There is a young talent program coordinated by the organizers of the Paraguayan Mathematical Olympiads.

Paraguay is an example in which the joint efforts of local mathematicians (who also obtained state contributions), UMALCA (particularly some of the member countries) and European countries (France and Spain) succeeded in producing a germ of mathematical development. This effort should be still supported for some years to produce lasting effects and to contribute to the benefits reaching the teaching of mathematics in primary and secondary schools.

Bolivia

In Bolivia the mathematical level is very low and although there have been isolated efforts, there are still no clear plans to try to improve it. It is undoubtedly the country in the Southern America South sub region with the least mathematical development. The educational level of the community is low, teachers do not have good training and in our opinion one cannot speak of research groups. There are some isolated initiatives, for example a program supported by the Swedish government which does not seem to have led to major changes yet. While some schools on basic subjects of background in mathematics (EMALCAs) have taken place in Bolivia, it seems that no tracking of these activities or students who participate in them is carried out. Also, there are no positions for some mathematicians returning to the country with a Ph.D. It is important to discuss which could be the strategies to improve the current situation.

Recommendations for Improving Mathematics in Latin America and the Caribbean

The Latin America and the Caribbean region suffers many painful problems producing social, financial and cultural drawbacks. Three hundred years of colonialism, political unrest, long standing dictatorships, bad administrative practices are some of the reasons behind the most acute problems: there are significant sections of the 570 million people who live in the LAC region in poverty conditions; most countries have a very inhomogeneous wealth distribution; the accumulated poor governmental policies are illustrated by the low investment in education, development, science, technology and innovation.

Most of the problems will need serious attention for decades to be controlled and solved. Public education has lost prestige, thus opening the way to proliferation of private institutions. Investment in higher education, science and technology is still behind the minimal recommendations of UNESCO. With the exception of Brazil and Venezuela, the minimal goal of governments expending 1% of GNP in science and technology is far from being reached. Nevertheless the region has dramatically improved its situation in the last decades: most of the children get basic education; women form 50% or more of the undergraduate students in most of the big national universities; the good performance in the Mathematical Olympiads shows that there are high level trainers and talented young people are systematically identified; some graduate programs are forming well trained mathematicians who go on to research in their own countries or abroad; some research centers have reached international recognition.

Latin America and the Caribbean have large untapped potential for mathematical talent. With a better use of the region's financial and human resources and the help of more developed countries some strategic actions could have an important effect in the development of mathematics. Here we present some specific, relatively low cost activities that may help the development and sustainability of mathematics in the LAC region. Most of these activities are already in practice in some countries at a good level. Most of the recommendations are suggestions for a better use of the individual and institutional resources available by the international community. They are addressed to individual mathematicians, to national math societies, to international organizations, the private sector, state governments and most prominently, to the IMU.

1. Promotion and support of high level schools and lecturer programs
    - The number of UMALCA schools, which have proved a success, should be increased. Part of the success comes from the international support of lecturers and the financial help from organizations, most significantly, CIMPA. Others funds could be used to push forward more systematic activities.
    - Other programs, such as the Volunteer Lecturer Program of the IMU could be more efficient if a network of contacts and potential hosts in many of the countries in the region were created.

2. Improving access to information about resources and opportunities through the creation of a regional IMU office in Latin America. The goal of this office would be to serve as a hub of information about mathematical activities and opportunities in the region. This office should be in close

collaboration with UMALCA. Some of the information that would be disseminated through a website and a mailing list is the following:

- congresses in the region, high level talks and courses;
- opportunities of scholarships for students to study in countries in the region (e.g. CIMAT, IMPA, CONICET, University of Puerto Rico, etc.);
- open access journals published in the LAC region;
- names of mathematicians willing to volunteer their time by either teaching and/or giving lectures in developing countries;
- sponsors which would be willing to support mathematical projects and volunteers;
- information on successful collaborations at national and regional levels between government, universities and industry.

