Consultant Report

Securing Australia's Future

STEM: Country Comparisons

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Study of Science, Technology, Engineering and Mathematics (STEM) and STEM-related issues in Argentina

Cynthia Fernandez Roich
Centre for the Study of Higher Education
University of Melbourne

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Definition

STEM is defined as learning and/or work in the fields of Science, Technology, Engineering and Mathematics. In contrast with the Australian classification system, health professions in Argentina are not considered part of STEM. Within the Argentinean classification system, universities generally divide the fields in the following faculties: *Facultad de Medicina* [Faculty of Medicine], *Facultad de Ciencias Exactas y Naturales* [Faculty of Natural Sciences], *Facultad de Farmacia y Bioquimica* [Faculty of Pharmacy and Biochemistry] and *Facultad de Ingenieria* [Faculty of Engineering] and as separate divisions the faculties of *Ciencias Sociales* [Faculty of Social Science] and *Filosofia y Letras* [Faculty of Philosophy and Arts].

Therefore, the Australian classification of 'Health' can be found diversified in Argentina among three different faculties (Faculty of Medicine, Faculty of Natural Sciences and Faculty of Pharmacy and Biochemistry). In order to provide a broad picture of STEM disciplines this study will provide data indicative of trends on enrolment and completion of STEM related degrees for the three faculties mentioned above from the University of Buenos Aires (UBA)[1], the largest public university and the one that even now has a leading role in terms of teaching and research.

Typically STEM students in Argentina are concentrated in the Faculty of Natural Sciences and the Faculty of Engineering. The Faculty of Natural Sciences includes biological sciences, atmospheric sciences, information technology, physics, geology, mathematics, chemistry and food engineering. It also includes oceanography and palaeontology. In regards to Engineering, the country has recently declared that 21 engineering disciplines are of national interest, these being: Aeronautics, Surveying, Food, Environmental, Biomedical and Bioengineering, Civil, Computer, Electrical, Electromechanical, Electronics, Hydraulics, Industrial Computing and Systems, Materials, Mechanical, Metallurgical, Mining, Nuclear, Oil, Chemistry and Telecommunications. Up to 2011 the 21 specialities were taught in 303 institutions across the country.

Even though this report will focus on two specific STEM careers, Engineering and Biotechnology, it will also provide enrolment/completion figures for the rest of STEM careers. It will focus on Engineering and Biotechnology as the first one of these disciplines has been declared to be of 'national interest' for the current government (Kantor, Broitman, & Samela, 2010; Página 12, 2012b; Stewart, 2007) and its teaching had been considered by the state as a key professional field for the economic development of the country (Morano, 2011). The second one has been promoted as a 'strategic area' by the Ministry of Science, Technology and Productive Innovation (Ministry of Science, 2010).

Summary and broad findings

The current government of Cristina Fernandez de Kichner (and the previous government of her former husband Nestor Kichner)[2] has increased the investment in research and development (I+D)[3], strengthened the links between industry and academia and launched six different strategic plans to increase scientific capacity and to address the

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[1] According to the last figures released in 2010, UBA captured 294,837 students out of 1,312,549 students from all universities across the country, holding 22.5% of the university enrolment (Ministerio de Educación de la Nacion, 2010).

[2] Nestor Kichner was president of Argentina from 2003 to 2007. Cristina Fernandez de Kichner was president from 2007 to 2011 and was re-elected for four more years with 54% of the votes in 2011.

[3] I+D stands for *Investigación y Desarrollo,* the equivalent of R & D, Research and Development. Please refer to the list of Acronyms.

engineer's labour shortage. These plans were put in place between 2003 and 2010 and three out of six are still ongoing.

Public funding for science and technology projects experienced a significant increase and the government launched an ambitious set of public policies declaring engineering as a discipline of 'national interest' creating a specific program to improve teaching skills for the field through the *Proyecto para el mejoramiento de la enseñanza de la ingenieria-PROMEI* [Project for the Improvement of Teaching Engineering Programs – PROMEI].

The creation of the Ministry of Science and Technology in 2007 was considered a milestone for the scientific community, accustomed to minimal budgets and a lack of public funding support in the past; the program RAICES [Foundations] allowed the re-expatriation of remarkable Argentinean scientist who were working overseas due to a lack of professional opportunities in the country.

One of the causes of the shortage of STEM related professionals in the country is related with the teaching of mathematics at primary and secondary school, where the majority of students failed to pass the subject or do not fully comprehend the minimum subject content. Teacher's training is also insufficient and problematic.

1.1 Attitudes towards STEM

Attitudes towards STEM in government

In the last decades of the twentieth century, Argentina suffered a costly 'brain drain' with regards to engineers due to systematic cancellation of financial aid, subsidies or investment plans in basic infrastructure by the government (Agosta, 2012)[4]. Argentina experienced a significant deindustrialisation process during the Menem administration (1989-1999) when more than a hundred state-owned companies were privatised; the process included association deals and concessions for fuel extraction, railway concessions, gas and transport distribution as well as water and electricity supplies, and the privatisation of the national petrol company YPF (Jun, 2009). STEM disciplines reduced its participation in higher education, and their decline was especially pronounced in engineering during the 1990s, reaching its lowest level between 1996 and 1999 (UNESCO, 2010a). A decline in STEM disciplines was also observed in vocational education[5], where students tended to choose Humanities over Natural Sciences or Engineering. The following table provides a snapshot of the 1997 vocational education enrolment; Engineering and Architecture was located at the end of the preferences (Delfino, 1998).

[4] See section 4 where government's strategies are further explained.

[5] In Argentina the vast majority of vocational students during the 1990s were females because they tended to graduate as school teachers, the working hours were family-friendly, the time taken to complete a degree was shorter than nowadays (2 to 3 years in contrast with the current 4 years) and the teaching wages were reasonably good, in contrast with current teachers' wages.

Field	Amount of students	Percentage	Women's percentage
Medical Sciences	24,881	6%	71%
Natural Sciences	6,770	2%	60%
Mathematics & comp sciences	32,871	8%	47%
Humanities	**276,403**	**71%**	**80%**
Law and economy	47,407	12%	55%
Engineering & Architecture	**2,383**	**1%**	**30%**
Total	390,715	100%	73%

Source: (Delfino, 1998)

That preference affected the STEM teacher's provision for the following decades, as it is described in section 1.5. In summary, the 1990s marked a point of inflexion in terms of the amount of students and teachers in STEM related disciplines[6]. In contrast, after the abandonment of the fixed exchange rate regime or 'convertibility' plan[7], the country started down a path of remarkable economic growth both in terms of magnitude and duration. After a sharp fall of over 18% in its GDP between 1998 and 2002, the country started a process of the most unprecedented economic expansion in the last fifty years, with an average annual growth of 8% (only interrupted by the effect of the global economic crisis in 2009). In 2010 the level of investment in science, technology and innovation represented about 23% of the GDP, exports grew at an average annual rate of 9% and the country achieved uninterrupted fiscal solvency (Dirección Nacional de Políticas y Planificación, 2012).

This new scenario modified significantly the trends in enrolment, completion and provision of STEM related careers. For instance, engineers passed from accounting for 6% of the total employment in 1998 to 10% of total employment between 2002 and 2004 (INDEC, Centro Redes, & SECYT, 2006).

Engineering

Engineering as a degree suffered significant deterioration both academically as well as professionally during the 1990s, as a result of deindustrialisation, economic recession, and the significant unemployment rates among engineers (Gómez, Rufolo, Contartese, & Marollo, 2000); this had a considerable effect on civil engineering (Agosta, 2012) and other disciplines that depended on economic policies. For example, the specialisation in railway engineering was suspended in the 1990s due to the privatisation of the railway system and the subsequent decline in railway activity (Rosito, 2011). In addition, the teaching of mathematics at high school level, which is crucial for the future provision of university STEM students, dropped following a significant reduction in the number of technical high schools (Rosito, 2011). As a result, there was a strong shift in university enrolments, social sciences grew by 120% whereas the enrolment in engineering fell by 30% (Kantor et al., 2010).

Economic recovery began in 2000 and gradually experienced a real 'boom' after 2003, resulting in a shortage of engineers (Perazo, 2010); the following table provides a broad overview of other STEM related degrees as related to Engineering. It was produced by the University of Buenos Aires (UBA)[8] on degree completion for undergraduates

[6] Figures/information on vocational student enrolment from 2000 onwards were unable to retrieve on line.

[7] The convertibility plan pegged the national currency (the peso) with the American dollar resulting in 1 peso = 1 American dollar.

[8] The figures correspond only to graduates from UBA.

between 1992 and 2005[9] and the contrast between Engineering and Medicine is remarkable, as on average, the number of doctors is quadruple that of engineers.