3. Maximize access to the resources of major research centers in the region
    - Identification of mathematical centers in the LAC region that support development of nearby countries. Dissemination of the opportunities available at those centers. For example, through training of students and sending faculty to teach advanced courses.
    - Creation of a network of centers with the purpose of attracting and facilitating exchanges of high level students and researchers.

4. Promotion of Mathematical Olympiads
    - Promoting increased participation in the Mathematical Olympiads. The more participants in the first stages of these competitions, the more students benefit from the enthusiasm that these competitions may awake.
    - Special efforts should be done to assure the undergraduate and graduate studies of the talented students who are identified via these competitions.
    - Supporting regional Mathematical Olympiads to ensure their continuity.

5. Dissemination of existing mathematical content through a collaboration of research centers
    - Improving communication through distance conference technologies. Many activities (congress, conferences, courses) could be shared and reach bigger audiences.
    - Video recording and posting online of research talks in mathematics at major research centers to create a repository of mathematical research talks in Spanish.
    - Creating mechanisms to facilitate access to mathematical publications (books and magazines).

6. Improving the education level of university faculty
    - Supporting national and regional efforts to develop masters' and doctorate programs.
    - Providing scholarships for students from countries without graduate programs to attend graduate programs in countries in the LAC region.
    - Promote the establishment of sandwich doctorate programs.
    - Promote the establishment of bilateral and multilateral cooperation schemes such as the French ECOS and MATHAMSUD, and individual cooperation projects.

- Creating incentives for students with research education abroad to return to their home countries, for example reducing the teaching load for faculty who are research active (e.g. matching funds for universities in the region which provide assigned time for research).

7. Increasing involvement of mathematicians in mathematics education
   - Support the creation of partnerships between the mathematical community at the university, and pre-university levels.

8. Making more effective use of the money invested in creating access to research articles.
   - Promotion of open source journals and books. To quote from a recent interview in *The Guardian* with Robert Darnton, director of Harvard Library:

"We all face the same paradox. We faculty do the research, write the papers, referee papers by other researchers, serve on editorial boards, all of it for free … and then we buy back the results of our labour at outrageous prices…The system is absurd, and it is inflicting terrible damage on libraries …We simply cannot go on paying the increase in subscription prices. In the long run, the answer will be open-access journal publishing, but we need concerted effort to reach that goal."

   - Consortia of universities, within each country and internationally, should be formed for the buying of journals and other mathematical periodicals.

9. Mathematics' large potential impact on society is underutilized in the LAC region. This causes mathematics to be seen as disconnected from society with unfortunate consequences such as low investment from universities, governments and industry.
   - Universities and governments should diversify the evaluation methods for mathematical productivity to consider not only academic papers in peer reviewed journals but also activities with technological and social impact.

10. Minimizing the negative effect of bureaucracy on research
   - Carrying out a survey-based study to better understand the effect of bureaucracy on mathematical productivity.

11. Increase investment in mathematics and the science in general
   - Promote increased investment in mathematics and education from governments, industry and private institutions.

Appendix A: Contacts in the Latin American and the Caribbean[4]

Country	Name	Institution	e-mail
Argentina	Andrea Solotar	Universidad de Buenos Aires	asolotar@dm.uba.ar
Argentina	Elsa Fernández	Universidad Nacional de la Patagonia San Juan Bosco	elsafer9@gmail.com
Argentina	Mariano Ferrari	Universidad Nacional de la Patagonia San Juan Bosco	mferrari7@gmail.com
Argentina	Nicolás Andruskiewitsch	Universidad Nacional de Cordoba	andrus@mate.uncor.edu
Argentina	Ricardo Scorolli	Universidad Nacional de la Patagonia San Juan Bosco	delegado.madryn@unp.edu.ar
Belize	Joaquin Urbina	University of Belize (UB)	jurbina@ub.edu.bz
Belize	Steven Lewis	UB	sdlewis@ub.edu.bz
Bolivia	Efraín Cruz	Universidad Mayor de San Andres, La Paz, Bolivia	efcruz@gmail.com
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Brazil	Marcelo Viana	IMPA	marceloviana000@gmail.com
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Chile	Rafael Labarca	Universidad de Santiago de Chile	rafael.labarca@usach.cl
Chile	Servet Martinez	Universidad de Chile	smartine@dim.uchile.cl
Colombia	Alf Onshuus	Universidad de los Andes	onshuus@gmail.com
Colombia	Andrés Villaveces	Universidad Nacional	avillavecesn@gmail.com
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[4] The contacts represent people in the countries who either filled out surveys or were mentioned in the surveys. The list is meant to be a resource for future development efforts.

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Appendix B: Survey from the Commission for Developing Countries (CDC) of the International Mathematical Union (IMU) for studying mathematics in America[5]

A. A brief account of the current situation of mathematical development in America
   (i) By country
   (ii) By region (North, Central, South and the Caribbean)
   (iii) By mathematical specialty
   (iv) By educational infrastructure

   Questions:

   1. Which countries in America have a strong university education in mathematics? In which mathematical areas are their strengths?

   2. Which countries have viable centers for research in mathematics? What mathematical areas are represented?

   3. Which countries have a strong development in secondary mathematics education?

   4. Which countries have a strong development in elementary mathematics education?

   5. How do schools in urban centers compare with schools in the countryside?

   6. What are the existing national, regional or international networks of relationships as regards mathematics teaching and research?

   7. What is the role of local culture on mathematics?

   8. What are the locations and who are local contacts which would be interested in hosting volunteers from the volunteer lecturer program of the IMU?

   9. Are there pathways and support for under-represented groups in higher education (indigenous, African-American, women, low income) to have access to university programs in mathematics?

B. An analysis of strengths and weaknesses in mathematics
   (i) By country
   (ii) By region
   (iii) By mathematical specialty

[5] In some countries where it was difficult to obtain information, emails with a few direct questions were more successful than the use of this comprehensive survey. This survey was based on the one used for the Templeton Report for Africa but was modified for the LAC region. Some changes include questions on whether respondents would be willing to host VLP volunteers, whether there is equal access to under-represented groups and if an online repository of research information would be useful.

(iv) By educational infrastructure

Questions:

1. Which areas of mathematics are strongest in your country? How do these map to needs in your country? In which international mathematics research journals have mathematicians in your country published in the last 5 years? If possible, indicate the rough number of publications in each of these journals authored by mathematicians in your country.

2. What are the advantages and disadvantages for mathematical development of linkages with neighboring countries?

3. What are the appropriate roles of countries such as USA, Mexico and Brazil in the mathematical development of your country?

4. What is the role of the countries in Western Europe and other parts of the world, in enhancing your mathematical development?

5. Would having a volunteer lecturer come and teach an intensive course (45 contact hours in 3 weeks) at the master's level be an activity which you think would be helpful?

6. Would you be willing to be the host (help make course and housing arrangements) for a volunteer lecturer? If you are not able to be a host, do you have contact information (name, institution and email) for someone who could?

C. School mathematics:

(i) by region

(ii) by educational policy

Questions:

1. On a per-country basis, what is the teacher-student ratio in each level of elementary and secondary math education?

2. What is the normal education level of primary and secondary school math teachers in each country? Do they need bachelor's degrees?

3. What are the math teacher organizations within the country and in the region? Provide the relevance and role of each organization, contact person and email address.

4. What is the typical level of education of university professors?

D. What are the opportunities for talented/high achieving students?

(i) by region

(ii) by educational policy

Questions:

1. Are there screening systems to identify exceptionally gifted math students?

2. If such screening tools exist, are they effective? Do such screening procedures lead to placing these highly-gifted students in special accelerated schools or courses?

3. Is there a system of educational tracking of highly talented math students to assure their entry into top flight universities with strong mathematics departments?