Year	Natural Sciences[10]	Pharmacy and Biochemistry	Engineering	Medicine
1992	324	419	554	2239
1993	400	466	1021	2500
1994	382	446	682	2349
1995	345	449	451	1342
1996	410	369	463	1422
1997	362	397	391	1715
1998	374	373	352	1800
1999	323	362	353	1768
2000	315	377	470	1807
2001	408	421	373	2307
2002	391	400	454	2768
2003	377	396	440	2628
2004	415	309	314	2502
2005	538	363	490	1874

Source: UBA Statistics series 1992-2005, Graduation rates. Table no. 7

Biotechnology

Argentina developed molecular biology jointly with genetic engineering and biotechnology. Within the Faculty of Natural and Exact Sciences, special mention should be placed on Molecular Biology and the award-winning work of Professor Ana Belen Elgoyhen at the Institute for Genetic Engineering and Molecular Biology of Argentina who received a prize in 2008 for her contribution to the understanding of molecular basis of hearing (UNESCO, 2010b).

Modern biotechnology derived from molecular biology as a new discipline founded in the 1930s aims to apply methods from physics in biology (Ministry of Science, 2010). Biotechnology is an intense scientific discipline, characterised by its multidisciplinary nature and strong ties to other existing technologies. Its development is closely linked with technical progress and it plays a significant role when it is properly integrated with other technologies in the production of food, agriculture and services. This point is critical for countries like Argentina where the agricultural and agribusiness sectors play an essential role in the national economy (Ministry of Science, 2010). The most important biotechnological applications in the country have been developed in the fields of human and animal health, agriculture and livestock, production of materials for the food industry. The following applications are the most developed: agricultural biotechnology, medical biotechnology and biomedicine, livestock biotechnology and Industrial biotechnology (Ministry of Science, 2010).

Since the 1980s biotechnology has had a significant economic impact on the agronomic and pharmaceutical sectors and these technologies spread quickly among companies around the world. Argentina was a pioneer country in Latin America in these areas of research and the development of new biotechnology products for agriculture, as well as in creating biopharmaceutical companies that began to use biotechnology to develop their products. The creation of biotech companies in the region increased significantly by 2001 with a total of 432 companies in 14 countries, most located in Argentina, Brazil and

9 Please note that UBA is the largest and most prestigious public university in Argentina.

10 The Faculty of Natural Sciences of UBA includes the following bachelor degrees in biology sciences, food technology, information technology, physics, geology, mathematics, chemistry, food engineering, oceanography, palaeontology, and teacher degrees in all the disciplines mentioned above.

Chile, working in the agriculture, food, health (human and animal) and industrial development (Estébanez & De Fanelli, 2007a).

The Argentinean government played a significant role in the development of biotechnology in the country from the 1980s through the former Science and Technology Secretary (currently the Ministry of Science, Technology and Productive Innovation). It supported a handful of programmes to promote biotechnology such as the National Programme of Biotechnology (1982-1991) which supported projects financially; the National Priority Programme for Biotechnology (1992-1996) which concentrated funds for projects in the private sector; the Biotechnology Multi-year Plan for Science and Technology (1998-2000) which set up thematic priorities to fund research and development projects and the Strategic National Plan for Science, Technology and Innovation 'Bicentennial' (2006-2010) which defined biotechnology as a priority area. Following this public policy, the Promotion of Production and Development of Modern Biotechnology Act 26,270/07 was passed in 2007, which provided tax cuts to new research and development (I + D) projects and created a special 'Incentive Fund' for the initial financial capital required to start a project (Ministry of Science, 2010).

Among biotechnological techniques used in Argentine agriculture the three most popular are: the clonal plant propagation (micro-propagation) that allows rapid multiplying of new plants a-sexually, efficiently and in large quantities; the genetic improvement of breeding with molecular indicators and the development of genetically modified organisms for agricultural use. The adoption of these new technologies has had a major impact on agriculture and on the overall economy of Argentina. The first genetically modified crop incorporated into Argentine agriculture was the soybean resistant to the glyphosate herbicide, approved in 1996. With this achievement, Argentina has become the second largest producer of this type of crop behind the United States (Ministry of Science, 2010).

On December 13th 2011 a group of businessmen created the Argentine Chamber of Biotechnology with the aim of contributing to public-private policy in the field, to take advantage of Argentina's strength in natural, human and scientific resources. Members of the organisation came from a variety of fields such as human and animal health, food industry, agriculture, forestry and biofuels (Infobae, 2011b).

There are a considerable group of plans in place to promote, support and encourage science and technology activities in the country as a whole. Such activities have renewed momentum after 2003 with the economic recovery. For example, Argentina's National Agency for the Promotion of Science and Technology (ANPCYT) is a decentralised body that reports to the Ministry of Science, Technology and Productive Innovation (MINCYT) and manages four funds. Firstly, the Technological Fund of Argentina (FONTAR), which finances technological modernisation and innovation in the productive sector, including via technological services for institutions and small and medium-sized enterprises, technical assistance and training, entrepreneurial incubators and technology parks. Secondly, the Scientific and Technological Research Fund (FONCYT) that provides public or private non-profit research and development institutions with subsidies. Thirdly, the Trust Fund for Promotion of the Software Industry (FONSOFT), which was created by law in 2004 and which finances development of the software industry in small and medium-sized enterprises. Finally, the Sectoral Fund (FONARSEC) which provides subsidies for the upgrading of research and development capacities for transfer to the productive and social sectors.

The ANPCYT through its funds promotes financial support to projects that improve the social, economic and cultural rights in Argentina. In 2008, the agencies awarded a total of US$ 234.6 million for the execution of 2293 research and develop projects. Of this, US$ 135 million went to FONCYT, US$ 94 million to FONTAR and US$ 5 million to FONSOFT (UNESCO, 2010b). Further details are provided in the last section of this report.

Attitudes towards STEM in educational institutions

Engineering

Statistics show that the majority of students take more than five years to complete their engineering degree, only 9.6 per cent of Argentinean students complete their degree in the time frame expected of five years (UNESCO, 2010a). The total number of graduate engineers in the period 1998–2003 was 11,460 from national universities, 10,250 from the National Technological University and 4,090 from private universities (UNESCO, 2010a). The main engineering fields were computer sciences and industrial, electronic, civil, and chemical and mechanical engineering.

One of the main obstacles to mass university enrolment is the generalised social perception that STEM degrees are more difficult to follow than traditional ones. There has been strong prejudice against engineering degrees, as it is considered less prestigious than law or medicine (C5N News, 2011). Taking into account all the universities nationwide, only 6% of students choose engineering as a degree due to a number of reasons. These reasons include the almost total lack of technical high schools, the cultural preference for humanities and the ‘bad press’ mathematics is given at high school (Infobae, 2011a). During 2010, several deans from leading universities such as *Universidad Argentina de la Empresa* (UADE), *Instituto Tecnologico de Buenos Aires* (ITBA) and *Universidad Tecnologica Nacional* (UTN) agreed on the common factors deterring students from STEM disciplines, these being: significant fear of science among Argentinean students, especially of mathematics and physics, which are fundamental to engineering, coupled with an extended bias from high school against these vocations, the idea that engineering is difficult and that choosing that career will make it impossible to achieve a work/life balance once graduated (Kantor et al., 2010).

In terms of educational institutions’ attitudes, engineering has historically been dominated by a very conservative design, founded in disciplinary traditions which dismissed closer links to basic science, to promote doctoral graduates or include activities in research and development (I + D) as a central component of curriculum (Estébanez & De Fanelli, 2007b). In addition to this problem, teachers are scarce; engineering suffered a chronic shortage of teachers due to low wages, lack of incentives for an academic career and high demand for mobile professionals who can take on regional projects and therefore cannot commit to teach for a whole semester (San Martín, 2007).

Biotechnology

Biotechnology has been included in the school curriculum in Argentina since 1990; however, most students do not understand the meaning of the concept of biotechnology[11]. The vast majority concentrated on related biotechnology with activities that directly involve genetic engineering such as cloning, medical reproduction or transgenic applications, leaving aside other uses. One possible explanation is that media tend to cover those uses when reporting about biotechnical process; another possible reason is the fact that secondary schools only addressed biotechnical process within the genetic engineering framework (Occelli, Malin Vilar, & Valeiras, 2011).

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[11] The study was carried out in the province of Cordoba among 138 students of 6 secondary schools.

In an attempt to close this information gap and help teachers and students get a better understanding of the field, the Argentine Council for Information and Development of Biotechnology (ARGENBIO) was created to disseminate information on biotechnology, contributing to its understanding and encouraging its development. To meet this commitment, ARGENGBIO is actively working in the following areas: providing training for professionals and teachers, providing information for the media and disseminating information about biotechnology to the general public (ARGENBIO, 2007).

Attitudes towards STEM by employers

In regards to employers, key players in the field also concurred with the negative diagnosis made by academia on attitudes towards engineering; companies argued that potential students still ignored the real increasing demand for STEM graduates locally as well as globally, stressed the preference for short degrees instead of long ones such as engineering (Perazo, 2010) and described the problem in global terms, commenting that engineering was not a first choice degree because of its difficulty and because there was no clear knowledge of what set of activities an engineer could do (Kantor et al., 2010).

With regards to the software market, for example, the lack of trained human resources in information technology careers could lead to a stagnation of this field and it is a point of great concern for business, specialist and public officials. Nevertheless, an important portion of potential students responded saying that they were 'not sure what it is' when referring to a degree in information technology (National Observatory of Science, 2007, p.12). In addition, Argentina faces a persistent problem in regards to copyright protection laws. The Argentine Government has made few efforts to impose criminal penalties in commercial piracy cases and stop counterfeit importation; however, there have been substantial delays in the completion of criminal and civil infringement cases. As a consequence, losses by the Argentine software industry to illegal copying were estimated at US$140 million in 2001 (Thorn, 2005).

Since 2003/2004 with the economic recovery there has been a match between job demand and study interest in the areas of agriculture, mechanical engineering, chemical and naval engineering, pharmacy and biotechnology (San Martín, 2004). Biotechnology in particular has been a growing field in the country, similar to the information technology revolution of the 1990s (San Martín, 2004) and it has been diversifying in the biomedical field, agro-food crops, genetically modified animals, and even the environment (San Martín, 2004).

Attitudes in the community/media

In terms of media coverage, the shortage of engineers received considerable attention between 2010 and 2011. The television medium provided a significant coverage of the issue in the news programs which helped to put the topic in the public agenda[12]. The cable news channel C5N informed that out of a total of 100,000 university undergraduates, only 5,000 were engineers; the figures showed 1 engineer per 6,700 inhabitants. Due to the shortage of professionals, companies were forced to hire engineering students in the midst of their degrees, which aggravates the problem, as the students tend to drop the degree once they have got a steady income in the industry and work long hours (C5N News, 2011). The digital news channel 360 interviewed several university students asking about their career choice combining their statements with interviews with experts in the field, and these confirmed that less than 3% chose to study

[12] The use of television as a source of information or entertainment is a widespread cultural habit among Argentineans, regardless of gender, age or educational level. On a typical day nine out of ten people watch television; almost 60% do so between two and three hours per day and 20% do so four hours or more (National Observatory of Science, 2007)

engineering at the University of Buenos Aires (UBA) the biggest university in terms of enrolments (Busaniche, 2011). Channel 13, one out of five main private TV channels, provided a complete report on the issue in 2011 (Telenoche, 2011).

As part of a set of strategic plans to support and encourage STEM careers, Argentina officially launched on April 18th 2012 the first state television channel with exclusive content on science and technology. One of the aims of the channel is to promote scientific vocations among youth. *TEC-Tecnópolis TV*[13] offers a program dedicated to interviews with Argentine scientists, a fictional series about a molecular biologist and various stories about repatriated scientists working on maths, video games and technology.

Attitudes in the community

The gender gap

It has been established that differences in young people's choice of field of study can be attributed to traditional perceptions of gender roles and identities as well as the cultural values sometimes associated with particular fields of education (OECD, 2012). In western societies, 'being masculine' is often identified with competitiveness, aggressiveness and independence; men are interested in technical issues, have analytical competences and professional ambition, are orientated towards control and domination, and prioritise the achievement of goals over emotion (Sagebiel & Vázquez-Cupeiro, 2010). By contrast, the stereotype of 'being feminine' revolves around the belief that women care for the welfare of others, are interested in affective interpersonal relationships and are child-friendly (Sagebiel & Vázquez-Cupeiro, 2010). This gender vision is translated in career choice; for example, some fields such as science, engineering, manufacturing and construction, are often regarded as 'masculine' and preferred by men, whereas other fields such as education and health, are often perceived as 'feminine' and preferred by women (OECD, 2012). The situation varies according to disciplines; for example, in Argentina, Physics women represents only 25% of the 2012 university enrolments (Gallardo, 2012), whereas the situation is reversed in Biology where women account for 63.5% of the university enrolments (Gallardo, 2012).

Nevertheless, Argentina is not an exception in terms of gender segregation; this type of segregation has the same root causes as gender segregation in the labour market as a whole: gender stereotypes, choice of study field, gender division of labour and time constraints, and covert barriers and biases in organisational practices (European Comission, 2012). In the case of Argentina, despite the fact that female STEM students finish their degree faster and with better grades than their male counterparts, they are still only able to secure low-ranking roles within research organisations (El Litoral, 2011). Silvia Wolansky[14] argues that there are still strong stereotypes in Argentinean society that perceive women as too sensitive to be a strong team leader and not capable of balancing work and family commitments (El Litoral National University, 2011). These persistent stereotypes perpetuate exclusion systems that have pushed away female candidates from top positions in academia, where they have not exceeded 10% for decades (Maffia, 2008).

[13] http://www.tectv.gob.ar/index.php

[14] Silvia Wolansky is a researcher and the academy secretary of the Faculty of Engineering and Water Science from El Litoral National University, in Santa Fe province, Argentina.

Despite the constant segregation, women outnumbered men at Argentinean tertiary education and are getting better grades and overall study performance (Casanovas, 2006). The available data from the University of Buenos Aires (UBA) confirmed this trend. For instance, between 1960 and 2000 the female student population has multiplied seven times, from 59,000 to 226,000 students (Sosa, 2000). In 2000, 8 out of 13 faculties had female student majorities: Psychology (83%), Pharmacy and Biochemistry (71%), Law (69%), Medicine (68%), Social Sciences (63%), Veterinary Sciences (61%) and Architecture (59%) (Sosa, 2000).

The following table shows the enrolment trend for undergraduates from 1992 to 2004:

	1992	**1996**	**2000**	**2004**
Undergraduate population	168,808	183,347	253,260	293,358
Male	45.4	41.7	39.8	39.4
Female	**54.6**	**58.3**	**60.2**	**60.4**
No data	0.0	0.0	0.0	0.2
Total	100.0	100.0	100.0	100.0

Source: Census 2004, Academic Secretary, University of Buenos Aires (UBA).

In 2006 the number of female student graduates from Pharmacy and Biochemistry reached 74.7% of the total student population (Casanovas, 2006). Despite being the majority of students in the Faculty of Medicine (17,013 female students and 6,607 males students) no woman has even been appointed dean of such faculty ever (Casanovas, 2006).

Women also represent the majority of recipients of both full-time and part-time research scholarship in the I+D sector, according to data from the Science and Technical Secretary (SECTY), secretary under the supervision of the MINCYT published in 2006:

Academic degree	**Female** research scholarship recipients	**Male** research scholarship recipients	Total
Undergraduate	**4,862**	**3,943**	8,805
Master	175	154	329
PhD	**386**	**263**	649
Others (lecturer, vocational teachers, etc.)	567	458	1,025
Total	5,990	4,818	10,808

Source: Report on Science and technology in Argentina, Gender situation July 2006-December 2007.

Even though women make up the majority of research scholarship recipients and enjoy considerable equality in regards to leading research projects, they still make up the minority in the assessment stages (always less than 40%) in all of the cases analysed. For example, they are the minority in Advisory Committees, ad-hoc commissions, Peer Review Boards from I+D institutions, Peer Review Boards for Teaching and Research Incentive Programs; the only place where women are not the minority is in the Technical Advisory Committee of the UBA (Baringoltz & Posadas, 2006-2007).

Motherhood has been identified as one of the main obstacles for Argentinean female scientists in acquiring decision-making positions at universities; it generates a conflict between work and family roles that is resolved by delaying motherhood, abandoning a scientific career, attempting an herculean work-life balance at the expense of personal time, opting for more manageable professional occupations such as teaching, or simply not having children at all (Maffia, 2008). Motherhood also appears to be a major obstacle for European scientists, as an extensive body of knowledge shows that family and career tensions play an important role in explaining the low rates of women embarking on a scientific career (European Comission, 2012). However, the latest review concluded that 'Marriage and children do not appear to have a significant influence on women's scientific productivity and academic performance' (European Comission, 2012, p.18) and that to explain gender differences in scientific careers it would be necessary to investigate more complex mechanism, such as discrimination and cumulative advantage and disadvantage (at least for the European context).

In addition to motherhood, the Argentinean Network on Gender, Science and Technology (RAGCyT[15]) has identified other obstacles such as internal and external barriers, horizontal and vertical segregation, unequal pay and minimisation[16] (Maffia, 2008). For instance, the lack of female role models in science is recognised as an internal barrier; the fact that the administration, decisions and control of domestic work is still a woman's responsibility in Argentinean society constitutes an external barrier. Vertical segregation is linked with the number of projects and the funding that women manage (fewer projects with less funding than their male counterparts). Although they participate in evaluation committees they are notably absent in the funding distribution committees; this systematic absence is sometimes justified by lack of time, which is related to domestic duties. However, segregation is seen as a choice and not as gender discrimination. The fact that women are heavily concentrated in a few sectors that have lower social status and generally poorer working conditions is an example of horizontal segregation. Finally, unequal pay is not only a worldwide phenomenon in science (European Comission, 2012) but in Argentina this occurs in parallel with the fact that women in general terms stay longer in each research category and take longer to be promoted than men.