4. What are the educational career opportunities for highly-talented math students in your country? How does this vary with that of the countries near yours?

5. What are the commercial or specialized career opportunities, such as research, engineering, etc, for talented and well-trained math students in your country?

6. Are all talented mathematics students encouraged equally to pursue mathematics education regardless of gender, ethnicity, or socio-economic class?

E. Highlight a selection of opportunities for highly leveraged investment in mathematical future. In other words, what are the greatest opportunities for improvement in mathematical development and training?

F. Provide a vision for cohesive, sustainable development through networking and building on existing nodes of quality. Consider the single nation strategies vs. regional or international approach.

G. Would you and your students likely use a repository of available information about free online mathematics resources? What would you like in it?

H. Would you be interested in being able to view lectures at major research institutes using Skype or other free online tools? Would you want to watch them live or would they be just as useful available online?

I. Provide a vision of the mechanics of investment in America's mathematical development.
Questions:
1. What are the current initiatives to encourage the development of mathematics and mathematics education in your country? In the neighboring countries?

2. To what extent is cooperation with these initiatives, as opposed to initiating new ones, is a more effective and highly leveraged strategy?

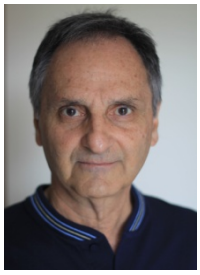
J. Expectation from IMU: What can IMU do to support the mathematics development in the region?

Appendix C: Biographies of Authors

Luis Cáceres studied mathematics at the Universidad Javeriana in Bogotá and he obtained a MS in applied mathematics from the University of Puerto Rico. He obtained his PhD from the University of Iowa. He is currently professor at the University of Puerto Rico, Mayaguez Campus. He is the director of the Mathematical Olympiad program in Puerto Rico and coordinates several programs in mathematics education in the island.

José Antonio de la Peña got a PhD in mathematics from the National University of Mexico in 1983 and went to postdoctoral work in the University of Zurich from 1984 to 1986. His areas of interest are the representation theory of algebras and spectral graph theory where he has published more than 120 papers in specialized journals. He has a full research position at the Institute of Mathematics at UNAM, where he was director from 1998 to 2006. He was President of UMALCA from 2001 to 2009. Among other distinctions he received the TWAS Prize 2002, the National Art and Sciences Prize 2005 and the Humboldt Prize 2006. Currently he is General Director of CIMAT at Guanajuato and President of the Commission for Developing Countries of the IMU.

Angel R. Pineda studied high school in Honduras and his bachelor's degree at Lafayette College. He obtained his PhD in applied mathematics from the University of Arizona (2002) and had a postdoctoral fellowship at Stanford University (2002-2006). Since 2007, he works at California State University, Fullerton where he is associate professor of mathematics. During 2008 and 2009 he was a volunteer lecturer in Cambodia for the IMU and the US National Academy of Sciences.



Carlos Di Prisco Carlos Di Prisco studied mathematics at the Universidad Central de Venezuela and the Massachusetts Institute of Technology (Ph.D. 1976). His main research interests are mathematical logic and combinatorial set theory. He was a Guggenheim Foundation Fellow 1991-1992, and President of the Venezuelan Mathematical Association from 2004 to 2010. He is currently Emeritus Researcher of the Instituto Venezolano de Investigaciones Científicas, member of the Academia de Ciencias Físicas, Matemáticas y Naturales of Venezuela and member of the Academy of Science for the Developing World (TWAS).

Andrea Solotar studied mathematics at Universidad de Buenos Aires where she also obtained her PhD (1988). She worked as a postdoc at Universite de Strasbourg. She has been Secretary of Union Matemática Argentina and Regular Associate of ICTP. She is currently professor at Universidad de Buenos Aires, Principal Researcher of CONICET (Argentina) and member of the Governing Board of CIMPA.

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Jose Angel Chavarria from CIMAT created the graphics for this report.

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