Low socio-economic status, minorities, rural-regional minorities

Statistics related to higher education enrolment of low socio-economic students or students from minority groups did not appear in the wide range of material reviewed for this report. Similarly, rural and regional minorities were neither represented nor addressed in the reports studied. However, it was possible to obtain information about 'Bicentennial Scholarship Program for Scientific and Technical Careers'. The program was recently launched by the government with the aim of supporting low-income students entering the higher education system in the fields of applied sciences, natural and exact sciences and basic science (undergraduate, university and technical degrees as well as vocational degrees in the same areas). The program also aims to support advanced students who are in the last two years of engineering degrees and have between 3 and 10 subjects to complete their degree. The program is designed to increase the number of students from low-income households in degrees in strategic fields for the country's economic and productive development[17] and to support the completion of studies in higher education, technical education and vocational education in the strategic areas already mentioned (Ministry of Education, 2012a). The funding consists of two different amounts, one that ranges from $6,000 (AUS 1,178) to $14,400 (AUS 2,827.29) per year for students entering an undergraduate degree; the other one from $4,200 (AUS 824.62) to $6,000 (AUS 1,178) per year for those entering a vocational teaching diploma. The payment is made in 10 instalments (Ministry of Education, 2012a).

1.2. Perceived relevance of STEM to economic growth and well-being

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[15] RAGCyT stands for the Spanish acronyms *Red Argentina de Género, Ciencia y Tecnología.*

[16] The concept of 'minimisation' corresponds to the widespread attitude of Argentinean male scientists who treat female colleagues as 'eternal minors' (Maffia, 2008).

[17] A complete list of the 'strategic careers' supported by the Argentinean government can be found in the following web site: http://www.becasbicentenario.gov.ar/listado_de_carreras_prioritari/carreras_de_grado/

There is an apparent disconnect between citizens' perception of STEM and its importance to economic growth and well-being. One of the possible reasons for this lack of knowledge can be found in the population's access to information about Science and Technology. Science and technology do not appear among their preferences; more than half of society is poorly informed about science & technology issues. In fact, 22% has never had contact with specific information on science and technology (Polino, Fazio, & Castelfranchi, 2005). The vast majority of Argentineans do not see the need to have such information for use in their daily routine, only a minority, usually highly educated people, are in the habit of obtaining scientific information as part of their routine (National Observatory of Science, 2007). In addition to this lack of knowledge about scientific activity, the majority of people think that the country does not offer scientists the necessary working conditions, institutional support or wages to ensure they stay in local science and technology institutions (National Observatory of Science, 2007).

Despite this widespread perception, Argentina needs to produce and nurture new scientific teams in order to face new economic challenges. In 2010, six critical areas of work relating to STEM professionals were identified by the engineering community[18]: transport infrastructure, transport operation and safety; energy supply; urban sanitation; a better distribution of activities and population to reduce inequality and transform informal settlements[19] and the need to promote engineering enrolment, graduation and training (UNESCO, 2010a). Even though these areas presented a significant demand for engineers, Argentinean society still ignores the importance of engineering in carrying out a variety of tasks that impact directly on economic growth and well-being. For example, it is not public knowledge that engineers are needed to perform feasibility studies to guarantee the quality of building infrastructure[20] (Agosta, 2012). In addition to this lack of knowledge, engineering as a career is not perceived socially as having the same status as medicine or law, and this is also a point of concern as social perception shapes career choice to a great extent.

An illustration of this widespread perception occurred when President Cristina Fernandez de Kichner launched the Strategic Plan for Engineering Education on November 6th 2012. The newspaper *Página 12* covered the announcement with the headline 'A plan for my son, the engineer' (Página 12, 2012b). The headline was a play of words having come from the expression 'My son, the doctor' which synthesised the ideals of Spanish and Italian immigrants from the first seven decades of the twentieth century; they believed that the key to their children avoiding poverty and suffering was for them to study a traditional career at a free public university. This was clearly shown in the famous theatre play 'My Son, the Doctor' by Florencio Sánchez; the Uruguayan playwright (1875-1910), and has been indissolubly associated with this expression thanks to his play; and he became a celebrity after its premiere in Buenos Aires in 1903. The theatre play is studied at Argentinean high schools as part of the Literature subject.

The most attractive option in the social status landscape of the first decades of the twentieth century was that of 'doctors', especially physicians and lawyers. Here was the possibility of being successful and having economic welfare without needing a family fortune. The belief that social promotion can be achieved by studying liberal professions still continues in poor rural areas that have asymmetric social structures and are in the urban mindset; medicine is still the most prestigious career for Argentineans (National

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18 The original statement in the UNESCO 2010 report did not specify who has identified those six critical areas. It could be assumed it was the engineering community as the section is written by the following authors: Conrado Bauer (former president of Argentine Union of Engineers), Mario Telichevsky (President of the Argentine Union of Associations of Engineers) and Miguel Yadarola (Advisor to the Ministry of Education for Engineering Accreditation Standards).

19 Informal settlements refer to precarious houses such as slums or shantytowns, which poses challenges in terms of water supply and safe infrastructure.

20 Specifically for the 13064 Ley de Obra Pública [Public Infrastructure Act 13064]

Observatory of Science, 2007). Furthermore, the Argentinean Supreme Court of Justice agreed to the giving of the title ‘doctor’ to the majority of liberal professions (lawyers, doctors, accountants, bio chemists) without the requirement of actually completing a PhD. There is no evidence of reason to support the legal disposition of this decision; nevertheless it is commonly accepted in Argentinean society without even being questioned (Kulemeyer, 2010). The *Pagina 12* headline crystallised the government’s plan to start changing this social mindset still present in contemporary Argentina.

1.3 Patterns of STEM provision and participation

This section provides an overview of the Argentinean educational system and then refers to specific problems in enrolments in STEM disciplines in primary/secondary education, technical and vocational training (TVET) and STEM provision and participation in tertiary education. It also identifies two factors affecting STEM provision and participation in tertiary education; on one hand the difficulties in teaching and learning mathematics in primary as well as secondary school, on the other hand the lack of articulation between school and the workplace.

Because every educational reform has been historically ‘biased’ because of political interest, and technical education is currently a critical point of interest for President Cristina Fernandez de Kichner, this report included information extracted from independent sources such as the publications of Maria Antonia Gallart, an Argentinean scholar who works for the International Institute for Educational Planning (IIEP) of UNESCO and Cristina Varsvasky, also an Argentinean scholar, who works at Monash University as Associate Dean (Education) for Science.

The education system in Argentina consists of four levels: pre-primary, primary, secondary and higher education. The aim of the new national education law introduced in 2006 was to converge towards 1 year of pre-primary, 6 (or 7) years of primary and 6 (or 5) years of secondary education[21]. The higher education system is divided into the non-university sector (which provides teacher training and technical education) and the university sector. Under the new education law both pre-primary and secondary schooling are mandatory, raising the number of years of compulsory education to 13 (Varsavsky & Anaya, 2009).

TVET – 1. Technical education

Technical education in Argentina has a long and rich history of more than a century. Its first manifestation was the Industrial School Otto Krause in the nineteenth century, created along the German model of technological school and oriented to the main process of production (Mechanical, Chemical, Electricity and Construction). During the 1960s the National Council for Technical Education was created, following the model of the National School of Technical Education (ENETS). Technical secondary schools became very popular among students as they not only provided a technical degree but also allowed them to pursue a degree in higher education; this double advantage allowed technical schools to concentrate almost a third of all middle school students across the country during the 1960s (Gallart, 2004). The ENET model consisted of a six year post-primary school curriculum with a strong laboratory time component; three years of secondary school (basic cycle) followed by a three year of specialisation; the most popular were Mechanical, Electrical, Construction and Chemistry. This curriculum existed until the end of the twentieth century (Gallart, 2006) and produced graduates with relatively high levels of theoretical expertise that allowed them to continue engineering studies or architecture (Gallart, 1987).

[21] The division between the first three levels varies by district

In the late seventies industry lost prominence and there was a sharp decline of industrial employment; the service sector began to concentrate job demands, which seriously challenged the Argentine technical education system. As a consequence, there was a 'secondarisation of technical education' which emphasised the secondary school component at the detriment of the technical component (Gallart, 2006). The previous situation was exacerbated during the 1990s by the deterioration of the labour market which marked an increase in unregistered work and a significant rise of unemployment. The percentage of families below the poverty line reached unprecedented levels and as a result, affected technical education in two ways: on the one hand by students' lack of family support to perform well in technical schools which were more demanding than secondary schools and on the other hand, by the scarcity of job placements for graduates (Gallart, 2006).

The International Institute for Educational Planning (IIEP) from UNESCO dedicated part of its report *'Trends in technical and vocational education and training in Latin America'* to explain the changes in technical education experienced by Argentina since the particular moment or 'turning point' (the 1990s) with the implementation of the Federal Education Law, in the following terms

> In the early 1990s, the technical schools and vocational training centres were transferred to the provinces, along with the other secondary schools. During this period, Federal Education Law 24.195/93 changed the education system, moving from seven years at primary school and five in general secondary school or six in technical school to a structure where primary education lasted for nine years and secondary or polymodal education for three years. The technical qualification was obtained following the polymodal education system and vocational technical extra-curricular options. The introduction of this reform led to a high level of fragmentation in the TVET programme.
>
> The Law of Technical and Vocational Education and Training (26.058/05)[22] introduced in 2005, aimed at restoring an integrated model of technical education. It established the objective of regulating and ordering TVET at secondary and non-university higher education, respecting federal criteria and regional diversity, and providing a link between formal and non-formal education, general training, and vocational training to form part of continuous and lifelong education.
>
> This new law establishes that secondary-level TVET study programmes should last for a minimum of six years and be structured according to the criteria adopted by each province (Briasco, 2010).

Technical schools have typically more students than secondary schools and are, overwhelmingly, male dominated spaces and traditionally publicly funded (Gallart, 2006). Overall, the ratio is divided 70% male students, 30% female students (Triano & Lucarini, 2011). One of the challenges of the new curriculum is that it also requires a large number of hours per week at school and this demand, jointly with the full-time study dedication, increases the dropout rate (Gallart, 2006).

TVET – 2. Vocational education

[22] New Law of Ordinance referring to the whole system, No 26206/06, was also introduced, establishing that professional technical education was to return to its earlier four-tier structure (initial, primary, secondary, and higher) and making secondary-level education obligatory (Briasco, 2010).

Overall, in Latin American and the Caribbean (LAC), the cost of large numbers of youth dropping out of formal training without receiving a qualification or acquiring basic skills is higher than ever because employment opportunities for the unskilled have diminished in the region. As a consequence, TVET is sometimes used as a strategy to help keep poor children and youth off the streets. However, TVET cannot be an end in itself, as it does not help to overcome the stigma that is associated with TVET as a 'second-class option' (UNESCO-UNEVOC, 2012). This type of stigma against vocational education persists in Argentina, where qualified vocational students are seen as unable to enter university (Australian Trade Commission, 2011) and therefore 'not good enough' which seems paradoxically in a country with free access to university[23].

As previously mentioned, after the completion of secondary school there are two options in the form of subsystems: university institutions and non-university institutions, also known as tertiary institutions. Non-university institutions include teacher training institutions [*Institutos superiores de formación docente*], technical training [*Institutos de formación técnica*], art education schools, and various 'short courses' (courses lasting one to four years). Historically, there has been almost no coordination between the two subsystems (Theiler, 2005). It is important to highlight that there is interest from the Argentine Government to develop a TVET system similar to the Australian TAFE system since the economic recovery of 2003/2005 which showed a lack of skilled and technically qualified workers in the Argentine workforce (Australian Trade Commission, 2011).

University

Argentina was at the forefront of the development of higher education throughout much of South America during the twentieth century; during the 1950s and 1960s experienced a significant scientific development, having regional leadership in production of scientific publications and accepting large numbers of foreign students. Unfortunately, recurrent crises caused by the continuing interruptions of democracy led to the collapse of the Argentine university model between 1966 and 1983, the mass exodus of talented people, and a strong decline in the quality of higher education (Theiler, 2005).

Since the return of democracy in 1983[24], most students are freely admitted to national universities without admission tests[25], as part of the claim associating free access to university with the democratisation of university (Moreno, 2005). The exception to this unrestrictive access is Medicine, which is considered one of the most controversial and selective admission processes within the Argentinean university system (Debeza & Morán, 2005). The absence of a general admission test has been questioned by several scholars as it has been argued that since 1983 a chain of fallacious ideas were established such as 'admission test-inequality-dictatorship' and 'free access-equity-democracy' and that those chains of thought remain valid in contemporary Argentina (Moreno, 2005; Sigal, 2003). Furthermore, 40 to 50% of dropout rates in the first year, and low graduation rates bought into question whether or not the free access system was applicable (Sigal, 2003).

[23] Please refer to the next section 'University'.

[24] From 1930 to 1983 Argentina did not have continuity in democratic governments, having a series of coup d'états with brief democratic periods. In 1973 the 'unrestricted' access to university was introduced, removing the admission test. The admission test was restored at the beginning of the last military regime (1976-1983) which also imposed also a quota on vacancies. Once democracy was re-established in 1983 the system returned to the unrestricted access mode.

[25] The ways to access national universities can be classified as unrestricted, by exam and by exam and quotas. Access depends to a great extent on career choice. For example, medicine requires passing an exam and all the degrees at national universities require doing a Basic Common Course (in Spanish *Ciclo Basico Común* or CBC) of one year duration (Moreno, 2005).

The university budget tripled since 2003 and there were significant changes in the allocation of resources; at all levels of education, wages are a critical variable, with the majority of the allocated resources covering wages at primary, secondary and university level. The deterioration in teachers' wages was important but it started to recover from 2003 onwards. Today the universities' unions have the same dynamic as traditional unions and fight for better wages, working conditions and they often manage very corporate criteria in doing so (De Vedia, 2008).

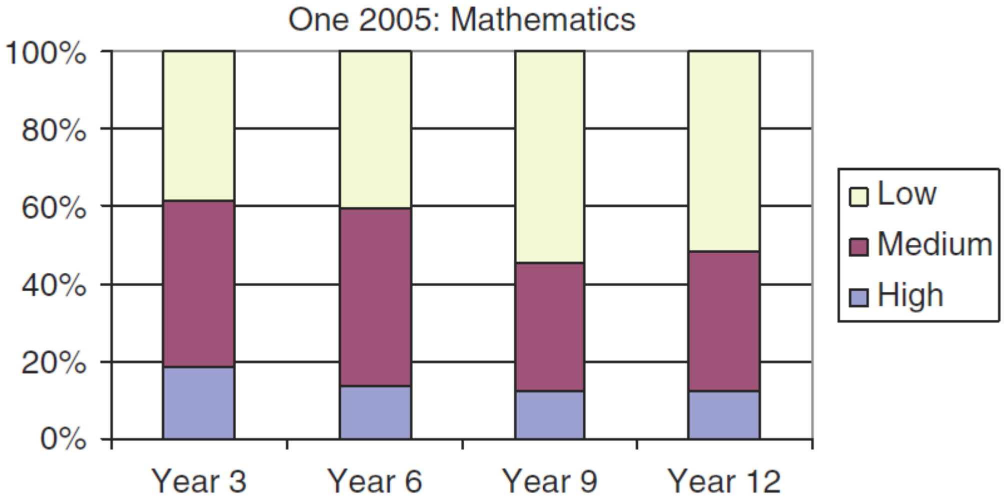
Teaching of mathematics

At primary and secondary school levels, teaching of mathematics has proven to be problematic, which is a point of great concern as mathematics is the foundation of all the STEM disciplines. The vast majority of research focuses on secondary school. However, in terms of primary school one of the main obstacles that has been identified is the fact that teachers take little account of students' interest or disregard everyday tasks that require mathematical knowledge and could be easily linked to their classes (Gervasi, 2005).

One of the strategic goals of the Technical Education Act 26,058 passed in 2006 which replaced the 1993 Federal Education Law or *Ley Federal de Educación*, was to restore the integrated model of secondary technical education, which was broken in 1993 (Jacinto, 2007). The new law introduced very tangible changes such as a sustained increase in investment in education and in science, a focus on the recreation of technical education which was almost eliminated during the Menem administration (1989-1999) and more recently with a project providing three million secondary school students with a netbook each (Beech & Barrenechea, 2011). Despite these efforts, basic science (mathematics, physics, chemistry and biology) do not get much attention from students. There are different curricular structures available for the senior levels which allow for specialisations. The specialisation that attracts the largest number of senior secondary students is business and administration (34%); the basic sciences uptake is only 18%[26]. Other specializations chosen are humanities and social sciences (28%), services (16%), and arts and design (4%) (Varsavsky & Anaya, 2009).

Mathematics is a problematic subject as mathematical competency worsened as students' progress from primary to secondary school, meaning mathematics became even more difficult for the students at secondary level. Indeed, more than 50% of secondary students – including both junior and senior secondary students – demonstrated a lower than expected level of mathematical ability (Varsavsky & Anaya, 2009).

[26] DiNIECE, 2006, Anuario estadistico educativo 2006. *[DINIECE: Dirección Nacional de Información y Evaluación de la Calidad Educativa]* Available at http://www.ses.me.gov.ar/diniece/



National Testing One 2005 - Percentage of students in each performance level
Sample size: 30,000 students for each year level, 1,500 class groups per year level and 1,200 schools per year level. Source: Cristina Varsavsky & Marta Anaya (2009): Mathematics education in Argentina, International Journal of Mathematical Education in Science and Technology, 40:1, 87-100.

Despite the high graduation rate for primary students (around 90%), the graduation rates of senior secondary students are significantly lower (48.4%) and also lower in comparison with the World Education Indicators (WEI) average (57.7%) and the Organisation for Economic and Co-operation and Development (OECD) average (78%). This is a point of concern because Argentina has one of the highest annual expenditures per senior secondary student (2.883 purchasing power parity (PPP)[27] dollars compared to the WEI average of 1.157 PPP dollars), but this is still significantly lower than the OECD average (7.121 PPP dollars). In summary, even though Argentina is spending more money per senior secondary student than the World Education Indicators, the academic results suggest that extra money is not spent wisely as it is not leading to better educational outcomes.

[27] The PPP is a mechanism for comparing the purchasing power of different countries

Lack of articulation between school and workplace

In addition to the lower graduation rates at secondary school, there is also a lack of connection between the school and the business sector; Guillermo Olivetto - Dean of UTN - expressed the need to improve high school technical training and to acquire a deeper relationship between academia and industry as it is a necessity that any given engineer performs a minimum of 200 hours of supervised practise. Ricardo Orosco - Dean of UADE - concurred and expressed the opinion that future strategies need to include the figure of high school teachers as a key motivator (Kantor et al., 2010). This lack of connection was also observed between universities and the business sector. Juan Carlos Tedesco - Ministry of Education - stressed that the brain drain in Argentina is not a problem of poor quality education but a general weakness of the productive system which does not have the necessary mechanism to incorporate the trained scientists (De Vedia, 2008).

One of the main causes of STEM degree shortage in contemporary Argentina can be traced back to the technical high school crisis of the 1990s and the subsequent re-emergence of the technical schools that came with the new Professional Technical Education Act 26,058 enacted in 2006. In the context of economic recovery, the government passed the new law to strengthen and reorganise the labour force for certain industrial areas (Jacinto, 2006). The 26,058 Act aimed at restoring an integrated model of technical education, regulating and ordering technical and vocational education and training (TVET) at secondary and non-university higher education, respecting federal criteria and regional diversity and providing a link between formal and non-formal education (Briasco, 2010). It established that secondary-level TVET study programmes should last for a minimum of six years and it has also created the National Fund for Technical and Vocational Education, which guarantees the investment required to improve the quality of institutions (Briasco, 2010).

1.4. The role of STEM disciplines in both general education, and vocational and occupationally-specific programs in education and training

Poor preparation of teachers in science has been well-documented not only in Argentina but worldwide (ICSU, 2011) and this compounds the already limited scientific knowledge of the Argentinean population (National Observatory of Science, 2007). In terms of vocational education there have been significant efforts by the National Institute of Teacher Training (INFD) in collaboration with the University Policy Secretary (SPU) to improve the training of teachers of STEM related subjects at secondary school level. The process included a review of teaching techniques in chemistry, biology, mathematics and physics; the review unveiled severe obstacles for future secondary school teachers wanting to acquire a good handle on STEM related subjects (Ministry of Education, 2012b)[28].

For instance, chemistry content was found to be disconnected from students' interests and the current problems chemists face in the field; teaching did not include the humanistic nature of chemistry or its social implications and did not take account its links with other disciplines such as biology, physics, mathematics or earth sciences. Another point of concern was the little time allocated in class to conduct and explain lab experiences and to plan and conduct research; this situation did not allow for the development of students' observation, interpretation and argumentative skills. This

[28] Even though there were considerable reports published by the National Institute of Teacher Training (INFD) acknowledging the obstacles in teaching of mathematics, chemistry, biology and physics and plans to revert this situation, there were no reports on results of those plans.

collaborative review is currently taking place in the country and results will be available by 2013 (Ministry of Education, 2012b).

The role of STEM disciplines in general education can be read in the following section. As the study of mathematics affects all STEM degrees, occupationally specific programs in education and training are scarce[29].

1.5. Student uptake of STEM programs and factors affecting student performance and motivation

Three factors have been identified as affecting student performance and motivation in STEM related degrees: learning difficulties in mathematics and natural sciences at primary and secondary school, poor teaching performance and an alarming shortage of lecturers at university.

In terms of teaching and learning mathematics at school, there is a persistent problem with the students and teachers. Mathematics is perceived as a difficult subject and it is poorly taught (Kantor et al., 2010). For instance, a survey made among 153 primary school teachers found that less than half could define three basic mathematical concepts that should be taught at fourth grade and the situation was worse for the natural science subjects, where fewer than 3% of the primary teachers were able to express basic concepts of the curriculum. In fact teachers commonly confused concepts such as ‘environment’ with ‘ecosystem’ (Valverde & Näslund-Hadley, 2010).

In regards to the students, extensive research has established five main difficulties that arise for secondary school students in mathematics: difficulties associated with the complexity of mathematical objects, mathematical thought process (logical thinking), and difficulties associated with the teaching process, the student cognitive process and emotional attitudes towards mathematics (Abrate, Pochulu, & Vargas, 2006). The majority of students do not like mathematics and develop fear and tension towards the subject, influenced by the hierarchical nature of mathematical knowledge, the teacher’s attitude, the teaching style and the negative attitudes that were transmitted by their own family towards mathematics (Abrate et al., 2006). In the particular case of Engineering, the career is perceived as difficult not only by the negative image of mathematics at school but also by the perception of the difficulty of the degree itself; the degree is seen as too long and too demanding, with no prospects of work/life balance once graduated. In addition, there is a considerable lack of knowledge among students about the career’s prospect in terms of earning capacity and the possible areas of work.

However, it is also true that concrete efforts are being made in Argentina to promote mathematics, and capacity building in teaching of mathematics, when compared to the remainder of the Latin American countries. One notable example is the International Problem-Solving Conference and Seminar, which is held annually to coincide with the National Mathematics Olympics. This annual event brings together experts from all over the world and more than 300 Argentinean teachers for a week (Bosch, Alvarez Diaz, Correa, Druck, & MCeachin, 2010).

Nevertheless, difficulties in teaching and learning mathematics are not the sole obstacle. Another decisive factor at secondary level is the diminishing roles of teachers, who have been experiencing worsening working conditions and a considerable loss of their professional and symbolic status in the Argentinean society. Moreover, the administrative and legal frameworks that regulate teaching at secondary level have similar standards with the public employee framework which have incentive, evaluation

[29] Information about in-service professional development opportunities has not been found.

and promotion systems designed to promote formal procedures and to acquire experience through seniority in the job. Teachers and public employees have been experiencing a progressive decline and deterioration in wages and working conditions, similar to low-skilled workers, which brought disappointment and frustration to the teaching workforce (Ferreyra et al., 2006).

In addition, it is important to highlight that primary and secondary teachers in contemporary Argentina are facing considerable challenges at work on a daily basis; teachers starting at entry level positions usually must work in disadvantage schools, distant from their homes and located in areas of great social unrest; students come from low-income households with unsatisfied basic needs. This situation increases school violence and contributes to a great extent to the psychological burden of teachers (Gavilán, 1999).

At university level, engineering also faces a shortage of teachers; lecturers between 30 and 50 years old are the most needed across all specialisations, and universities have found it extremely difficult to fill teaching positions because they cannot offer salary packages as good as the ones the industry pays; the aging teaching population is a structural problem that the university system faces today with no prospect of solutions being found in the short term.

The main reason is the recovery in the labour market post 2003; companies demand high commitment, tight schedules and travelling for regional projects. Many lecturers cannot commit to teach for the whole semester. Furthermore, the industry's wages are much more attractive. For instance, in 2007, a junior engineer could earn $4,000 a month, while a full-time assistant professor earned $2,000 per month and a full-time professor with several years' experience could reach $3,500[30] (San Martín, 2007).

1.6. Access of STEM graduates to the labour markets, and labour market take-up of STEM knowledge and skills

The skill set required for university trained professionals can be divided at least into two types: specific to the profession and generic, that is, shared by all professions. Within specific capabilities, it is important that future engineers develop skills in project management, design of products and processes, economics and management of human resources (Morano, 2011). These requirements have modified the profile of an engineer over the years, changing it significantly in the last ten years. Germán Guido Lavalle - Vice Chancellor of the ITBA - spoke recently on the TV program 'To build Argentina' regarding the new profile of the engineer, emphasizing that the 'new engineer' is a person with interdisciplinary ability and business vision, contrary to the popular vision of an engineer as a lineal-thinking professional (Argentina para armar, 2012).

Engineers are particularly good at setting up their own businesses. Research carried out by the Inter-American Development Bank, together with the National University of General Sarmiento of Argentina, showed that on average, 6 out of 10 Latin American entrepreneurs were university graduates and within this group engineering graduates were the most dynamic entrepreneurs (40%), followed by graduates from economics (30%). The study defined entrepreneurs as those capable of creating a new enterprise that, within a 3-year period, went on being in business and grew substantially, thus becoming a small-medium company with more than 15 employees (Morano, 2011). Human resources recruiters also emphasised the flexibility of some engineering profiles

[30] Note that figures are presented as a comparison example between academia and workplace, as salary levels were affected significantly by the inflation rate from 2007 to current times. At 2012 the average salary of an engineer before taxes was around $20,000 to $25,000 per month (Jueguen, 2012).

such as industrial engineers who can easily secure a job in a variety of fields given the ample and generalised training that engineers complete, which encompasses various different areas (Jueguen, 2012).

1.7. Strategies, policies and programmes used to enhance STEM at all levels of education, and judgment concerning the success of those programmes

On December 1997 the Science and Technology Cabinet (GACTEC) launched within the National System of Innovation (SIN) a plan called National Plan for Science and Technology 1998-2000; it was the first time the country had developed a science and technology plan and as such, it was a novelty not only for being the first but also because it was set up within an official framework for SIN (Chudnovsky, 1999). At that time the Argentinean financial system was unable to finance long-term investments in intangible assets, the educational system was also unable to establish a link with the productive sector and the scientific institutions were inefficient to interact with the productive and educational system. Even though the plan acknowledged these issues, it did not pay enough attention to reverse them (Chudnovsky, 1999).

From 2003, with the economic recovery, six major steps have been taken by the national government to support and increase STEM careers in Argentina:

- The Quality University Program (2001) followed by the Project for the Improvement of Teaching Engineering Programs (PROMEI) (2005)
- The creation of the Ministry of Science, Technology and Productive Innovation (MINCYT) in 2007
- The Bicentennial Strategic Plan (2006-2010)
- The Strategic Plan for Engineering Education (2012-2016)
- The Medium-Term Strategic Plan in Science, Technology and Innovation (2005–2015)
- The 'RAICES' Program in 2003, later enacted by law 26,421 - also known as 'The RAICES Act' - in 2008.

Quality university program and PROMEI

In terms of quality university teaching, considerable efforts have been made to set uniform standards and organise a functional accreditation system for universities. The government's first initiative was implemented in 1995 with the Higher Education Act 24,521 that regulated the entire higher education system (both public and private) and provided a legal basis for many of the structural changes of the decade[31]. The act allowed universities to institutionalise a system of evaluation and accreditation of higher education institutions by creating an independent body of evaluation called the National Commission of University Evaluation and Accreditation (CONEAU)[32]. Its mission was to ensure and enhance the quality of university programmes and institutions, with this being responsible for undergraduate degree accreditation, particularly degrees that directly affect citizens' health, security, rights or assets, such as medicine, engineering, architecture, pharmacy, odontology and biochemistry. The Project for the Improvement of Teaching Engineering Programs (PROMEI) was designed to address weaknesses that CONEAU identified during the accreditation process (Stewart, 2007).

In terms of the accreditation process for engineering, the first stage was held between 2001 and 2005 and only 19 out of 211 degrees fulfilled all the standards of accreditation for a 6 year degree; the vast majority completed accreditation for the first 3 years with

[31] Private education tuition has continued to increase between 1994 and 2010 (Narodowski & Moschetti, 2012).
[32] In Spanish Comisión Nacional de Evaluación y Acreditación Universitaria (CONEAU).

the commitment to improve and implement quality plans for the rest of the years (A. Garcia de Fanelli, 2011). Due to this situation the University Policies Secretary created a funding program, the Quality University Programme, to support national universities financially in order for them to be able to fulfil the accreditation process; PROMEI was included in this program.

The accreditation process was the result of significant and long-lasting deliberation among deans of the top engineering faculties who recognised the need to improve the quality of the degree, as well as to make assessment criteria and specialities uniform. The Federal Council of Engineering Deans of Argentina (acronym in Spanish, CONFEDI) produced two key reports prior to the accreditation process: the Blue Book in 1996 named 'Curriculum unification for the Teaching of Engineering in Argentina', and the Green Book in 2000 named 'Proposal for the Accreditation of Engineering Degrees in Argentina'. Both were key guidelines that became the foundations of the accreditation process, which was intended to develop standards and criteria for engineering degrees, later approved by the Ministry of Education in consultation with such universities (Villanueva, 2008). The specific rules for the Engineering accreditation were approved in December 2001; this occurred once the national standards for accrediting engineering degrees were approved. This approval allowed the unification of engineering degrees across twenty-one specialties (Morano, 2011).

As part of the strategies to improve teaching standards and retain teaching staff, universities implemented a variety of steps: UBA increased PhD scholarships to encourage teaching; ITBA chose to focus on engineering students as future teachers by creating a tutor program. Within the program, students from 3rd, 4th and 5th year worked with students from the first two years. UADE provided financial support to lecturers doing a PhD as well as providing additional benefits under a mutual agreement that they would remain teaching at the university (San Martín, 2007). Moreover, UTN increased its permanent teaching staff from 5% to 10% in 2010 thanks to the funds it received from the Ministry of Education.

The *Proyecto de mejoramiento de la Enseñanza de las Ingenierias* [Project for the Improvement of Teaching Engineering Programs] (PROMEI) was undoubtedly one of the most important government plans to tackle the problems associated with the quality of engineering teaching. It was launched between 2005 and 2010 among the national universities of Argentina within the Quality University Program. It was an innovative public policy that linked public funding to the accreditation of undergraduate universities so that undergraduate courses that had been accredited for three years could meet their commitment to fulfil improvement plans.

There have been positive evaluations of this public policy based on two factors: first, diverse stakeholders from the engineering community participated in the formulation of the policy; second, the funding items took into account the multiple factors that intervene in order to improve the teaching activity. Furthermore, the project had an additional unexpected effect by contributing to legitimize the quality accreditation procedures (A. M. Garcia de Fanelli, 2012).

The PROMEI had three general objectives:

- to promote improvement in the quality of engineering teaching according to the improvement plan developed for each engineering school as a result of the accreditation process;
- to encourage cooperation between regional and local engineering schools (e.g. inter-university academic networks) in order to avoid overlap and promote the advantages of sharing human and physical resources;

- to encourage engineering degree courses to use research activities, and create links to the community to contribute to local and regional development.

Argentina's engineering schools were declared of public interest and thirteen engineering disciplines (e.g. civil, electric) were subject to CONEAU's accreditation process that concluded in 2005 (Stewart, 2007). Nevertheless, PROMEI also faced two main obstacles. On the one hand there was the complexity of the Argentine university system, which includes fragmented groups of highly complex universities that respond differently to broad government-directed funding mechanisms, and on the other hand the uncertainty that existed with regards to the receipt of government's funds (Stewart, 2007).

Despite the aforementioned obstacles and the recent application of the PROMEI, overall results look promising. The country's engineering degrees fulfilled 93% of their commitments and recommendations of the first accreditation, which took place between 2002 and 2004. The performance of beginners, measured in the number of subjects students pass, improved by 47% and the number of graduate students by 19% over the same period (Morano, 2011). The five-year period of specific investment in engineering careers saw a total investment sum of one hundred and twenty million dollars (US$ 120 M) out of which, funds corresponding to teachers' salaries, were definitely incorporated into the university budget. At the same time, a MERCOSUR accreditation system was established in 2004 and its first phase called 'Experimental Accreditation Process' (Spanish acronym MEXA) was carried out by twenty-nine professional engineering training courses in five countries: six in Argentina, six in Brazil, seven in Bolivia, five in Paraguay and five in Uruguay (Morano, 2011).

Ministry of Science, Technology and Productive Innovation (MINCYT)

On December 6th 2007 the Argentinean Congress amended Law 26,338 and created the MINCYT to formulate policies and develop plans to strengthen the country's capacity to develop a sustainable production system with goods and services that have a higher technological component (Ministry of Science, 2009). In terms of investment, the government increased by 88% its investment in science and technology research when compared to the period 2004-2009 and by a further 40% for the Research and Development sector (I+D). With these percentages, Argentina continues to rank among the top investors in science and technology among the Latin American nations (Ministry of Science, 2009). In 2009, the government investment in Scientific and Technological Activities (ACyT) increased by 21% compared to 2008; the investment also increased on research and development (I+D) with an annual increase of 26% (Ministry of Science, 2009). The investment in science and technology in relation with the GDP increased from 0.49% in 2004 to 0.67% in 2009[33] (Dirección Nacional de Políticas y Planificación, 2012). In the case of I+D percentages the increase was from 0.52% to 0.60%. Although these percentages are still far from the international standards observed in developed countries (between 2 and 3% of GDP) these figures show an increasing trend in Argentina (Ministry of Science, 2009). The investment in science and technology in relation with the GDP increased from 0.49% (2004) to 0.67% (2009).

In terms of public funding distribution by scientific discipline engineering and technology received 34%, followed by natural sciences with 22% and agricultural sciences with 14%. Medical science received only 11% as well as social sciences, and humanities only received 5%. The amount of funds remained stable for the same fields between 2006 and 2009 (Dirección Nacional de Políticas y Planificación, 2012). The MINCYT produces a wide range of publications with the latest up-to-date information in regards to

[33] Figures from previous years showed 0.33 in 1985-1990, 0.40 in 1994 and 0.46 in 1996 (Chudnovsky, 1999).

strategic plans implemented in the last ten years, surveys and bulletins, yearbooks and reports about science, technology and public policies. All the information is free under the section 'Publications' and can be downloaded from the web site http://www.mincyt.gov.ar/publicaciones/index.php

The Bicentennial Strategic Plan

The following table shows the four main aims set up by the Bicentennial plan:

Challenges	Strategic Aims
1. Increase social cohesion and equality	Strategic goal 1: to focus I+D to a better understanding of social issues, improving quality of life and social development
2. Open path of sustainable development	Strategic goal 2: to create and apply knowledge to responsible use of natural resources, protecting the environment
3. Articulate an Innovative National System, building a new profile on productive expertise	Strategic goal 3:streghten innovation, modernisation and technological links between industrial and farmer production
4. Access to a society and an economy based on knowledge	Strategic goal 4: Increase the scientific base and technological capacity

Source: Guidelines for the Strategic Plan Bicentennial 2006-2010 (Secretary of Science, 2006).

The Bicentennial Strategic Plan for 2006-2010 proposed as a desirable scenario (strategic goals 1 and 4) to progressively increase the number of researchers and trainees working in the I + D sector up to a total amount of 40,000. The latest data available for the number of people engaged in the I+D sector showed that 44,000 out of 59,683 were full time researchers and trainees, which exceeds the figure originally proposed by the Bicentennial plan (Dirección Nacional de Políticas y Planificación, 2012). The plan has chosen a much higher growth for investments than for researchers because Argentina faces a critical problem of under investment, which is even more critical than the shortage in staff. The lack of continued investment directly affects researchers' wages (one of the main reasons for the 'brain drain').

The Strategic Plan for Engineering Education

On October 16th 2012, Education minister Alberto Sileoni launched the Worldwide Forum on Engineering Education in Buenos Aires (Página 12, 2012a) followed by the official launch of the Strategic Plan for Engineering Education on November 6th 2012 by President Cristina Fernandez de Kichner. The plan aimed to have one engineer per 4,000 inhabitants by 2016 and increased last year's figures of one registered engineer per 5,700 inhabitants. In addition, the government launched 2,000 scholarships for engineering students which added to the current 12,000 scholarships already granted; in total this equates to a 20% increase in the scholarship budget at tertiary level (Página 12, 2012b).

The plan aims to improve academic indicators, generate early vocations for engineering at secondary school and facilitate the shifting between educational systems; it also seeks to increase retention rates in the basic cycle as well as in the expertise stage and increase the number of engineers working in the scientific, technology and innovation fields.

The Medium-Term Strategic Plan in Science, Technology and Innovation

In addition to all these measures, Argentina also launched a Medium-Term Strategic Plan (2005–2015) that was designed to address challenges related to innovation and social development. The plan established four strategic goals to guide the medium and long-term development of science, technology and innovation. The first goal has a social dimension and relates to improving quality of life and social development. The second goal addresses the responsible exploitation of natural resources and environmental protection. The third goal relates to strengthening innovation in industry and agricultural production, particularly in the most advanced fields, those that nurture the development of a knowledgeable economy and society. The fourth goal sets out to strengthen Argentina's science and technology capabilities and develop its support infrastructure (UNESCO, 2010b).

The plan had two stages: the first involved a wide range of discussions conducted among experts in the field and representatives of the public and private sector with regards to the future scenarios for Argentinean science, technology and innovation. The discussions cover a variety of scenarios: macroeconomic, demographic, environmental, and competitive and employment (Secretary of Science, 2006). The second stage consisted of a survey on expectations about the socio-economic development and its articulation with the scientific research, technology and the innovation in Argentina (Secretary of Science, 2006).

The plan has so far concluded that there is a positive assessment of the country's scientific and technological capacity and a high consensus about the policies' orientation for the scientific and technological field which mainly needs to focus on support and encourage scientific culture in the country, promoting a link between I + D and the productive sector and considering the scientific capacity in the decision making process on economic policies (Secretary of Science, 2006). The aim of the plan is to attain a ratio of three scientists and engineers for every 1,000 Argentinians who are economically active. The country is moving towards this goal; since 2005 CONICET[34] has taken in 1,500 PhD students annually leading to a pool of nearly 7,000 active scholarship-holders in 2009 (UNESCO, 2010b).

[34] The National Council for Scientific and Technological Research (CONICET) was created in 1958 to promote and conduct research. CONICET played a key role in establishing research as a formal career in Argentina. Approximately 80 percent of the research financed by CONICET falls within the fields of biology, physics, chemistry and engineering (Thorn, 2005).

The RAICES program

The word RAICES means ‘foundations’ and the acronym stands for *Red de Argentinos Investigadores y Cientificos en el Exterior* [Argentinean Researchers and Scientist Network Overseas]. The RAICES program aimed to re-expatriate scientists who emigrated overseas due to the lack of opportunities in the country. The novelty of the program in comparison with previous attempts is based on two pillars:

- the RAICES program promotes action lines that follow the frameworks of *brain gain, brain drain* and *brain circulation*;
- the program uses different tools that promote links between scientists abroad, conduct short-term research in the country, promote the return of scientists to the country and offer information about job opportunities in the country.

The enactment of the 26,421 Act in October 2008 declared RAICES part of the state policy and in its article no. 2 stated that it would develop networks to link Argentinean researchers living overseas, promote scientific and technological activities in the country and overseas and facilitate the return home of highly trained researchers in order that they continue their work in Argentinean institutions. The new Act aimed to repair the paradoxical situation of Argentinean science; on one hand the formation of human resources in science and technology has been one of its main pillars, on the other hand, Argentina was one of the Latin American countries that brought more talent to developed countries as a result of lack of professional opportunities for those scientists in Argentina (Ministry of Science Technology and Innovation, 2008).

The program offers a ‘return allowance’ covering the return flight and a total of 5000 pesos (AUS 981), which can be used to purchase equipment, moving expenses or to cover a second flight ticket if the Argentinean researcher has a job offer in the country. If the researcher does not have a job offer, the program offers him or her the service of sending his or her resume to 3,500 companies, institutes and universities (Bar, 2008).

Since 2003[35] the RAICES program has resulted in 820 scientists returning to Argentina. The program reached over 13% of Argentinean scientists abroad, estimated to be 6,000 people (Ministry of Science Technology and Innovation, 2008).

[35] The repatriation program started in 2003 but the Act 26,421 that declared the repatriation of scientist part of the state policy was passed on October 2008.

Acronyms

ACyT	Actividades Científicas y Tecnológicas [Scientific and Technological Activities]
ANPCYT	Agencia Nacional de Promoción Científica y Tecnológica [Argentina's National Agency for the Promotion of Science and Technology]
ARGENBIO	Consejo Argentino para la Información y el Desarrollo de la Biotecnología [Argentine Council for Information and Development of Biotechnology]
CONEAU	Comisión Nacional de Evaluación y Acreditación [National Commission of University Evaluation and Accreditation]
CONFEDI	Consejo Federal de Decanos de Ingeniería [Federal Council of Engineering Deans]
CONICET	Consejo Nacional de Investigaciones Científicas y Técnicas [National Council for Scientific and Technological Research]
ENETS	Escuelas Nacionales de Educación Técnica [National School of Technical Education]
FOMEC	Fondo de Mejoramiento de la Calidad Universitaria [Fund for University Quality Improvement]
FONARSEC	Fondo Argentino Sectorial [Argentinean Sectoral Fund]
FONCYT	Fondo para la Investigación Científica y Tecnológica [Scientific and Technological Research Fund]
FONTAR	Fondo Tecnológico Argentino [Technological Fund of Argentina]
FONSOFT	Fondo Fiduciario de Promoción de la Industria del Software [Trust Fund for Promotion of the Software Industry]
GACTEC	Gabinete Científico Tecnológico del gobierno [Science and Technology Government Cabinet]
I+D	Investigación y Desarrollo [Research and Development]
INFD	Instituto Nacional de Formación Docente [National Institute of Teacher Training]
ITBA	Instituto Tecnológico de Buenos Aires [Institute of Technology of Buenos Aires]
LAC	Latin America and Caribbean
MINCYT	Ministerio de Ciencia, Tecnología e Innovación Productiva

	[Ministry of Science, Technology and Productive Innovation]
OECD	The Organisation of Economic Co-operation and Development
PROMEI	Proyecto de Mejoramiento de la Enseñanza en Ingeniería [Project for the Improvement of Engineering Teaching]
RAGCyT	Red Argentina de Género, Ciencia y Tecnología [Argentinean Network on Gender, Science and Technology]
SECTY	Secretaria de Ciencia y Técnica – dependiente del MINCYT [Science and Technical Secretary] – Under the MINCYT
SIN	Sistema Nacional de Innovacion [National System of Innovation]
ST&I	Science, technology and innovation
SPU	Secretaría de Políticas Universitarias [University Policy Secretary]
TVET	Technical and vocational education training
UADE	Universidad Argentina de la Empresa [Argentinean Business University]
UBA	Universidad de Buenos Aires [University of Buenos Aires]
UTN	Universidad Tecnológica Nacional [National Technology University]
WEI	World Education Indicators

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